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# COMPOSITION OF THE LEZOUX, LYON AND AREZZO SAMIAN WARE

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## 1. INTRODUCTION

The main object of this survey is to determine the chemical characteristics which make it possible to differentiate between Samian ware from three centres of production: Lezoux, Lyon and Arezzo. Although this is comparatively easy to do for Lyon and Arezzo it is more difficult at Lezoux because of the great variety of compositions found here. It was therefore necessary to study products from Lezoux in detail so as to be systematic. This was an opportunity to elucidate some of the important characteristics of Samian ware, particularly that of Italic tradition.

## 2. THE LEZOUX PRODUCTION CENTRE

The samples of Samian ware used as a basis for this survey were chosen so as to offer the widest possible range both of date and of geographical location within the production centre. They therefore give a fairly general view of the whole of the Lezoux production of Samian ware.

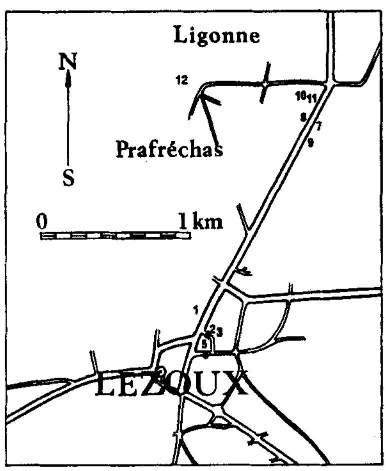


Figure 1

The compositions of some of the Lezoux Samian ware samples have been tabulated in table 1 and others have been represented on figures 5–11. The number allotted to each piece of pottery indicates its geographical location within the centre (see map, figure 1) and the century is shown by roman numerals followed by a, b, c or d for each subdivision corresponding to a quarter of a century (e.g. IIb=125–150; IIbc=125–175). The samples are numbered chronologically and the percentages refer to calcined potsherds.

An appendix shows the essential characteristics of the method used for analysis.

Table 1 *Lezoux Samian ware of the first century*

| *Sample no.* | *Date A.D.* | *CaO %* | *$Fe_2O_3$ %* | *$TiO_2$ %* | *$K_2O$ %* | *$SiO_2$ %* | *$Al_2O_3$ %* | *MgO %* | *Location* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ia | 2.80 | 5.45 | 1.22 | 3.60 | 54.9 | 27.0 | 1.20 | 1 |
| 2 | Ia | 2.30 | 3.90 | 1.08 | 3.80 | 57.8 | 26.2 | 1.00 | 1 |
| 3 | Ia | 2.70 | 5.50 | 1.40 | 3.50 | 53.5 | 27.4 | 1.50 | 1 |
| 4 | Ia | 2.30 | 5.10 | 0.92 | 3.90 | 58.3 | 26.6 | 1.35 | 1 |
| 5 | Ia | 2.70 | 5.70 | 1.02 | 3.75 | 57.4 | 24.8 | 1.45 | 1 |
| 6 | Ia | 1.20 | 3.85 | 1.07 | 4.30 | 60.1 | 26.6 | 1.40 | 6 |
| 7 | Ia | 1.20 | 3.90 | 1.08 | 4.15 | 59.6 | 26.8 | 1.35 | 6 |
| 8 | Ia | 0.95 | 3.90 | 1.10 | 4.20 | 60.0 | 26.7 | 1.50 | 6 |
| 9 | Ia | 1.20 | 3.90 | 1.07 | 4.25 | 59.8 | 26.6 | 1.35 | 6 |
| 10 | Ia | 0.95 | 3.90 | 1.10 | 4.20 | 60.3 | 26.8 | 1.30 | 6 |
| 11 | Ia | 1.20 | 3.90 | 1.08 | 4.25 | 59.8 | 26.7 | 1.40 | 6 |
| 12 | Ia | 1.20 | 4.00 | 1.07 | 4.25 | 59.0 | 26.5 | 1.35 | 6 |
| 13 | Ia | 0.95 | 3.95 | 1.09 | 4.10 | 59.8 | 27.2 | 1.45 | 6 |
| 14 | Ia | 0.95 | 3.85 | 1.08 | 4.20 | 59.7 | 26.5 | 1.15 | 6 |
| 15 | Ia | 0.95 | 3.95 | 1.10 | 3.95 | 59.8 | 27.2 | 1.45 | 6 |
| 16 | Iab | 0.70 | 4.05 | 1.25 | 3.85 | 57.8 | 28.4 | 1.85 | 10 |
| 17 | Iab | 0.80 | 4.25 | 1.29 | 3.75 | 57.2 | 28.7 | 1.70 | 10 |
| 18 | Iab | 0.80 | 4.50 | 1.16 | 3.90 | 58.0 | 28.3 | 1.70 | 10 |
| 19 | Iab | 1.50 | 6.15 | 0.97 | 3.80 | 55.6 | 29.0 | 1.55 | 10 |
| 20 | Iab | 1.30 | 6.30 | 1.00 | 3.85 | 56.4 | 28.2 | 1.40 | 10 |
| 21 | Iab | 1.10 | 5.15 | 1.37 | 3.95 | 55.5 | 28.2 | 1.35 | 10 |
| 22 | Ic | 2.90 | 5.90 | 1.00 | 3.35 | 55.1 | 25.7 | 1.35 | 1 |
| 23 | Ic | 1.80 | 7.10 | 1.28 | 3.80 | 57.3 | 26.2 | 1.30 | 1 |
| 24 | Icd | 1.30 | 6.15 | 1.14 | 3.85 | 58.3 | 26.6 | 1.75 | 7 |
| 25 | Icd | 2.80 | 6.45 | 1.16 | 3.70 | 57.4 | 25.2 | 1.55 | 1 |
| 26 | Icd | 0.90 | 6.55 | 1.32 | 3.90 | 58.1 | 26.8 | 1.95 | 1 |
| 27 | Icd | 1.40 | 5.80 | 1.20 | 3.75 | 58.1 | 26.9 | 1.65 | 1 |
| 28 | Icd | 1.40 | 6.65 | 1.01 | 3.90 | 55.5 | 28.4 | 1.50 | 1 |
| 29 | Icd | 1.70 | 4.40 | 1.22 | 3.85 | 57.6 | 26.3 | 1.25 | 1 |
| 30 | Icd | 2.30 | 6.10 | 1.04 | 3.95 | 57.1 | 25.6 | 1.40 | 1 |
| 31 | Icd | 2.70 | 6.50 | 1.16 | 3.50 | 55.3 | 25.8 | 1.70 | 1 |
| 32 | Id | 3.20 | 5.10 | 0.86 | 3.75 | 60.1 | 23.2 | 1.00 | 1 |
| 33 | Id | 2.20 | 5.40 | 0.93 | 3.85 | 58.8 | 26.0 | 1.30 | 1 |
| 34 | Id | 1.70 | 5.20 | 0.96 | 3.90 | 55.2 | 27.6 | 1.00 | 1 |
| 35 | Id | 1.80 | 4.90 | 1.14 | 4.25 | 60.9 | 24.2 | 1.30 | 1 |
| 36 | Id | 3.40 | 5.50 | 0.96 | 4.15 | 56.0 | 25.0 | 1.40 | 1 |
| 37 | Id | 3.40 | 5.55 | 0.99 | 4.20 | 57.9 | 26.0 | 1.70 | 1 |
| 38 | Id | 3.50 | 4.70 | 0.95 | 4.00 | 56.8 | 27.7 | 1.20 | 4 |
| 39 | Id | 6.90 | 4.70 | 0.92 | 4.00 | 57.3 | 23.7 | 1.25 | 4 |
| 40 | Id | 5.30 | 4.40 | 0.87 | 3.85 | 57.5 | 25.9 | 1.30 | 4 |
| 41 | Id | 3.60 | 4.50 | 0.93 | 4.15 | 58.6 | 25.8 | 1.20 | 4 |
| 42 | Id | 4.60 | 4.70 | 0.92 | 4.00 | 57.4 | 26.0 | 1.20 | 4 |
| 43 | Id | 4.20 | 4.70 | 0.96 | 3.85 | 56.2 | 27.4 | 1.30 | 1 |

