Title
A LYONS BRANCH OP THE POTTERS-MAKING FIRM OF ATEIUS OF AREZZO

Authors
Widemann, F.
Picon, Maurice
Asaro, Frank
et al.

Publication Date
1973-11-01

Submitted to Archaeometry

LBL-1964
Preprint

A LYONS BRANCH OF THE POTTERY-MAKING FIRM OF ATEIUS OF AREZZO

F. Widemann, Maurice Picon, Frank Asaro,
H. V. Michel and I. Perlman

November 1973

Prepared for the U. S. Atomic Energy Commission
under Contract W-7405-ENG-48

DISCLAIMER

A LYONS BRANCH OF THE POTTERY-MAKING FIRM OF ATEIUS OF AREZZO*

F. Widemann†, Maurice Picon††, Frank Asaro, H. V. Michel, and I. Perlman‡

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

November 1973

ABSTRACT

51 waster sherds of Terra Sigillata (~ 20-0 B.C.) from Arezzo, Italy and Lyons, France have been chemically analyzed for twenty-eight elements by neutron activation and seven by x-ray fluorescence. Most of the elemental abundances were measured with high precision and cross comparisons of the two techniques of measurement (and sample preparation) give added insight as to their relative precision, the calibration differences and the extent to which volatile materials such as carbonate or water influence the results. The sherds from Arezzo formed a homogeneous and distinctive chemical group while all but two of those from Lyons were classified into three such groups. Two of the Lyons groups (MML A and MML B) were from Montée de La Muette and one was from Loyasse. Four additional sherds from houses excavated in Strasbourg and one from Lyons, all of which bore the signature of the famous Arretine pottery-making firm of Ateius, were also analyzed by the same techniques. These signed sherds all had the same composition pattern and it closely matched one of those from Montée de La Muette (MML A) in Lyons. It is therefore suggested that these 5 sherds bearing the Ateius signature were made in the general vicinity of Lyons and were part of the output of an as yet unknown Gallic branch of the firm of Ateius.

---

*Work performed under the auspices of the U. S. Atomic Energy Commission.

†On leave from Laboratoire de Spectrométrie Nucléaire, 91406, Orsay, France.

††Laboratoire du CERGR, 74 Rue Pasteur, 69365, Lyon CEDEX, France.

‡Present address: Department of Archaeometry of the Institute of Archaeology at the Hebrew University in Jerusalem.

I. INTRODUCTION

A. Romans and the Gallic Market of Ceramics

During the second and the first centuries B.C. large quantities of Italic ceramics, mostly Campanian A and B with black glaze (Lamboglia, 1952) appeared on the Gallic market. Shortly thereafter imitations of these wares were produced in Gallic workshops, particularly those in the region of Vienne and Lyons in the Rhone Valley.

After the middle of the first century B.C., a new class of ceramics with a red glaze† ("terra sigillata"), mostly signed, appeared in Italy. This pottery came predominantly from the workshops which were producing Campanian B, (Goudineau, 1968) especially those in Arezzo. These new ceramics were soon exported and met with considerable success. Again, this work was quickly imitated in Gaul, and some of the imitations came from the workshops of Loyasse in Lyons. These imitations, however, were technically very different from their models. In particular, the local potters could not obtain a red glaze comparable to that from the workshops of Arezzo, but only a porous one of low quality. These imitators also distinguished themselves by not signing most of their productions.

The success of their red glazed products probably stimulated the potters of Arezzo to establish branches closer to the new markets which had been opened by the Roman conquests in Gaul and on the Rhine. This interpretation is supported by the existence of the large complex of workshops of La Montée de la Muette in Lyons, which did not produce imitations but, and apparently for the first time in Gaul, red pottery which had all the characteristics of those from Arezzo. Furthermore, out of the 14 fragments of moulds which have been discovered in La Muette, two show a distribution of major chemical elements which suggests

---

†The word "glaze" is not strictly correct for this type of ceramic , however, we use it here for lack of a better word.

a provenience from Arezzo (Picon et al., 1973). In addition, the major-element distribution of 13 stamps found in La Muette also indicates the same provenience. Finally, the names (Lasfargues et al.) of many of the masters and slaves from the pottery workshops of Arezzo are found among the signatures of pots unearthed in La Muette.

Among the large firms of Arezzo, Ateius held the attention of scholars largely because of its prominence in the market in Gaul and in the Germanic frontier garrisons (Fiches, 1972; Lombard, 1971; Ettlinger, 1962). Because many sherds with the Ateius signature had been found in Gaul and none in Arezzo, it had been suggested by Ritterling and Oxé that these potteries may have been locally made. These arguments were revised after the discovery of the Ateius workshop in Arezzo (Maetzke, 1959). The possibility still remains, however, that some Ateius pottery was made in Gaul although none has been found in excavations of pottery workshops up to the present time.

Recently a systematic study (Picon et al., 1971) was made by x-ray fluorescence analysis of the abundances of the major chemical elements of many Italic ceramic imports found in Gaul. Six sherds bearing the Ateius signature had chemical composition patterns or "fingerprints" which were not only distinctly different from that of pottery excavated in Arezzo, but were rather similar to those of pottery excavated in workshops around Lyons.

Although this information pointed to Lyons rather than Arezzo as the place of manufacture of these vessels, it was thought that a more detailed examination of chemical compositions might provide a surer basis for making a judgment.

II. EXPERIMENTAL TECHNIQUES

A. Trace Elements and Provenience Problems

Besides the major elements found in pottery there are many more which occur only in minute traces, often in just a few parts-per-million (ppm). The potential importance of these trace elements for determining provenience of pottery by chemical fingerprinting lies in the breadth of chemical properties which are included in such a large array of elements. Clays arise from the weathering of certain rocks which might be quite similar in composition. Chemical fractionations take place in forming the clays, and environmental conditions will no doubt effect various elements differently. If one examines elements which exhibit a diversity of chemical properties, there will be more chance for detecting the consequences of subtle environmental differences between one place and another.

There are some obvious requirements for success in using trace elements for this purpose and two of these are interlinked. For a trace element to be useful, it must not behave chaotically, that is, its distribution within a clay source must be quite uniform. If pottery from one source showed a wide dispersion in values for this element, it would have little use in distinguishing one source from another. In this regard, experience has shown that many of the trace elements are just as well behaved as the major constituents.

