

The spectra were photographed in a Hilger large quartz spectrograph. 5 ± 0.05 mgm. of a 1:1:1 mixture of sample/graphite/ammonium sulphate containing 1.5 per cent lithium carbonate were arced at 8–9 amp. for 30 sec. in shallow graphite cups against a flat cathode. The arc gap was kept at 4 mm.; a 3-mm. diaphragm 2.5 cm. from it helped to reduce the background. The dilution of the sample was found to improve the burning properties of these refractory materials and to reduce matrix effects^{2,4}. The lithium was also useful as an internal standard in some of the experiments.

Considerable systematic regional variations in the concentrations of calcium, sodium, titanium, magnesium and manganese were observed by visual comparison with the spectra of series of mixtures of oxides of 50 elements in an ammonium sulphate base arced under similar conditions. The variations in iron, copper, zirconium, vanadium, chromium and nickel content were either small or masked by the random fluctuations from sample to sample. By means of British chemical standard samples of silica brick and firebrick, calibration curves were set up for the first group of elements. To check the internal consistency of the method in the case of manganese, calcium, and titanium, calibration curves for two lines of different intensities were used. The concentrations of the chosen elements in typical samples were averaged for each kiln area and the results are shown in Table 1. Another 80–100 samples of less certain attribution on archaeological grounds were then similarly analysed and the results compared with those in Table 1. In most cases the two kinds of evidence taken together have made the kiln area virtually certain. The details of this work will be published elsewhere, together with results for further kiln-site material as they become available.

From the results it seems that the number of elements for which the quantitative analyses were carried out is sufficient to differentiate between material from well-separated regions. The differences of concentration of the various elements from region to region, when taken together, should leave little ambiguity about the source of the material when deciding between a limited number of archaeological alternatives. The decision is made easier in some cases: for example, the compositions of the samples from Lincoln show high titanium, and from Colchester high calcium.

The results for some colour-coated wares, selected by Mr. G. Webster (Table 2), also show significant trends. It is impossible to determine the origin of much of this pottery on purely archaeological grounds, and it is for this kind of problem that the spectrographic method may become useful. The colour-coated samples have also been analysed for potassium, gallium, strontium, barium and lead by a different technique, and the results obtained so far suggest that these data will add further criteria of the origin.

E. E. RICHARDS
K. F. HARTLEY

Research Laboratory for Archaeology and
the History of Art,
Oxford.

¹ Prelim. Repts. Reference Clay Minerals Amer. Pet. Inst., Research Project No. 49 (1951).

² Birks, F. T., Atomic Energy Research Establishment C/R 1177 (1953).

³ Waring, C. L., and Ansell, C. S., *Anal. Chem.*, **25**, 1174 (1953).

⁴ Weaver, J. R., and Brattain, R. R., *Anal. Chem.*, **21**, 1038 (1949).

Neutron Activation Analysis of Ancient Roman Potsherds

THIRTY-TWO fragments of Roman samian ware have been analysed for their sodium and manganese content, using neutron activation and γ -ray spectrometry. They were chosen from at least 10 of about 30 factories at which this fine-grained pinkish-red Roman table-ware was manufactured. The body of the sherds from all factories is very similar in appearance and a chemical method was sought to differentiate between factories. Similar analyses on other types of pottery have been done by Sayre *et al.*^{1,2} at Brookhaven National Laboratory, who found quantitative chemical differences in material from different places. Our results, summarized in Table 1, for 10 or more of the factories, show that this also holds in general for samian ware.

Table 1

Region	No. of factories	No. of sherds analysed	Manganese Average content*	Standard deviation	Sodium Average content*	Standard deviation
1. Italy	?	3	8	0.5	2.2	0.25
2. North-east Gaul (east of Moselle valley)	3	9	4	0.45	1.6	0.2
2 (a). Chémery, north-east Gaul (east of Moselle valley)	1	3	2	0.2	2.4	0.1
3. Central-south Gaul	3	11	3	0.15	0.7	0.15
4. North-east Gaul (west of Moselle valley)	2	6	3	0.1	0.6	0.1

* In arbitrary units.

50-mgm. samples from the interior of the sherds were irradiated together (so that results for different sherds would be comparable) for 4 hr. in a flux of 1.1×10^{12} neutrons/cm.²/sec. in *Bepo* at Harwell. The quantities of the elements present were measured in terms of the intensity of the 0.84 MeV. manganese-56 γ -ray and the 2.76 sodium-24 γ -ray, and as no standards were used the results are in arbitrary units. The reactions considered were the thermal neutron reactions manganese-55 (n,γ) manganese-56 and sodium-23 (n,γ) sodium-24, any contribution to the total sodium-24 activity from the fast neutron reaction aluminium-27 (n,α) sodium-24 on aluminium in the sherds being negligible.

Sherds tended to group regionally, and one factory at Chémery in north-east Gaul (east of the Moselle valley) was distinct from the other three in the region. That manufactured close at hand and to the west of this valley is also distinct (group 4), but on the other hand, does not differ significantly from that made in south and central Gaul. Whatever the reason for these differences they are of archaeological interest, and suggest a means for locating the region of origin of samian sherds which cannot be placed stylistically.

We gratefully acknowledge the help of Mrs. E. Heckmann, who initiated the work and developed the gamma-ray spectrometer used.

V. M. EMELEUS
G. SIMPSON

Research Laboratory for Archaeology and
the History of Art, Oxford, Dec. 3.

¹ Sayre, E. V., and Dodson, R. W., *Amer. J. Archaeol.*, **61**, 35 (1957).

² Sayre, E. V., Murrenhoff, A., and Weick, C. F., Brookhaven National Laboratory, Chemistry-General, **122**, 508 (1958).