A number of coarse potsherds of different kinds were also analysed by the same method and the results are shown in table 3.

Now, if we examine the whole range of Samian compositions in table 1 and figures 5–11 we find distinct differences according to the period under consideration, the main difference being that of the percentage of lime (CaO): in the first century these percentages are systematically lower and in some cases very much lower than those of the following centuries.

Table 2 *Lezoux second and fourth centuries Samian ware samples: distribution between sites*

| *Location* | *Sample numbers* |
|---|---|
| 1 | 44 |
| 2 | 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86 |
| | 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116 |
| | 117, 118, 119, 120, 121, 122, 123, 124, 125 |
| 3 | 87, 88, 89, 90, 91, 92 |
| 5 | 93, 94, 95, 96, 97, 98 |
| 7 | 45, 46, 47, 48, 57, 58, 59, 60, 99, 100, 101, 102 |
| 9 | 49, 50, 51, 52, 53, 54, 55, 56 |
| 11 | 103, 104, 105 |
| 12 | 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71 |

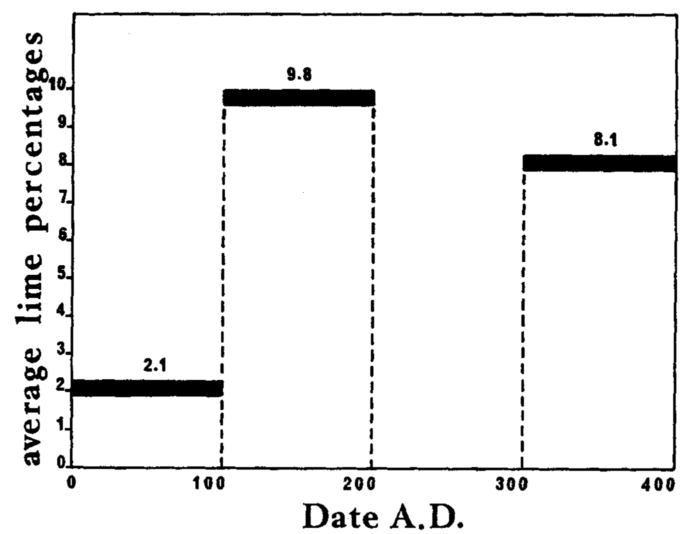


Figure 2 *Changes of average lime percentages in Lezoux Samian ware, century by century*

Figure 2 shows the variation through the centuries of average lime percentage in Lezoux Samian ware. The absence of Samian ware of the third century will be noted, as very few Lezoux specimens are known whose date is certain. For the second and fourth centuries there is little variation in the average lime percentage: it could result merely from the usual