Closely connected with the requirement that diagnostic elements have a small variability within a source is the necessity for measuring them with the required accuracy. Neutron Activation Analysis (NAA) is a technique which combines accuracy and sensitivity for a wide array of elements. A considerable number of elements present in clays can be measured to an accuracy of a few percent or better, even though they are present in the parts-per-million range.

It is the practice in such fingerprinting to draw inferences from pottery samples themselves rather than to compare them with clays from the suspected region of manufacture. In principle, it might be more convincing to demonstrate that a piece of pottery relates directly to a specific clay source but there are problems in attempting to do such "absolute provenience" work. Firstly, it is by no means easy to decide where the ancient potters drew their clays nor even whether the deposits still exist. In addition, practices employed in pottery-making can cause changes in chemical composition which would negate the opportunity to relate pottery directly to the clay. Such changes could occur in the processes of levigating clay, which removes coarse particles including some limestone; tempering clay, which introduces organic materials, rock products or old pottery into the clay; and firing calcareous clays at different temperatures, which can result in large variations in the carbonate content.

By analyzing pottery alone, one relies upon some conservativism by the potters in the selection of their clays and in their refining and tempering practices. (Some deductions of the uniformity of these practices will appear in the discussions which follow.) With this supposition, ceramics made by particular potters will be uniform.

A group of pottery can be considered to be a suitable reference group for locally made ware if it meets a couple of criteria: (1) It belongs to the region of excavation according to archaeological evidence. This is particularly convincing if waster sherds are found in or about kiln areas. (2) The composition of the pottery is uniform. Often, a number of different styles of pottery, which belong to different time periods, all show the same composition, and such findings enhance confidence in the deduction that each group was locally made.

B. Statistical Criteria for NAA

As mentioned, NAA is a technique which can measure a wide array of elements with good accuracy and therefore it well adapted to provenience determination for pottery. In the modification used for the present work (I. Perlman and F. Asaro, 1969 and 1971), some 50 elements are looked for in each pottery sample; about 40 are usually observed, and the abundances of over 20 of these elements (the one used to fingerprint the pottery) are measured with an average precision of $\sim$ 2%.

Some simple statistical criteria (F. Asaro and I. Perlman, M. Artzy et al., 1974) have been employed to arrange and interpret the chemical abundance of data in order to judge matters of provenience. The treatment is deliberately kept simple in order not to lose sight of the fact that we cannot easily prove that some of the statistical parameters have the necessary randomness for a rigorous analysis. As an example, the abundances of the various elements selected for the characterization of pottery vary independently to some extent, but also exhibit some coherent behavior for many of the elements. It will be seen, however, that the assignment of provenience does not hinge upon fine distinctions.

The first step in the statistical analysis is to obtain the chemical profile for a reference group. The reference group is generally a collection of sherds for which we assume, provisionally, that the provenience is known. For each element, the average value of its abundance (M) within the collection is obtained and the spread of values is computed in the form of the root-mean-square deviation (σ). A tabulation of $M \pm \sigma$ for all the diagnostic elements makes up the chemical profile or "fingerprinting" for this pottery group. For pots of unknown provenience to be members of this "reference" group, the abundances of the

various elements should agree with the mean values of the group within certain limits. If we make these limits very small, (e.g. one σ for $\sim$ 20 elements) we will be able to ascertain the provenience of only a small portion of the pots ($<<$ 1%) which actually belong to a reference group. If we make the limits much larger, on the other hand, (e.g. 4 σ for $\sim$ 20 elements), we would be able to classify essentially all of the pots which are members of the group but would enhance the probability of overlapping chemical compositions which would necessitate a more complex statistical treatment. The limits best suited to a particular problem depend on the degree of homogeneity of the reference group and the similarity in composition of other such groups. The following example would serve to classify about 99% of the pots of unknown provenience which are members of known groups and adequately distinguishes between the reference groups. From an analysis for 20 elements, all pots of unknown provenience would be considered a member of a given group except those for which: (1) one or more elements differed from the group means by $\geqslant$ 4 σ; (2) or two or more elements differed by $\geqslant$ 3 σ; (3) or five or more elements differed by $\geqslant$ 2 σ; (4) or 13 or more elements differed by $\geqslant$ 1 σ.

Sometimes all or nearly all of the measured abundances of a sherd will deviate systematically from the group averages by almost a constant factor. As will be discussed in a later section, however, this can be interpreted as a dilution of the clay of the sherd or of the group by undetected major constituents, e.g. water and CO_2, and appropriate corrections to the abundances can be made.

For a given pottery group the smaller the values of σ for the various elements and the larger the number of useful elements included in the analysis, the smaller is the probability of making an erroneous assignment of provenience

by this method. In practice, it has been found that if about 20 carefully selected elements are used and the average value for σ of their abundance is 10% or less in the reference group, then the determination of provenience is reliable. The selected elements should be measured with a precision substantially better than 10% and then should vary somewhat randomly with respect to each in the different clay beds, but should not vary erratically in the same pot.

To compensate for this possible erratic behavior, as well as the uncertainties in the assumption of a Gaussian distribution of chemical abundances and the occurrence occasionally of low probability statistical events, the one element out of the 20 which shows the poorest agreement between the pot of unknown provenience and the reference group has often been discarded. In the present experiments we were fortunate and this was not necessary. It is possible and even likely that the foregoing criteria might not be sufficient to distinguish potteries made from clay beds which have a very similar geochemical and environmental history, such as deposits laid down along the course of a long river, and for those more stringent criteria would be necessary.

C. Selection of Sherds

The sherds selected for the neutron activation analyses (NAA) were taken from larger groups which had been previously analyzed (Picon et al., 1971) by x-ray fluorescence (XRF). That the ones selected for NAA are representative of the larger collection can be seen from the XRF data in Table I. A map of the sites studied in this work is shown in Fig. 1.

Pottery from Arezzo - Twenty-three sigillata sherds excavated at Arezzo were selected for analyses. These sherds are a priori likely to be of local manufacture since they seem to be "factory rejects".

Pottery from Lyons - As reference sherds from Lyons, we used pieces of broken, misbaked, or deformed pots of terra sigillata from dumps found near the kilns. Twenty-two samples excavated from La Muette and 6 from Loyasse were used in the present measurements. The coarse pottery found here was not appropriate as reference material because it was definitely made from a different type of clay, which among other features, was not calcareous. It has been noted before in studies of pottery from Cyprus (F. Asaro et al., 1972) and from Lezoux, France (Vertet et al., 1970) that different types of clay were sometimes used to produce different styles of pottery.