Table 3 *Lezoux coarse pottery*

| Sample no. | Date A.D. | CaO % | $Fe_2O_3$ % | $TiO_2$ % | $K_2O$ % | $SiO_2$ % | $Al_2O_3$ % | MgO % | Location |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ia | 1.40 | 4.95 | 1.09 | 3.85 | 59.8 | 26.0 | 1.55 | 1 |
| 2 | Ia | 1.00 | 4.35 | 1.10 | 4.00 | 59.9 | 26.5 | 1.50 | 1 |
| 3 | Ia | 1.10 | 4.70 | 1.10 | 4.05 | 58.3 | 27.2 | 1.45 | 1 |
| 4 | Ia | 1.20 | 5.65 | 1.41 | 3.60 | 58.0 | 28.0 | 1.65 | 8 |
| 5 | Ia | 5.20 | 5.75 | 1.01 | 3.60 | 56.5 | 25.6 | 1.65 | 8 |
| 6 | Ia | 1.90 | 5.50 | 1.06 | 3.70 | 60.7 | 24.2 | 1.45 | 8 |
| 7 | Ia | 0.70 | 5.75 | 1.52 | 3.80 | 56.9 | 28.8 | 1.85 | 8 |
| 8 | IIcd | 3.90 | 6.30 | 0.70 | 4.30 | 63.0 | 19.6 | 1.45 | 2 |
| 9 | IIcd | 3.90 | 6.05 | 0.62 | 4.15 | 64.2 | 18.8 | 1.35 | 2 |
| 10 | IIcd | 2.50 | 5.40 | 0.70 | 4.15 | 66.5 | 18.8 | 1.60 | 2 |
| 11 | IIcd | 0.90 | 6.10 | 1.09 | 4.10 | 66.7 | 18.0 | 1.50 | 2 |
| 12 | IIcd | 1.40 | 6.75 | 1.12 | 4.00 | 65.1 | 18.0 | 1.60 | 2 |
| 13 | IIcd | 2.70 | 5.20 | 0.70 | 4.15 | 66.2 | 19.2 | 1.55 | 2 |
| 14 | IIcd | 3.80 | 6.65 | 0.64 | 4.15 | 64.2 | 19.0 | 1.65 | 2 |
| 15 | IIcd | 1.00 | 4.85 | 0.69 | 4.05 | 64.9 | 22.4 | 1.55 | 2 |
| 16 | IIcd | 1.00 | 4.95 | 0.68 | 4.05 | 65.1 | 22.4 | 1.75 | 2 |
| 17 | IIcd | 1.00 | 4.90 | 0.68 | 4.05 | 65.4 | 22.4 | 1.70 | 2 |
| 18 | IIcd | 1.60 | 5.20 | 1.01 | 3.50 | 59.9 | 25.2 | 1.30 | 2 |
| 19 | IIcd | 0.80 | 4.60 | 0.74 | 3.95 | 64.4 | 23.1 | 1.40 | 2 |
| 20 | IIcd | 3.70 | 6.55 | 0.70 | 4.05 | 62.1 | 21.2 | 1.50 | 2 |
| 21 | IIcd | 1.00 | 4.90 | 0.68 | 4.10 | 64.5 | 22.2 | 1.20 | 2 |
| 22 | IIcd | 1.10 | 4.90 | 0.68 | 4.05 | 64.7 | 22.2 | 1.40 | 2 |
| 23 | IIcd | 4.60 | 5.10 | 0.90 | 4.00 | 60.7 | 21.8 | 1.10 | 2 |
| 24 | IIcd | 4.10 | 5.65 | 0.72 | 3.90 | 61.5 | 22.0 | 1.20 | 2 |
| 25 | IIcd | 1.00 | 4.90 | 0.69 | 4.05 | 64.2 | 22.4 | 1.55 | 2 |
| 26 | IIcd | 0.90 | 4.70 | 0.99 | 3.80 | 59.9 | 26.2 | 1.15 | 2 |
| 27 | IIcd | 7.00 | 5.30 | 0.74 | 3.90 | 59.6 | 21.2 | 0.85 | 2 |
| 28 | IIcd | 0.60 | 5.60 | 0.78 | 3.95 | 64.3 | 22.4 | 1.15 | 2 |
| 29 | IIcd | 2.70 | 5.50 | 0.65 | 4.10 | 63.4 | 20.4 | 1.00 | 2 |
| 30 | IVd | 1.10 | 3.50 | 1.12 | 3.90 | 63.0 | 25.0 | 0.85 | 2 |
| 31 | IVd | 1.15 | 4.10 | 1.03 | 3.70 | 61.9 | 25.8 | 1.20 | 2 |
| 32 | IVd | 0.20 | 3.70 | 0.98 | 4.70 | 61.5 | 28.6 | 1.20 | 2 |
| 33 | IVd | 1.20 | 4.10 | 1.14 | 3.80 | 60.5 | 27.0 | 1.10 | 2 |
| 34 | IVd | 1.10 | 3.80 | 1.28 | 4.00 | 58.6 | 28.2 | 1.30 | 2 |
| 35 | IVd | 0.70 | 4.60 | 1.07 | 3.80 | 61.8 | 25.9 | 1.20 | 2 |
| 36 | IVd | 0.70 | 4.55 | 0.90 | 3.75 | 65.3 | 22.8 | 1.10 | 2 |
| 37 | IVd | 3.70 | 4.65 | 0.98 | 3.95 | 58.6 | 25.9 | 1.50 | 2 |
| 38 | IVd | 0.70 | 4.10 | 1.28 | 4.00 | 59.8 | 27.8 | 1.05 | 2 |
| 39 | IVd | 1.60 | 4.20 | 1.16 | 4.10 | 58.7 | 27.4 | 1.20 | 2 |
| 40 | IVd | 0.80 | 3.30 | 1.22 | 3.95 | 61.0 | 27.0 | 0.95 | 2 |
| 41 | IVd | 1.50 | 4.50 | 0.98 | 3.75 | 62.4 | 23.6 | 1.00 | 2 |
| 42 | IVd | 1.40 | 4.85 | 1.07 | 3.60 | 60.1 | 26.0 | 1.20 | 2 |
| 43 | IVd | 0.70 | 4.75 | 1.22 | 3.90 | 60.1 | 27.0 | 1.20 | 2 |
| 44 | IVd | 0.60 | 4.60 | 1.11 | 4.65 | 57.5 | 29.3 | 1.30 | 2 |
| 45 | IVd | 1.30 | 4.80 | 1.05 | 3.60 | 60.2 | 26.0 | 1.25 | 2 |
| 46 | IVd | 0.90 | 4.30 | 1.12 | 3.65 | 59.0 | 29.4 | 1.30 | 2 |
| 47 | IVd | 1.30 | 3.90 | 0.95 | 4.05 | 64.1 | 24.1 | 1.05 | 2 |
| 48 | IVd | 0.60 | 3.85 | 1.08 | 4.25 | 62.1 | 26.1 | 1.10 | 2 |
| 49 | IVd | 1.40 | 4.85 | 1.04 | 3.65 | 60.4 | 26.5 | 1.50 | 2 |
| 50 | IVd | 0.90 | 5.05 | 1.04 | 3.75 | 63.2 | 23.6 | 1.35 | 2 |
| 51 | IVd | 0.60 | 4.50 | 0.97 | 3.80 | 63.2 | 25.0 | 1.15 | 2 |
| 52 | IVd | 1.00 | 3.90 | 1.06 | 3.85 | 62.1 | 25.6 | 1.05 | 2 |

fluctuations in composition that are found in Lezoux at all times, accentuated in the case of fourth century potsherds by the fact that they all come from the same site.

This explanation certainly cannot account for the difference between the average lime values in the first and second centuries. The potsherds of both centuries come from different sites but the difference is still large. There must therefore be a large change in the composition of Lezoux Samian ware between the first and second centuries. This alteration is the more remarkable as it is accompanied by an even more important modification which concerns the slip or gloss of these potsherds.

In Lezoux the first-century Samian ware, which can be considered non-calcareous as opposed to second-century ware whose calcareous content is high, shows a practically unvitrified slip which is therefore permeable. In the second century, however, the slip is impermeable and vitrified. Now, the baking of this first-century ware, because of its unvitrified slip, is a far easier operation than that of normal Samian ware such as Arezzo ware. The baking atmosphere can only be partially oxidizing at the end of the operation otherwise serious problems will result for the colour of the slip (Picon and Vertet 1970, Vertet *et al.* 1971a, b).

This indicates that during the first century in Lezoux we are faced with a simplified technique which differs from the Arezzo technique both in composition of the paste and in the characteristics of the slip. On the other hand, in the second century the high lime content of the clay and the vitrified slip obtained from an oxidizing atmosphere seem to be a perfect reproduction of the Arezzo processes. These two factors—high lime content in the paste and vitrified slip—also characterize the Lyon Samian ware, as well as that from all production centres in southern Gaul, while the Lezoux techniques in the first century can also be found in other centres in central Gaul during the same period. In the second century the Lezoux techniques disappeared altogether from central Gaul and were replaced by processes using high lime content pastes and vitrified slips. Samian ware made with a non-calcareous paste is only found now in eastern Gaul.

The conclusion, therefore, is that the high lime content paste constituted an essential element of the manufacturing techniques of Samian ware of Italic tradition as also did vitrified slips in an oxidizing atmosphere. This conclusion is supported by a number of observations made in Lezoux and several other production centres.

Comparison between Lezoux Samian ware and coarse pottery is most instructive in this connection. The coarse pottery studied was unglazed and mostly belonged to types of vessels of the same size as the Samian ware. In the first century both Samian ware and coarse pottery were made with non-calcareous paste: there does not seem to have been any kind of clay set aside exclusively for the manufacture of Samian ware (compare analyses 1–7 in table 3 with analyses 1–43 in table 1). This conclusion, however, results mainly from more detailed investigation through optical emission spectrography which is not reproduced here.

From the second century things appear quite different. Non-calcareous pastes continue to be used, in the main, for coarse pottery as in the first century, while high lime content pastes are used for Samian ware. This is shown clearly in figure 3 where coarse pottery from the second half of the second century (numbers 8–29 in table 3) is compared to the same number of samples of Samian ware found with or near the coarse pottery, and of the same date (numbers 72–93 in figures 5–11). Each sherd is represented by a square whose position on the horizontal line indicates the nearest upper and lower integral value of its percentage lime content. Figure 3, and all similar diagrams that can be drawn for the second century sites in Lezoux show very clearly that high lime content pastes occupy an isolated position within the range of Lezoux production. Thus, although Samian ware is closely linked in manufacture to the other wares from Lezoux, production here is dominated by non-calcareous

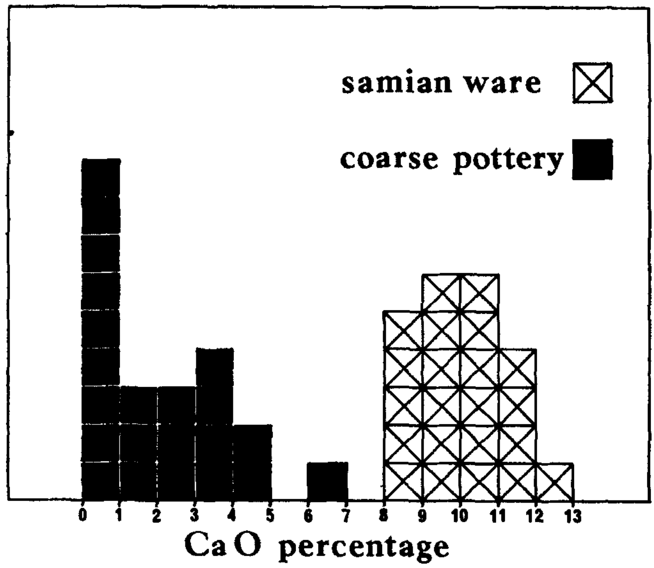


Figure 3 *Comparison between CaO percentages of Samian ware and coarse potsherds (Lezoux, second century)*

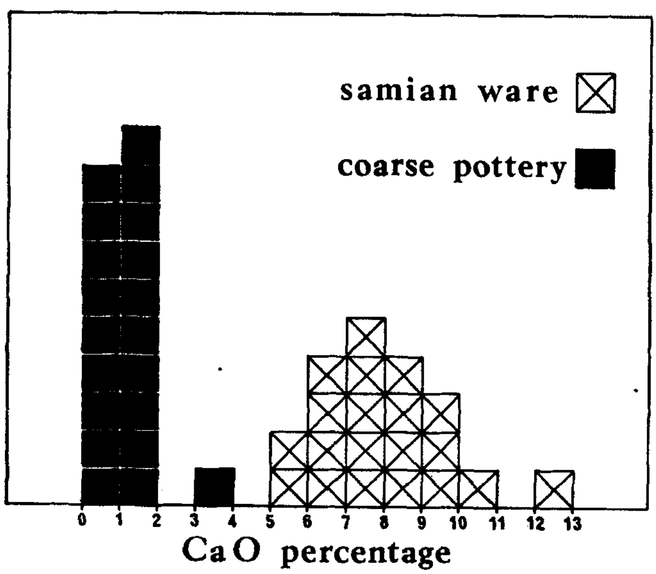


Figure 4 *Comparison between CaO percentages of Samian ware and coarse potsherds (Lezoux, fourth century)*

pastes, which seem to be a local tradition. This is still more apparent if Samian ware and coarse pottery from the fourth century (numbers 106–125 in figures 5–11, and 30–49 in table 3) are compared (see figure 4, which is drawn in the same way as figure 3). There is the same association between high lime content paste and Samian ware, although by now the slip glaze technique had greatly deteriorated. In this particular case the association is most striking as the coarse pottery consists only of grey ware which has the same shape as Samian ware and was found mixed with the latter in the same refuse dumps.

Observations of the same kind occur in many other centres of manufacture of Samian ware. In Lyon, for instance, objects made under Italic influence (e.g. Samian ware, lamps, thin-walled vases) are made of calcareous paste while pottery belonging to the local tradition (e.g. painted vases, bowls with red slip, pottery coated with micaceous slip) are made of non-calcareous paste. Once again there is the same link between Samian ware—or more generally speaking pottery of Italic tradition—and calcareous pastes. This, of course, does not exclude the occurrence occasionally of calcareous pottery that has no obvious link with Italic technical traditions. However, such cases are fairly few in central Gaul, where the local technical traditions prior to the Roman conquest seem to have been more or less ignorant of this type of paste.

Thus two questions arise. Why did potters prefer to use high lime content pastes for the manufacture of Samian ware, and how were they able to recognize them? The answer to the first question is still uncertain. Technical reasons may have imposed this choice: the slip may have harmonized better with high lime content pastes, for instance, but studies on this point are not yet advanced enough for it to be stated positively. On the other hand the second question raises no difficulties. In almost every centre making Samian ware of the Italic tradition (i.e. with high lime content paste and vitrified slip in an oxidizing atmosphere) the existence has been noted of annexe products characterized by black or brown vitrified slip and a yellowish, almost white, paste. The colour of the slip glaze in these products implies a reducing atmosphere during vitrification. Analysis shows that the pastes of these annexe products, which are also in the Italic tradition (lamps, thin-walled vases, etc.) are the same as the pastes used for Samian ware and as high in lime content. Only pastes of this kind can take on colours as different to each other as are those of Samian ware and annexe products, according to whether the atmosphere is oxidizing or reducing. It is therefore likely that this colour criterion was used to distinguish high lime content clays from those so-called non-calcareous clays. As for CaO percentages the limit between the two categories seems to lie around 7–8%, but naturally it more or less depends on the other constituents (Picon and Vertet 1970).

The annexe products mentioned are not shown in either of the tables that refer to the Lezoux compositions. They certainly cannot be placed with coarse pottery, as the manufacturing technique used and their typology unquestionably set them among pottery of Italic tradition, along with Samian ware. As the study was concerned with the relationship between common pottery and Samian ware they have been left out. There are few of them in Lezoux, and none in the first century when there are no calcareous pastes, though at the beginning of the second century, when Italic processes started in Lezoux, they are most numerous.

## 3. DISTINGUISHING FEATURES OF THE LEZOUX, LYON AND AREZZO PRODUCTS

From the foregoing results it is clear that the composition of Lezoux Samian ware and that of Lyon and Arezzo ware will not be confused if only the Lezoux ware made during the time when the Lyon and Arezzo production centres were active is considered: the Lyon and Arezzo centres were using only high lime content pastes for Samian ware, while the Lezoux centre was using only non-calcareous pastes. As was shown above, Lezoux only used calcareous pastes from the second century, i.e. long after the Lyon and Arezzo centres had closed down.