Ateius signed pottery - 4 sherds with the Ateius signature (ATE-1-4) were analyzed which had been excavated in Strasbourg and one (DIV-22) which had been excavated in Lyons. None of these sherds, however, came from pottery workshops. Photographs of these 5 sherds are shown in Fig. 2.

D. Sample Preparations and Measurements

Carbonate measurements - The samples used for x-ray fluorescence (XRF) measurements (Picon et al., 1971) had been refired in the laboratory at 1000°C prior to weighing, while those used for neutron activation analysis (NAA) were not. The substances removed in the refiring were most likely CO_2 and water. The CO_2 originated either from $CaCO_3$ (limestone) which was present in the clay before the original firing or which was reformed by absorption of CO_2 afterwards. Pottery fired at a low temperature retains its CO_2, that fired at 1000°C or above loses it, and that fired at intermediate temperatures may lose varying amounts. A comparison between measurements on a sherd by the two techniques shows the amount of volatile material, and, if the sherd is calcareous and the CO_2 content is

very low, indicates if it was well-fired. As will be explained below, it is possible to compare the earlier results from XRF measurements with the present NAA results even though one set of samples had been refired and not the other.

In order to determine the CO_2 content of some of the samples used for NAA measurements, a number of wet chemical analyses were made. The pottery powder was treated with cold 2N HCl and gently heated. The CO_2 released was entrained in stream of dry nitrogen, scrubbed with sulphuric acid and then dried over anhydrous $Mg(ClO_4)_2$. The CO_2 was then absorbed on ascarite and weighed. The CO_2 measurements were made by Lilly Y. Goda of the Lawrence Berkeley Laboratory.

NAA measurements - Pottery powder was obtained from a sherd by first cleaning a surface and then drilling or scraping with sapphire or diamond-tipped tools. Alternatively, a small cleaned corner was broken off and ground with a mortar and pestle. 100 mgm of the pottery powder was mixed with 50 mgm of cellulose binder and pressed into a pill one cm in diameter.

The elemental compositions of the pills are determined from the gamma-ray spectra of radioactivities produced by neutron irradiation. The detailed procedure has already been described (I. Perlman and F. Asaro, 1969), but since the date of that publication some modifications have been introduced which improved significantly the accuracy with which several of the elements can be determined. The analyzing system has also been automated, lessening the amount of personal attention required in operating the equipment to its capacity.

III. RESULTS

A. Provenience

The chemical abundances measured by XRF for the sherds used in this work are shown again in Table II. These are arranged, however, into chemical groupings determined by NAA. Some of the entries in Table II pertain to groups of sherds (the number of pieces appear just below the group designations); others are for individual sherds.

It will be noted that the 23 sherds considered to be from Arezzo still fall into a single group. However, the 22 sherds from Montée de La Muette which had been divided into two groups (Picon et al., 1971) have now had 5 sherds removed and tabulated individually under such headings as MML-14. Similarly, the group from Loyasse has had one sherd removed.

For each of the pottery groups, the mean value for each element is listed along with the root-mean-square (rms) deviation for the group. The last column in Table II gives the values for a single sherd along with the respective measuring errors as given by the authors (Picon et al., 1971). Data on other single sherds are presented without measuring errors.

The abundances measured by NAA for the elements most suitable for provenience determinations are shown in Tables III and IV. Table V shows 9 other elements or compounds which have (1) nearly identical behavior with other elements in Tables III and IV (Ce and Lu), (2) very poor precision (Ni and K), or (3) have previously exhibited erratic behavior in otherwise good chemical groups (Ba, Sb, Zn, and CO_2).

The format of Tables III and IV follows that of Table II, with a few additional entries. In the heading for each pottery group, there is an entry

"average σ" which refers to the average value of the rms deviation for the 20 elements expressed as percent of the element abundances. This number is an index of variability in composition averaged over 20 elements. The entries labeled "F" in Tables III-V will be explained below. The last two columns in Table IV (also in Table V) show the values of one standard deviation for the precision and accuracy of the NAA measurements on sherds of Group MML A, and these are generally typical of all of the measurements. The precision indicates how well multiple analyses on identical samples should agree if all were done by the same techniques used in the present work. The accuracy contains, in addition, systematic errors such as uncertainties in the calibration of the standard. These errors should be used in comparing these results with measurements made using other techniques or with different standards.

Table VI shows how closely individual sherds which are of uncertain provenience or which are somewhat aberrant in composition conform to the chemical group averages. Table VII shows a concordance between the sherd numbers used in the NAA and XRF measurements and those previously published.

Arezzo pottery - The 23 sherds form a very homogeneous chemical group with an average value of σ for the 20 elements shown in Table III of only 6.5%. This is well below the desirable 10% upper limit discussed previously, and these sherds are thus very suitable as a chemical reference group for assignments of provenience.

Aluminum and iron are two elements which were measured with comparably good accuracy by both the NAA and XRF techniques. Comparison of the Arezzo group between Tables II and III shows that there is agreement within statistical limitations. Because of the difference in sample preparation involved in the

two techniques, the amount of volatile material in the sherds must be very small (~ 1% or less). The calcium must have been present largely as $CaCO_3$ in the clay from which these pots were made, rather than as part of the clay minerals, because the variability in the Ca abundance for the 23 pots is considerably larger (in both measurements) than the variability of the common clay mineral elements. Thus, the Arretine sherds were well-fired originally with essentially all of the carbonate destroyed.

After the present measurements were performed, an article by Banterla, Stenico, Teviani, and Villani appeared which contained neutron activation analyses of a number of sherds of terra sigillata from Italy and Arezzo in particular. We cannot compare their work with ours since they did not give actual chemical abundances but instead ratios of gamma ray counting rates for different elements.

Lyons pottery, La Muette - Most of the 22 sherds from La Muette could be divided into two chemical groups which we have designated MML A, which has 13 sherds, and MML B which has 4 sherds. As can be seen from Table III, MML B is a very homogeneous chemical group with an average σ for 20 elements of only 5.9% and thus is a suitable reference group. The Al and Fe measured by XRF and NAA agree very well with each other and, for the same reasons as given for the Arezzo pottery, they were well-fired originally.