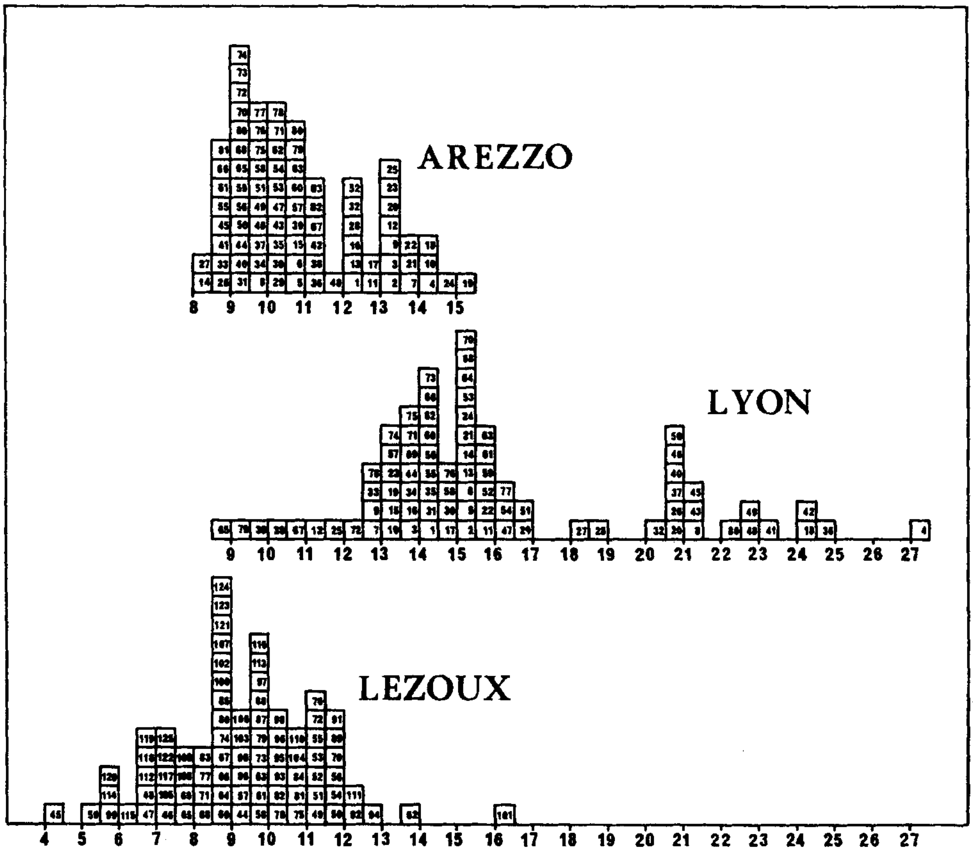


Figure 5 *CaO percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

However, it has been of interest to study the difference between the calcareous paste Samian ware from Lezoux and that from Lyon and Arezzo. In order to extend the present study to later production centres it is necessary to know the compositions of the Lezoux calcareous products; it is therefore important not to confuse the dates although this does not matter experimentally.

Comparative diagrams were made for each of the constituents for the three production centres under consideration (figures 5–11). The specimens on these diagrams are in approximately equal numbers—82 for Lezoux, 80 for Lyon and 82 for Arezzo. For Lezoux the