Two sherds MML-14 and MML-15, would have the same chemical fingerprint as MML B if all of their NAA abundances are enhanced by 8 and 16%, respectively. As shown in Table III, these two sherds after enhancement agree very well with group MML B. Comparison of the NAA and XRF data for Al and Fe indicate that the MML-14 and MML-15 samples used for the NAA measurements contained volatile material, to the extent of 8 and 19%, respectively. These values are in good

agreement with the enhancement factors used. The presence of carbonate in the MML-15 sample used for NAA was confirmed by wet chemistry which indicated 10.2% CO_2. Thus, some sherds in group MML B from Lyons were either not well-fired originally or had absorbed CO_2 since then. The volatile matter (CO_2 and water) acts as a simple diluent, of course, and this effect is responsible for the fact that the measured values for all of the elements are lower than those of the group (MML B) to which these sherds belong.

The 13 sherds of MML A form a homogeneous chemical group with an average σ of 6.4% for the 20 elements shown in Table IV. Thus, this is a suitable reference group for assignment of provenience. Comparison between the Fe and Al values measured by XRF and NAA, indicate the NAA samples contain on the average ~ 4% volatile material. That at least part of this material was due to carbonate was shown by wet chemistry on two sherds from this group which gave values of 3.0 and 1.3% for the CO_2 content.

One sherd, MML-16, was found to be a member of group MML A, if its abundances were all reduced by 15% as indicated in Table IV and V. Comparisons between XRF and NAA measurements on Fe and Al indicate there was no significant volatile material in MML-16. Therefore, 4 of the 15% reduction would be due to the volatile material in Group MML A. Another 5% could be attributed to the lower Ca content of MML-16, which would cause all of the other measured abundances to increase. The variation of Ca abundances in calcareous pottery is often larger than those for other elements because in addition to differences in clay mineral composition, it reflects differences in the potters' techniques for removing limestone. The remaining difference between Group MML A and MML-16, may be due to additional SiO_2 in MML A or some other diluent which is not measured.

Another sherd, MML-3 was a member of MML A if its abundances were enhanced by 8% as shown in Tables IV and VI. The Rb abundance differs by over twice the 9 ppm value of σ for MML A. The counting error on this particular sample, however, was 16 ppm, considerably higher than usual, and that value was therefore substituted for σ. Comparison of XRF and NAA abundance values indicate 14% volatile material in MML-3 and this is in good agreement with the optimum enhancement of 8% needed to make MML-3 agree with MML A and the 4% volatile material in MML A.

The remaining sherd from La Muette, MML-2, agrees in most respects with MML A if its abundance values are enhanced by 13% as shown in Tables IV and VI. Two elements, however, U and Co differ by over 3σ. This may represent some local variation in the MML A composition. The NAA and XRF values for Fe and Al, which are not very consistent for this sample, indicate about 12% of the sample is volatile material. This value is also not in very good agreement with the 13% enhancement needed to make MML-2 a member of MML A and the 4% of volatile material in MML A.

Loyasse - Five of the six sherds from Loyasse form a fairly homogeneous chemical group with an average σ of 8.6% for 20 elements and which is adequate for a chemical reference group. Comparison between XRF and NAA measurements of the Fe and Al in these samples indicate 12% volatile material. This is in good agreement with wet chemical analyses which show an average of 9.6% CO_2 in these 5 samples as shown in Table V. Thus, these samples either retained most of their carbonate after the original firing or absorbed CO_2 afterwards. One sherd from Loyasse, LOY-3, is somewhat different from the other 5 and probably reflects a local variation.

Ateius - The four signed sherds from Strasbourg have abundances which form an extremely homogeneous group of 20 elements with a σ of 3.8% as can be seen in Table III. If these abundances are reduced by 4%, they are in excellent agreement with Group MML A as shown in Table VI. Comparison between the XRF and NAA measurements for Al and Fe indicate these samples have very little volatile material, and this is confirmed by the results of CO_2 analysis shown in Table V. The 4% reduction is in excellent agreement with the volatile components in MML A, which are presumed to be also 4%.

One signed sherd, DIV-22, from Lyons has NAA abundances which agree well with MML A if they are enhanced by 9% as shown in Tables IV and VI. Comparisons between the XRF and NAA measurements for Fe and Al indicate this sherd has 9% volatile material which is in moderate agreement with the 9% needed to make DIV-22 a member of MML A and the 4% volatiles in MML A.

Thus, all 5 of these sherds agree very well in chemical composition with sherds known to have been made at La Muette. The four sherds from Strasbourg not only are members of MML A, but may represent a subgroup as they agree in chemical composition with each other extremely well. DIV-22 and one of the members of MML A would fit into this subgroup.

In making up a chemical pottery group, there are often some arbitrary decisions taken: whether to add a sherd or two to the group (or conversely to remove one or two); whether to divide the group into subgroups in which each is internally more homogeneous than the larger group. Although one may justify the decision to make subgroups on the basis of statistics alone, there is some reluctance to be encumbered with subdivisions if they do not lead to some new insight. Attention is called to such a subgroup in this case because all five

of the vessels with the Ateius signature fall within it. The reason for this may be quite trivial, but it seems worthwhile to keep a note of this occurrence pending further work on these wares which might illuminate the significance.

B. Comparison Between the NAA and XRF Measurements

For a number of samples, definite discrepancies were observed between the XRF and NAA measurements, but these could almost all be attributed to differences in the sample preparation procedure. For those sherds with little or no volatile material, the agreements between the XRF and NAA determinations of the same elements were excellent, and the abundance values can be used to determine the differences in the calibrations used in the two measurements. This latter group of samples will be discussed first.

Calibrations - If the abundances of the common elements for the groups, ARE, MML B, and ATE, are weighted according to the number of sherds, the NAA values are higher than the XRF values for Fe, Al, Ti, K, and Ca by +3, -3, -10, ~ -2, and +2%, respectively. The results for Fe, Al, and Ca are consistent for the three groups within 1%, but those of Ti and K show larger variations. The Ti variation and at least part of that of K could just be due to the counting errors inherent in the measurements.

With the corrections given above, the abundance determinations of the two laboratories (with the exception of Ti and K) can be compared with only a 1% calibration uncertainty.

The NAA and XRF measurements discussed here can also be compared to others made with rocks of the United States Geological Survey (U.S.G.S.) as calibration standards. A number of these rocks were analyzed by the same NAA-techniques

as used for the present measurements (H. Bowman et al.). The abundance values for Fe, Al, Ti, and K were higher than the tabulated ones (Flanagan, 1973) by +2, -3, -5, and -2 percent, respectively.

Refiring pottery samples - Refiring samples prior to weighing is generally not necessary for determinations of provenience. If many elements are being measured and distinctive chemical groups have been determined, one selected element (or more) may be used to normalize the abundances without a significant loss in sensitivity for provenience assignments.

If only a few elements are being measured, however, the loss of one may be serious, and determining the abundance of the volatile components would be more desirable. Even with many elements being used in the analysis, chemical groupings made after such determinations would be more homogeneous generally and possibly permit better distinctions between similar chemical groups from different sites.

IV. CONCLUSION

Pottery with the Ateius signature has been shown to have the same chemical composition pattern as many pottery rejects found near kilns in the large complex of workshops of Montée de La Muette in Lyons. We believe this indicates definitely that the great pottery-making firm in Arezzo, Ateius, had a branch workshop in Lyons around 10 B.C. This branch was probably opened with experienced workers and equipment from Arezzo in order to shorten the distance to the new markets of Gaul and the Germanic border legions.

Further measurements of the same type may give information on the extent of the diffusion of pottery from Lyons workshops into Gaul and Germany and identify additional branch workshops of the firm of Ateius.

ACKNOWLEDGEMENTS

We are grateful to Professor Lawrence Grossman, Tek Lim, Supervisor, and the staff of the Berkeley Triga Reactor for the nuclear irradiation used in this work; the LBL Safety Services Department for rapid delivery of the irradiated samples; Duane Mosier for his invaluable electronic assistance; David Gok for the processing of the computer flow materials; the staff of the LBL computer facilities for the many calculations and graphs which were made, and Harry R. Bowman and Lilly Y. Goda for their assistance in the measurements.

FOOTNOTES AND REFERENCES

*The neutron activation measurements and their interpretation were performed under the auspices of the U. S. Atomic Energy Commission.

Artzy, M., Asaro, F., and Perlman, I., The Origin of the "Palestinian" Bichrome Ware, Lawrence Berkeley Laboratory Report LBL-1286, October 1972.

Asaro, F. and Perlman, I., unpublished data, see Perlman (1969).

Asaro, F. and Perlman, I., Acts of the International Archaeological Symposium, "The Mycenaeans in the Eastern Mediterranean", Nicosia, Cyprus, p. 213-224 (1972).

Banterla, G., Stenico, A., Terrani, M., and Villani, S., 1973 Characterization of Samian ware sherds by means of neutron activation analysis, Archaeometry 15, p. 209-220.

Bowman, H., Asaro, F. and Perlman, I., unpublished results.

The U.S.G.S. rocks used in the Fe measurements were AGV, BCR1, DTS1, G2, GSP1, and PCC1. For Al and Ti the same rocks were used except for DTS1 and PCC1, and for K only AGV, G2, and GSP1 were used.

Ettlinger, E., Vorbemerkungen zu einer Diskussion des Ateius Problems, Rei Cretariae Romanae Fautorum (RCRF) Acta IV (1962).

Fiches, J. L., La diffusion des sigillées italiques en Languedoc, Revue Archéologique du Centre de la France (RAC) XI (1972), p. 253-281.

Flanagan, F. J., Geochimica et Cosmochimica Acta 37, 1189-1200 (1973).

Goudineau, C., La céramique arétine lisse; de Boccard, Paris (1968).

Lamboglia, N., Per una classificazione preliminare della ceramica campana, Proceedings of the 1st International Congress on Ligurian Studies, Monaco, Bordighera, Genova, 10-17 April 1950, p. 139-206, published by Intern. Inst. of Ligurian Studies, Bordighera (1952).

Lasfargues, J. and A. and Vertet, H., La céramique des ateliers augustéens de la Muette à Lyon (to be published).

Lombard, R., Inventaire des estampilles de Poitiers, RAC X (1971), p. 81-91.

Maetzke, G., Notizia sulla esplorazione della fornace di C. N. Ateius in Arezzo, RCRF Acta II (1959), p. 25-27.

Oxé, A., Die Halterner Sigillatafunde seit 1925. Bodenaltertümer Westphalens VI (1943), p. 15-76. (Reference quoted by Goudineau, loc. cit. .)

Perlman, I. and Asaro, F., Pottery Analysis by Neutron Activation, Science and Archaeology, R. H. Brill, ed., MIT Press (1971), p. 182-195.

Perlman, I. and Asaro, F., UCRL-18734 (1969), Pottery Analysis by Neutron Activation, Archaeometry 11, 21 (1969).

Picon, M. and Lasfargues, J., Transfert de moules entre les ateliers d'Arezzo et ceux de Lyon, Mélanges Bruhl, Rev. Archéologique de l'Est 1973.

Picon, M., Vichy, M., and Meille, E., "Composition of the Lezoux, Lyons and Arezzo Samian ware", Archaeometry 13, No. 2 (1971) 191-208, and unpublished results.

Ritterling, E., Mitteil der Alt. Komm. für Westphalen II (1901), p. 142-146. (Reference quoted by Goudineau, loc. cit. .)

Vertet, H., Picon, M., and Vichy, M. Note sur la composition des céramiques du IV^{e} siècle de Lezoux. RAC no. 35-36 (1970).

Table I. Previous x-ray fluorescence measurements.[a] Comparison of chemical abundances of sherds selected for NAA measurements with those of the total group.

Site		Arezzo		Loyasse		La Muette			
Number of sherds	t[b]	71		34		89		20	
	S[c]	23		6		14		8	
		Mean	σ	Mean	σ	Mean	σ	Mean	σ
Si t	(%)	25.4	0.7	26.96	0.89	28.13	0.87	24.85	1.34
Si S		25.1	0.5	26.5	1.2	28.1	0.9	25.0	2.0
Al t		9.6	0.3	6.37	0.21	7.93	0.40	6.79	0.28
Al S		9.5	0.3	6.45	0.37	8.0	0.4	6.8	0.4
Mg t		2.35	0.10	0.89	0.16	0.86	0.18	1.23	0.17
Mg S		2.36	0.11	0.87	.16	0.88	0.23	1.25	0.12
Ca t		8.6	1.3	13.50	1.32	9.94	1.24	15.80	2.04
Ca S		9.4	1.1	13.39	2.13	10.0	1.5	16.0	3.2
K t		2.07	0.14	1.76	0.08	1.82	0.12	1.72	0.21
K S		1.99	0.11	1.77	0.04	1.80	0.09	1.63	0.25
Ti t		1.56	0.02	0.33	0.03	0.38	0.02	0.31	0.01
Ti S		0.53	0.02	0.34	0.04	0.38	0.02	0.30	0.01
Fe t		5.10	0.19	3.20	0.16	3.84	0.25	3.67	0.15
Fe S		5.16	0.17	3.22	0.13	3.80	0.25	3.57	0.13

a) Picon, Vichy, and Meille, 1971.

b) Total sherds in group.

c) Those sherds selected for neutron activation analysis.