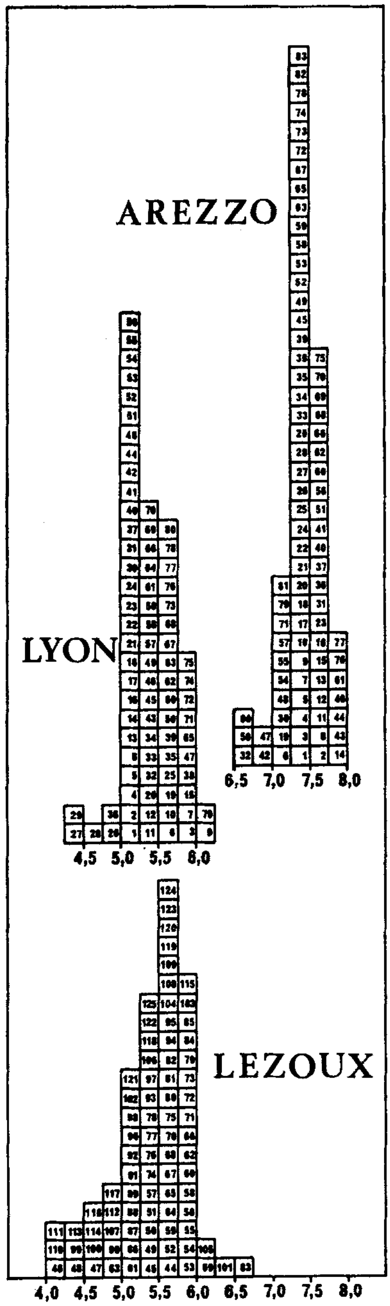


Figure 6 *$Fe_2O_3$ percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

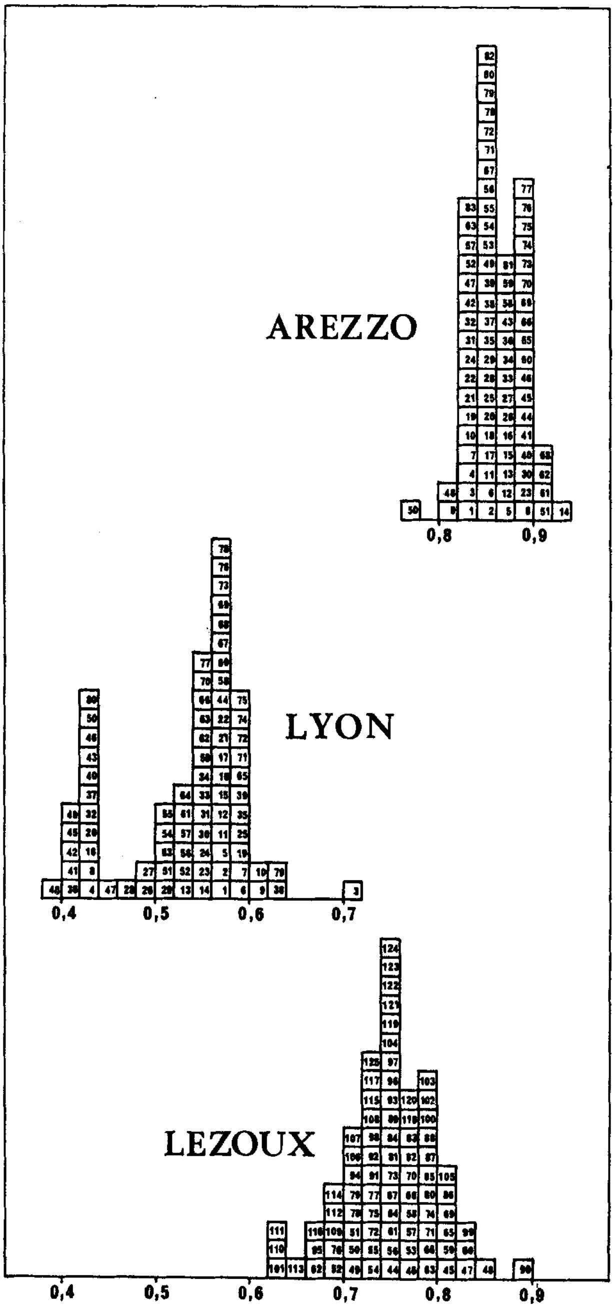


**Figure 7** *$TiO_2$ percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

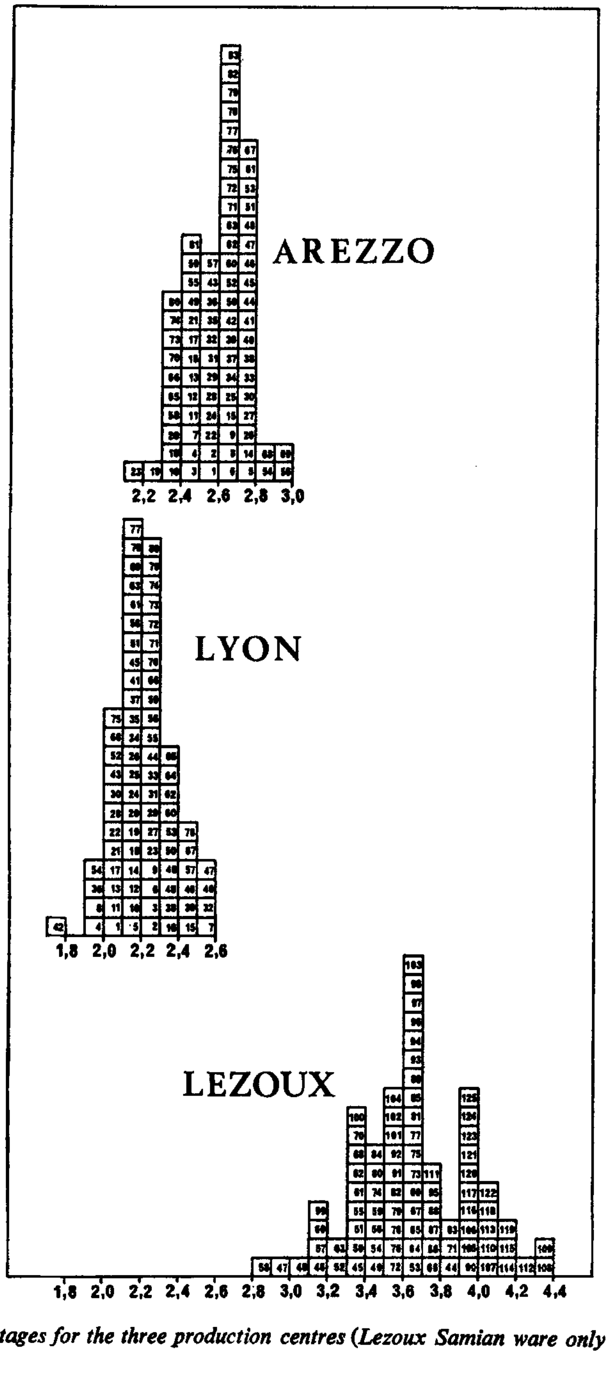


Figure 8 *$K_2O$ percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

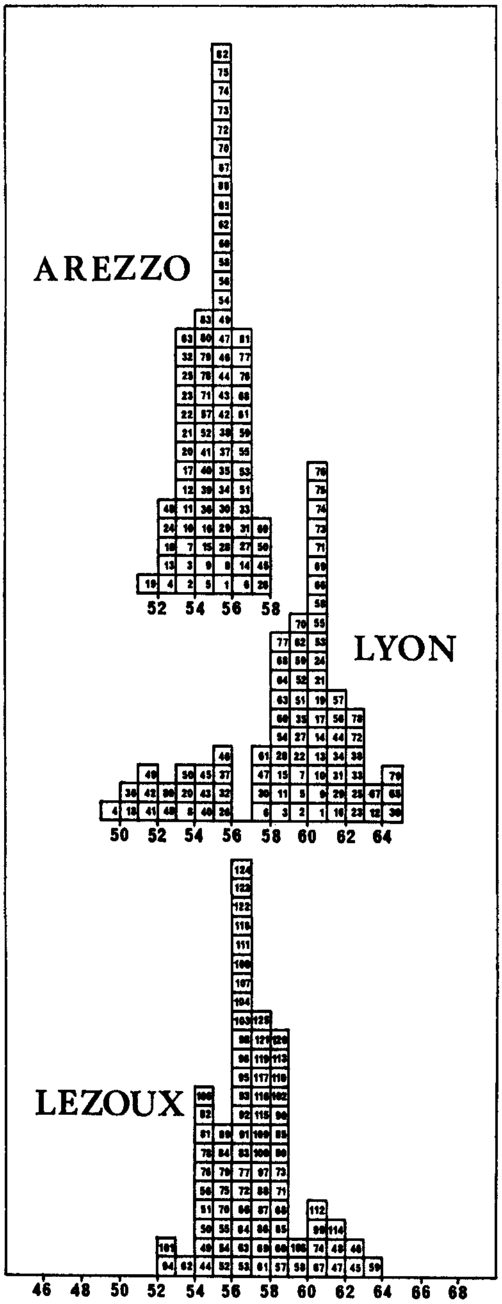


Figure 9 *$SiO_2$ percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

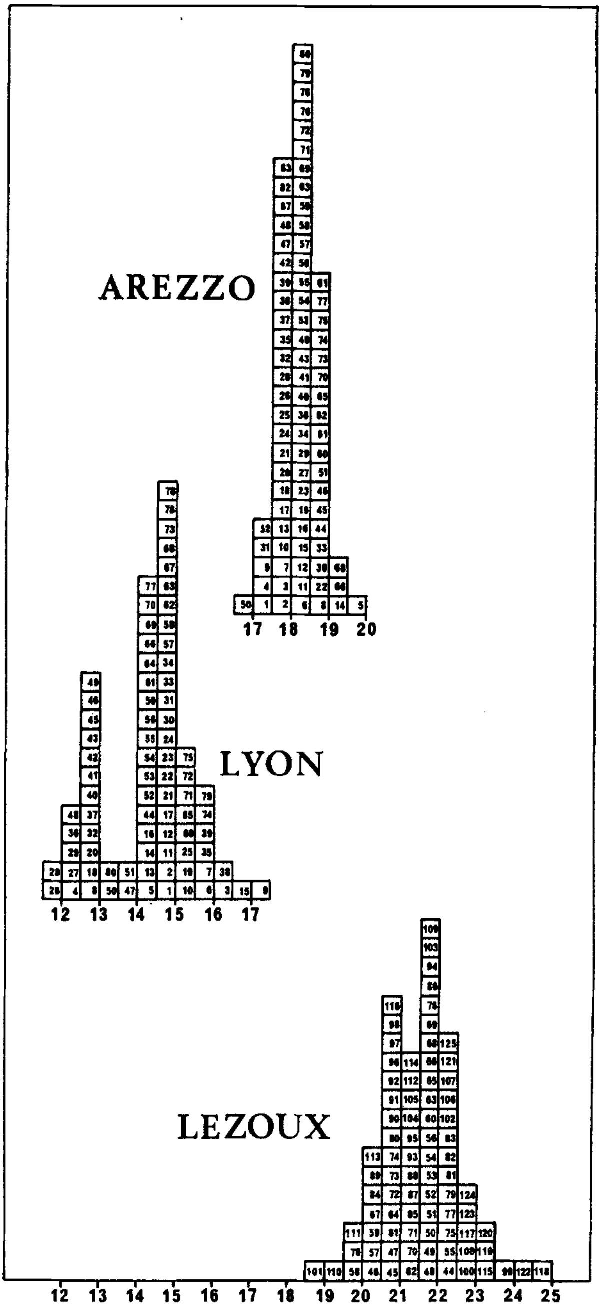


Figure 10 *$Al_2O_3$ percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

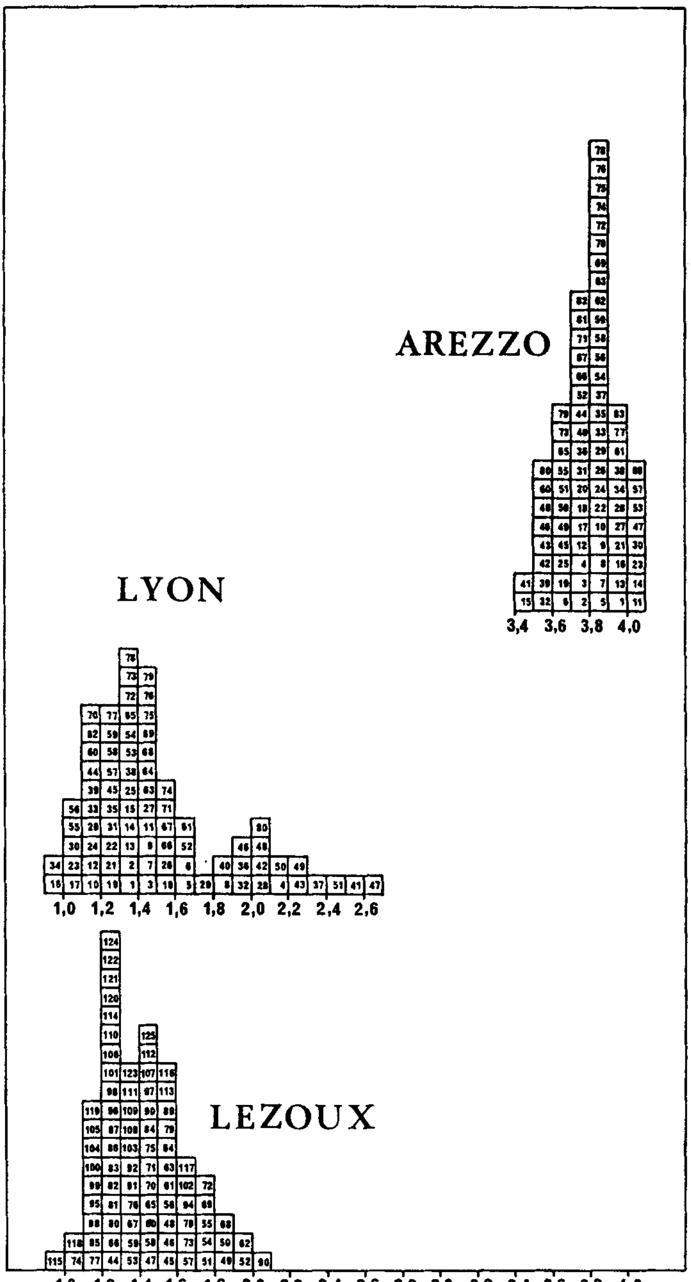


Figure 11 *MgO percentages for the three production centres (Lezoux Samian ware only from the second and fourth centuries)*

second- to fourth-century analyses were used. For Lyon, as with Lezoux, a set of Samian ware very representative of the Lyon workshops was collected. The largest possible number of types of vessels and the greatest variety of stamps were chosen. For Lyon almost all the specimens come from the workshop of the 'Muette' (Vertet *et al.* 1968). Only numbers 26–29 come from the Lyon workshop in 'Loyasse' which is not very well known, is probably slightly earlier than the 'Muette' workshop, and does not appear to be a very important one. The two workshops seem to have drawn from the same clay levels: the compositions of their respective ware show only secondary differences. The period of activity of the 'Muette' workshop appears to be between 10 B.C. and A.D. 10 but at present it is not possible to give a more accurate date within this period.

Arezzo sets a more difficult sampling problem as it was only possible to get a few Samian rejects found in Arezzo itself (analyses 1–25). From the shapes and stamps of these rejects it appears that all the various periods of activity of this production centre are represented among them. For the remainder, pottery found in the course of excavations away from Arezzo, often quite far from the town, had to be resorted to. This is why a group of Samian ware from Lyon (analyses 26–46), found in an earlier level than that of the activity of the Lyon workshops, i.e. approximately between 20 and 10 B.C., is included in this group. Lastly, a more important group of Samian ware (analyses 47–84) comes from excavations by the French School of Rome in Bolsena in the south of Arezzo (Goudineau 1968). The layers from which this pottery comes range from 50 B.C. to A.D. 60, covering the essential period of activity in Arezzo. The Samian ware found in Bolsena, which is still older, has earlier numbers than the more recent ware.