Table II. Chemical abundances[a] in pottery measured by x-ray fluorescence.

Group or sherd	ARE	MML B	MML-14	MML-15	LOY	LOY-3
Quantity of sherds	23	4			5	
Si(%)	25.1±.5	23.7±.4	23.8	25.8	26.0±.6	28.9±.6
Al(%)	9.5±.3	6.6±.1	6.5	6.7	6.4±.4	6.9±.3
Mg(%)	2.36±.11	1.36±.12	1.21	1.42	.89±.08	.75±.06
Ca(%)	9.4±1.1	17.9±1.3	17.9	14.8	14.2±.6	9.2±.4
K(%)	1.99±.11	1.51±.22	1.56	1.76	1.77±.04	1.80±.08
Ti(%)	.53±.02	.30±.01	.30	.31	.32±.02	.44±.02
Fe(%)	5.16±.17	3.57±.13	3.43	3.64	3.22±.15	3.22±.13

Group or sherd	MML A	MML-16	MML-3	MML-2	ATE	DIV-22
Quantity of sherds	13				4	
Si(%)	28.0±.9	29.4	29.4	25.8	28.8±.6	28.7
Al(%)	7.9±.4	8.7	7.7	6.9	7.6±.3	7.5
Mg(%)	.88±.23	.81	.69	1.21	.81±.06	.88
Ca(%)	10.0±1.5	7.2	9.3	14.4	9.5±.5	9.7
K(%)	1.80±.09	1.91	1.80	2.04	1.98±.08	1.76
Ti(%)	.38±.02	.41	.38	.31	.38±.01	.37
Fe(%)	3.80±.25	4.16	3.74	3.71	3.55±.12	3.53

(a) If there is more than 1 sherd in a group, the two entries for a particular element are the average abundance of that element and the root-mean-square deviation for the indicated sherds. If there is only 1 sherd listed, the two entries for a particular element are the actual abundance and the experimental accuracy (1σ).

Table III. NAA abundances [a] of selected elements in pottery from Arezzo and some from Lyons.

Group or sherd	ARE	MML B	MML-14 [b]	MML-15 [b]	LOY	LOY-3
Quantity of sherds	23	4			5	
Average σ	6.5%	5.9%	F = 1.08	F = 1.16	8.6%	
Al(%)	9.23±.55	6.41±.23	6.06	6.18	5.37±.38	6.76
Ca(%)	9.5±1.3	18.2±2.4	17.3	15.2	12.7±1.2	9.14
Dy	5.39±.21	4.58±.31	4.65	4.43	4.04±.44	5.31
Mn	1117±41	905±53	862	828	774±89	673
Na(%)	.606±.027	.454±.014	.449	.423	.507±.037	.687
U	2.70±.09	2.61±.22	2.60	2.43	2.33±.33	3.18
Sm	6.56±.20	5.04±.05	5.07	5.07	4.69±.28	6.10
La	39.4±1.1	29.7±.5	29.1	29.6	27.4±1.7	35.0
Ti(%)	.477±.024	.270±.020	.236	.282	.287±.015	.384
Ta	1.241±.039	.772±.018	.787	.799	.785±.048	1.133
Co	22.55±.86	12.87±.19	12.82	12.74	10.27±.82	11.84
Sc	19.06±.59	11.07±.33	10.95	11.33	9.80±.69	12.56
Fe(%)	5.24±.19	3.71±.06	3.66	3.73	2.96±.09	3.20
Yb	2.79±.08	2.25±.05	2.26	2.29	2.19±.11	2.87
Hf	3.95±.12	3.06±.13	3.30	3.17	4.12±.47	6.73
Cs	6.98±1.10	3.68±.61	4.32	3.77	5.30±.95	8.00
Cr	182±6	79±7	85	70	73±6	85
Th	13.44±.47	10.48±.13	10.44	10.45	9.70±.62	13.26
Eu	1.465±.054	1.122±.018	1.124	1.145	1.017±.059	1.250
Rb	132±16	82±21	81	82	92±19	126 [c]

(a) The two entries for each element in a group are the average abundance and the root-mean-square deviation. The values are expressed in ppm or in percent if indicated after the element symbol.

(b) True abundance values are equal to the listed value divided by the enhancement factor, F.

(c) The average Rb counting error for the Loyasse sample was 16 ppm.

Table IV. NAA abundances [a] of selected elements in pottery like Group MML A from La Muette.

Group or sherd	MML A	MML-16 [b]	MML-3 [b]	MML-2 [b]	ATE	DIV-22 [b]	Pre- [c] cision	Accu- [c] racy
Quantity of sherds	13	F = 0.85	F = 1.08	F = 1.13	4	F = 1.09		
Average σ	6.4%				3.8%		1.9%	
Al %	7.38±.48	7.16	6.92	7.20	7.32±.15	7.15	.13	.16
Ca %	10.7±1.6	6.9	12.9	13.0	9.6±.6	11.2	.5	.5
Dy	5.32±.28	5.60	5.19	5.31	5.37±.16	5.05	.14	.30
Mn	858±82	885	817	840	890±61	855	9	14
Na %	.363±.014	.365	.376	.364	.391±.012	.384	.007	.009
U	2.60±.13	2.40	2.83	3.08	2.64±.10	2.53	.03	.23
Sm	6.09±.28	6.21	6.02	6.11	6.18±.10	6.19	.03	.13
La	34.7±1.7	35.6	33.7	34.6	35.8±1.1	35.2	.5	.7
Ti	.328±.021	.324	.300	.293	.331±.014	.329	.014	.020
Ta	.984±.041	.957	.966	.977	.994±.017	1.000	.007	.031
Co	14.29±.78	14.47	14.78	11.74	14.09±.92	12.99	.19	.24
Sc	12.62±.65	12.77	12.12	12.31	12.78±.33	12.54	.07	.22
Fe %	3.73±.24	3.61	3.62	3.63	3.67±.11	3.60	.04	.06
Yb	2.70±.14	2.76	2.65	2.64	2.80±.10	2.73	.03	.35
Hf	4.11±.22	4.18	4.53	4.47	4.64±.12	4.70	.08	.31
Cs	6.47±.47	6.48	5.65	5.62	6.47±.34	6.27	.17	.72
Cr	89±9	89	80	85	89±5	84	1.5	5.0
Th	12.09±.54	11.73	11.86	11.77	12.14±.20	11.92	.09	.42
Eu	1.389±.072	1.399	1.330	1.390	1.425±.021	1.385	.015	.041
Rb	125±9	115	146 [d]	114	128±9	119	7	15

(continued)

Table IV (continued)

(a) The two entries for each element in a group are the average abundance and the root-mean-square deviation. The values are expressed in ppm or in percent if indicated after the element symbol.

(b) True abundances are equal to listed values divided by the enhancement factor, F.

(c) Value for one standard deviation.

(d) The precision for this Rb value was 16 ppm rather than 7.

Table V. Abundances [a] of other elements or compounds measured by NAA or wet chemistry.

Group or sherd	ARE	MML B	MML-14 [b]	MML-15 [b]	LOY	LOY-3
Number of sherds in group	23	4	F = 1.08	F = 1.16	5	
Ce	80.8±3.0	56.8±.9	58.1	59.1	54.0±3.6	70.0
Lu	.402±.017	.317±.022	.345	.350	.328±.021	.397
Ni	98±15	58±16	48	51	40±11	52
K %	1.88±.31	1.48±.32	1.54	1.44	1.39±.18	1.42
Ba	435±36	470±26	496	594	731±198	1217
As	6.5±1.0	27.0±3.9	31.3	31.8	25.9±10.2	16.9
Sb	.67±.07	1.42±.10	1.48	1.33	1.46±.40	
Zn	139±7	85±7	81	88	73±8	91
CO_2(%)				10.2 (4)	9.6±1.9	3.8

Group or sherd	MML A	MML-16 [b]	MML-3 [b]	MML-2 [b]	ATE	DIV-22 [b]	Pre-cision	Accu-racy
Number of sherds in group	13	F = 0.85	F = 1.08	F = 1.13	4	F = 1.09		
Ce	68.4±3.8	68.6	68.9	68.8	70.5±1.6	71.0	.7	3.4
Lu	.391±.025	.412	.432	.425	.395±.019	.374	.017	.039
Ni	58±15	67	77	46	56±8	52	9	22
K(%)	1.82±.34	1.67	1.58	1.27	2.19±.20	1.73	.21	.28
Ba	415±68	371	389	382	490±105	771	13	24
As	15.1±2.0	12.1	15.6	14.6	14.3±2.8	12.5	.7	2.5
Sb	1.25±.12	1.09	1.13	1.11	1.20±.10	1.52	.09	.10
Zn	83±8	80	171	59	87±12	243	5	
CO_2(%) [c]	2.0 [d]				.8±.4	4.2	.3	.3

(continued)

Table V (continued)

(a) The two entries for each element in a group are the average abundance and the root-mean-square deviation. The values are expressed in ppm or in percent if indicated after the element symbol.

(b) True abundances are equal to the listed values divided by the enhancement factor, F.

(c) All CO_2 values are true values without any enhancement.

(d) Two values only.

Table VI. Statistical comparisons of individual sherds with group averages from neutron activation analysis.

Range of deviation (σ)	Numbers of elements in different ranges of deviation from group average				Reference Group	Group Assignment
	0-1	1-2	2-3	3-4		
Expected [a]	~ 13	~ 6	~ 1	~ 0		
ATE-1 [b]	18	2			MML A	MML A
ATE-6 [b]	16	3	1			MML A
ATE-8 [b]	13	7				MML A
ATE-9 [b]	15	5				MML A
DIV-22 [c]	17	2	1			MML A
MML 2 [c]	13	5		2		
MML 3 [c]	13	7				MML A
MML 16 [c]	16	4	1			MML A
MML 14 [d]	15	5			MML B	MML B
MML 15 [d]	13	6	1			MML B

(a) Number of elements expected with different ranges of deviations from the group averages for a group member if the abundance distribution is Gaussian. Because enhancement factors were selected to optimize the agreement with the reference groups, the deviations from the group averages will generally be smaller than the Gaussian expectations.

(b) Abundances reduced by 4% to compensate for 4% average content of volatile material in MML A.

(c) See Table IV for enhancement factors.

(d) See Table III for enhancement factors.

Table VII. Sherd Concordance

Sherd designations used in NAA and XRF measurements		Published* sherd no.
Pottery from Arezzo		
Are group		
Are-2 → 4, -7 → 10, -15 → 17, -19 → 24		Same
Are-27 → 29, 32, 33, 35, 37		U**
Pottery from Montée de la Muette		
MML A group	MML-3	33
	5	30
	16	38
	17	39
	20	2
	21	3
	24	5
	25	6
	48	14
	59	25
	67	51
	69	53
	72	56
	94	71
	129	U
MML B group	MML-14	36
	15	37
	22	41
	23	4
	27	42
	135	U
Others	MML-2	32
Pottery from Loyasse		
LOY group	LOY-1# (29)##	U
	2 (30)	U
	4 (32)	U
	5 (33)	U
	6 (34)	U
Others	LOY-3 (31)	U

(continued)

Table VII (continued)

Ateius signed sherds	
ATE-1	U
2	U
3	U
4	U
DIV-22	U

*Picon et al., 1971.