The greatest problem arising from the use of pottery which is not workshop rejected is the risk of meeting elements of varied origins among it. While the Lyon series is particularly homogeneous and perfectly corroborates the data from the Arezzo group, the Bolsena range shows two specimens whose composition slightly deviates from normal compared with the compositions of pottery that unquestionably comes from Arezzo. These are numbers 64 and 84 and are both characterized by an abnormally high percentage of potassium. At the present stage of our knowledge it is difficult to decide whether this is a very little used variety of Arezzo clay, or they are potsherds from a different manufacturing centre, such as Pouzzoles or the Pô valley, for instance. Nevertheless the presence of these two specimens in no way prevents almost all the problems set by the attribution of the Lezoux, Lyon and Arezzo Samian ware to their respective manufacturing centres from being solved. However, one of the first things the laboratory plans to do next is to clear up the few remaining undetermined percentages caused by these two specimens. To this end we are considering analysing more rejects from Arezzo, as soon as another group can be obtained for the laboratory, and starting a study of other Italic production centres of Samian ware. As we cannot yet ascertain the exact origin of specimens 64 and 84 we have left them out of figures 5–11.

The following is a summary of the information supplied by figures 5–11, for each element. The production centres are compared in pairs.

1. *Lezoux and Lyon*

CaO The possibility of distinguishing between these two is very slight: above 17% CaO the attribution to Lezoux is unlikely to be correct, and under 8% attribution to Lyon is unlikely to be correct.

$Fe_2O_3$ The possibility of distinguishing between the two centres is almost nil.

$TiO_2$ Separation is almost complete for the majority of the ware from the two centres, except for a common region from 0.63%–0.72%. Outside this region the Lezoux values are all higher than those of Lyon.

$K_2O$ Complete separation of values for the two groups: 2.60% is the highest value for Lyon, and 2.90% the lowest one for Lezoux.

$SiO_2$ Separation is almost impossible except for a few values close to 50%—these are unlikely to have come from Lezoux.