**Unpublished.

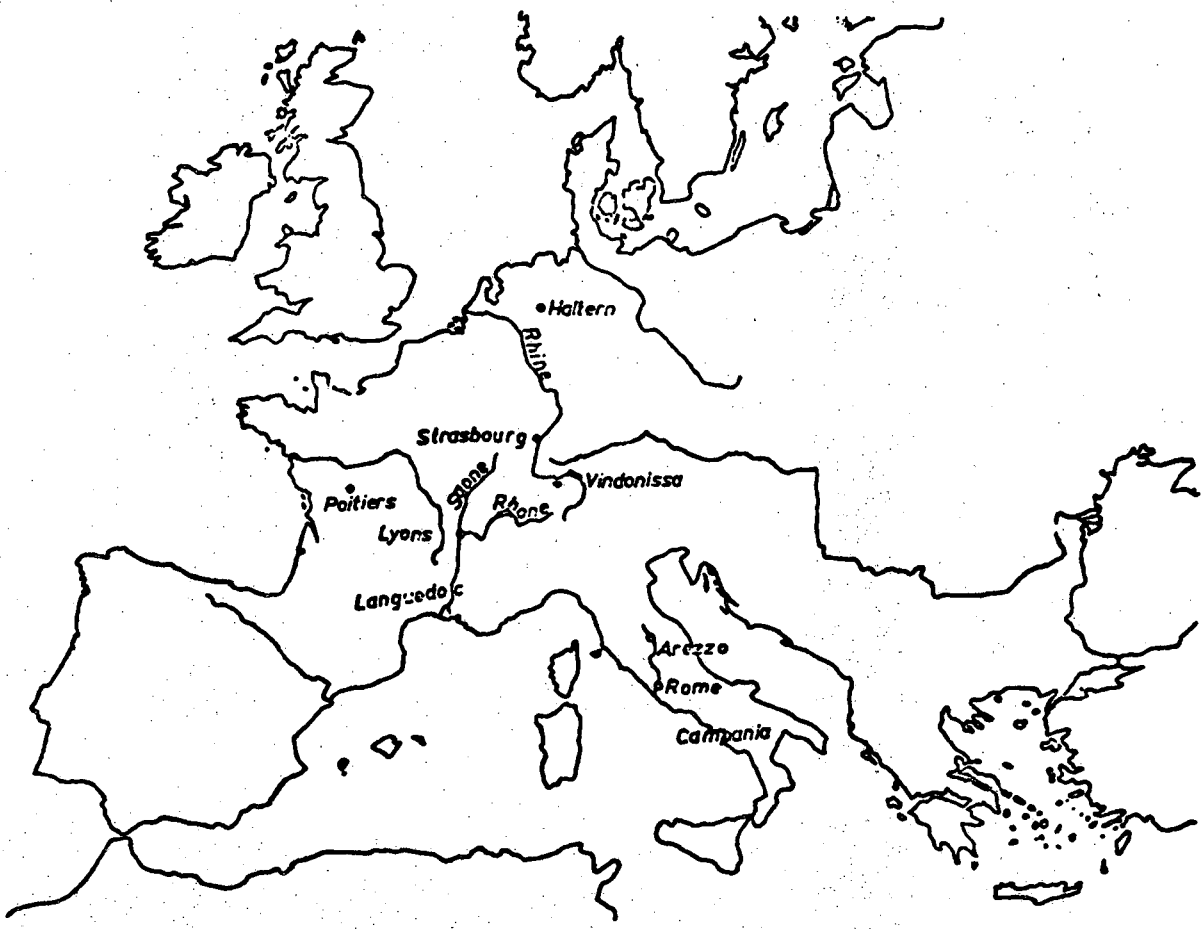
#Sherd numbers used for NAA measurements only.

##Sherd numbers used for XRF measurements only.

FIGURE CAPTIONS

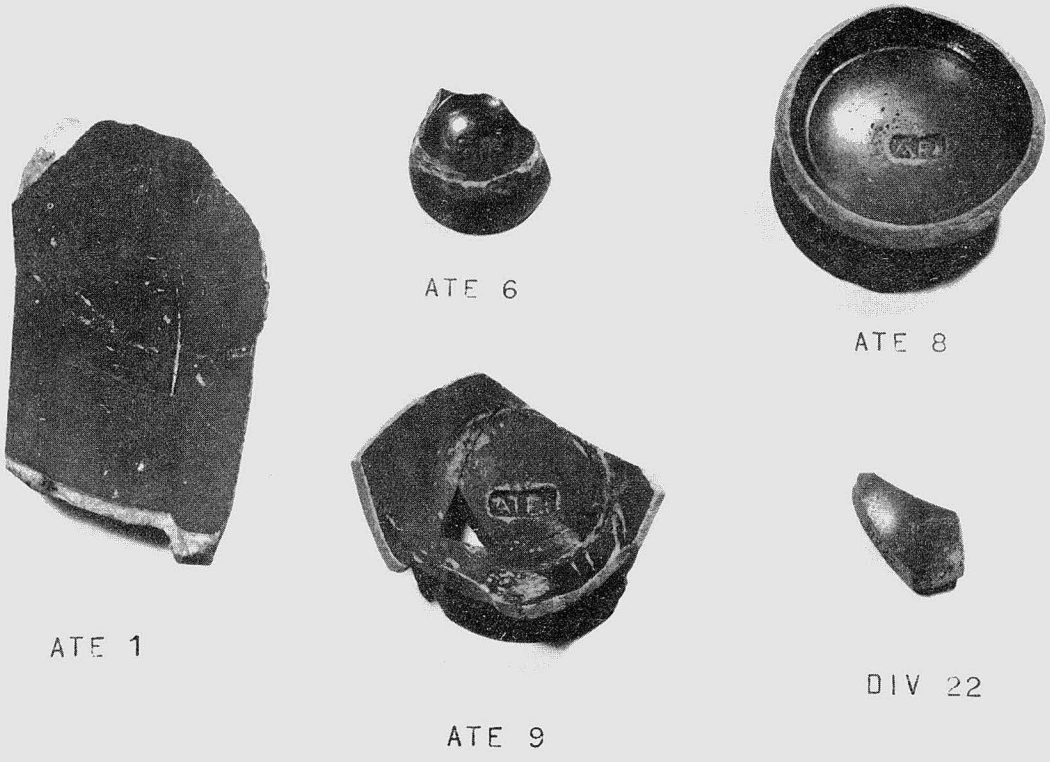
Fig. 1. Map of Europe showing the location of sites in this study.

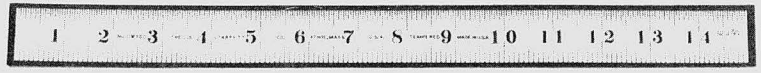
Fig. 2. Five terra sigillata sherds bearing the stamp of Ateius.



XBL 742-362

Fig. 1





ATEIUS

Fig. 2

CBB 722-1067

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720