$Al_2O_3$ Complete separation of values: 17.2% is the highest value for Lyon, 18.6% the lowest for Lezoux.

MgO The possibility of distinguishing between the two is very slight, but for values above 2.1% they are unlikely to have come from Lezoux.

2. *Lyon and Arezzo*

CaO The possibility of distinguishing between the two is slight, but above 16% they are unlikely to have come from Arezzo.

$Fe_2O_3$ Complete separation of values: 6.25% is the highest value for Lyon, 6.55% the lowest for Arezzo (6.30% instead of 6.55% if it is assumed that specimen 64 comes from Arezzo).

$TiO_2$ Complete separation of values: 0.72% is the highest value for Lyon, 0.78% the lowest for Arezzo.

$K_2O$ The possibility of distinguishing between the two is slight but not negligible: above 2.60% they are unlikely to come from Lyon, and under 2.10% they are unlikely to come from Arezzo.

$SiO_2$ A slight, but not negligible possibility of distinguishing between the two: above 58% they are unlikely to come from Arezzo.

$Al_2O_3$ Almost complete separation of values: the common area is from 16.8 to 17.2%; the Arezzo values are all above this region and the Lyon ones below.

MgO Complete separation of values: 2.70% is the highest value for Lyon, 3.45% the lowest value for Arezzo.

3. *Lezoux and Arezzo*

CaO The possibility of distinguishing between the two is slight, but with values under 8% they are unlikely to come from Arezzo.

$Fe_2O_3$ Almost complete separation of values: 6.60% is the highest value for Lezoux, 6.55% the lowest for Arezzo (6.30% instead of 6.55% if specimen 64 comes from Arezzo).

$TiO_2$ Some possibility of distinguishing between the two: with values under 0.75% they are unlikely to come from Arezzo.

$K_2O$ Almost complete separation of values: the common area is from 2.90% to 2.95% 3.35% instead of 2.95% if it is assumed that specimen 84 comes from Arezzo). The Lezoux values are all above this region and the Arezzo ones below.

$SiO_2$ The possibility of distinguishing between the two is slight, but with values above 58% they are unlikely to come from Arezzo.

$Al_2O_3$ Almost complete separation of values: the common area ranges from 18.6–19.6%, the Lezoux values are all above this region and the Arezzo values below.

MgO Complete separation of values: 2.05% is the highest value for Lezoux, 3.45% the lowest for Arezzo.

Thus Samian ware from Lezoux, Lyon and Arezzo can be attributed to its respective manufacturing centres without any difficulty. However, sums or ratios of constituents have not been used, as they are useless here, although they have proved of great interest for other centres being studied. They can be used to best advantage for main constituents.

The research work of the laboratory also includes a study of trace constituents by optical emission spectroscopy and neutron activation. There has also been a preliminary investigation into the compositions of Samian ware from many other production centres. This has shown that many of them look as if they can be separated as easily as those studied here. The only centres that remain difficult to separate, either by main constituents or by trace ones, are those that are in very similar geological situations, such as Lezoux and Vichy.

To conclude, there follows a few examples of the application of the preceding results.

Table 4

| *Sample no.* | *CaO %* | *$Fe_2O_3$ %* | *$TiO_2$ %* | *$K_2O$ %* | *$SiO_2$ %* | *$Al_2O_3$ %* | *MgO %* |
|---|---|---|---|---|---|---|---|
| 1 | 14.5 | 5.25 | 0.60 | 2.10 | 60.1 | 14.5 | 1.35 |
| 2 | 17.2 | 5.05 | 0.47 | 2.00 | 56.3 | 12.8 | 1.35 |
| 3 | 18.5 | 5.00 | 0.45 | 2.05 | 55.6 | 11.9 | 1.80 |
| 4 | 9.1 | 7.30 | 0.90 | 2.35 | 56.0 | 19.6 | 3.85 |
| 5 | 9.3 | 7.40 | 0.88 | 2.35 | 56.0 | 18.6 | 3.75 |
| 6 | 10.3 | 7.20 | 0.86 | 2.60 | 55.6 | 18.1 | 3.75 |
| 7 | 14.9 | 6.95 | 0.80 | 2.30 | 52.1 | 17.0 | 3.90 |
| 8 | 10.1 | 7.85 | 0.88 | 2.70 | 56.3 | 18.4 | 4.10 |
| 9 | 13.6 | 7.15 | 0.80 | 2.60 | 52.8 | 17.4 | 3.75 |
| 10 | 13.3 | 7.00 | 0.77 | 2.65 | 54.7 | 17.2 | 3.05 |
| 11 | 8.6 | 7.95 | 0.90 | 2.80 | 56.4 | 19.2 | 4.10 |
| 12 | 10.5 | 7.70 | 0.88 | 2.55 | 55.5 | 18.1 | 3.80 |
| 13 | 9.8 | 7.65 | 0.86 | 2.80 | 54.6 | 18.0 | 3.75 |
| 14 | 8.2 | 7.80 | 0.91 | 2.85 | 54.7 | 18.8 | 4.10 |

Table 4 takes up again the analyses of a number of potsherds which were found in workshops and which proved to have been manufactured elsewhere. No. 1 is a stamp and nos. 2 and 3 are two lamps and they all come from the Lezoux excavations. Their compositions have nothing in common with those of local products, but agree perfectly with those of products from Lyon, where lamps and Samian ware use the same clays. Lastly, no. 4, another stamp found in Lezoux (Vertet 1967), shows all the same features as products from Arezzo. However, it is the 'Muette' workshop in Lyon that has provided the most interesting applications. A number of stamps (nos. 5–12) were found there which, without the help of analysis, would have been thought local pottery, but their compositions show that they were imported from Arezzo. The same conclusion, though more surprising, holds good for two fragments of mould of decorated Samian ware (nos. 13 and 14) also found in the refuse of the 'Muette' workshop.

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## APPENDIX

### METHOD USED TO ANALYSE POTTERY

The pottery was analysed by X-ray fluorescence spectrometry in a vacuum (X-ray tube with Cr-target). Samples were prepared according to the Rose, Adler and Flanagan method (1963). The pottery was first crushed and then fused at 1100°C with a mixture of 85% lithium tetraborate and 15% lanthanum oxide, in the proportion of eight parts of mixture to one part of pottery. The glass obtained was crushed, a little boric acid was used as a binding agent, and it was then pelletized on a layer of boric acid for support. The minimum amount of pottery needed for analysis was about 150 mg. All the elements were determined on the same pellet. The matrix effect was evaluated for titanium taking the variable lime percentages into account. For other elements the matrix effects were not evaluated as they would be unlikely to cause errors greater than 3% in relative value, even in the most unfavourable cases. In practice, this uncertainty alone limited the precision of analysis. Errors due to the reproducibility of the method are negligible in comparison with that from matrix effects except for magnesium where it reaches $\pm 10\%$ at the 95% confidence level at lowest concentrations. No attempt was made to improve the precision of analysis to the detriment of rapidity of measurement and simplification of analysis. If the dispersion of concentrations existing within groups of Samian ware is taken into account this precision is at the moment sufficient.