

Research Letters/Navorsingsberigte

Preliminary report on the trace element analysis of clays and pottery from the Kavango and Caprivi areas of Northern Namibia

As part of a long-term project in which trace element concentrations have been used for provenance studies of archaeological¹⁻⁴ as well as more recent cultural objects,^{5,6} a suite of pottery and clays from the Kavango and Caprivi areas of northern Namibia was analysed. Smaller samples of pottery and clays from southern Damaraland and the Orange Free State were also included both as controls as well as for purposes of comparison. In the original study, of which this investigation is a continuation, pottery samples from the whole country were analysed in order to determine patterns of variability from site to site and whether any evidence for trade or exchange of pottery could be deduced from the data.¹ Subsequent work has focused on specific geographic areas, such as the Brandberg,⁴ and the northern regions (covered by this paper). The main purpose of this investigation was to analyse pottery and the clays from which they were made in order to evaluate the extent to which the trace element composition of a fired pot resembles that of the raw clay. This relationship is basic to provenance studies.

A secondary but no less important purpose of the investigation was to establish whether clay sources could be differentiated from each other. If this were the case, it would be possible to trace the source of a pot to the clay deposit from which it originated. If each village or, perhaps, each individual potter used a different clay it would be possible to link a vessel to a village or even an individual potter. (Photographs taken 70 or more years ago in the north, a time of still minimal European influence, show 'pottery traders' carrying their wares for sale.) It would then be feasible to map the extent of this exchange or trade system back into the past.

The northern regions of Namibia provide a ready-made laboratory for this kind of study as traditional potters are still plying their ancient craft there. Indeed, other aspects of traditional pottery making are currently being studied in the same area.^{7,8}

Table 1. List of analysed samples, of proven local origin.

1	Halili	clay	collected from river
2	Halili	sherd	used for grog
3	Katere	clay	rejected by potter
4	Katere	sherd	used for grog
5	Katere	clay	rejected by potter
6	Kadedere	clay & grog	from a finished but unfired vessel
7	Guma	clay	rejected by potter
8	Guma	clay	rejected by potter
9	Guma	clay & grog	clay prepared just prior to vessel shaping
10	Guma	grog	sherd used for grog
11	Kapako	clay	
12	Kapako	clay & grog	
13	Vungu Vungu	sherd	
14	Ihaha	sherd	
15	Sambio	sherd	
16	Linyanti	clay	
17	Oshombo	clay	
18	Oshombo	clay	
19	Ngoma	clay	
20	Ngoma	sherd	
21	Katima Mulilo	clay	
22	"White Lady" Rd	clay	Sample taken from river intersecting road just to the east of the Brandberg
23	"White Lady" Rd	clay	
24	Brandberg	sherd	sherd found in archaeological site
25	Brandberg	clay	
26	West of Uis	clay	
27	Orange Free State	clay	from a termite mound
28	Spitzkoppe	clay	

N.B. 'grog' refers to crushed sherds mixed in with the clay.

Experimental

The place of origin and description of the analysed samples are given in Table 1. For the northern Namibia samples the clays

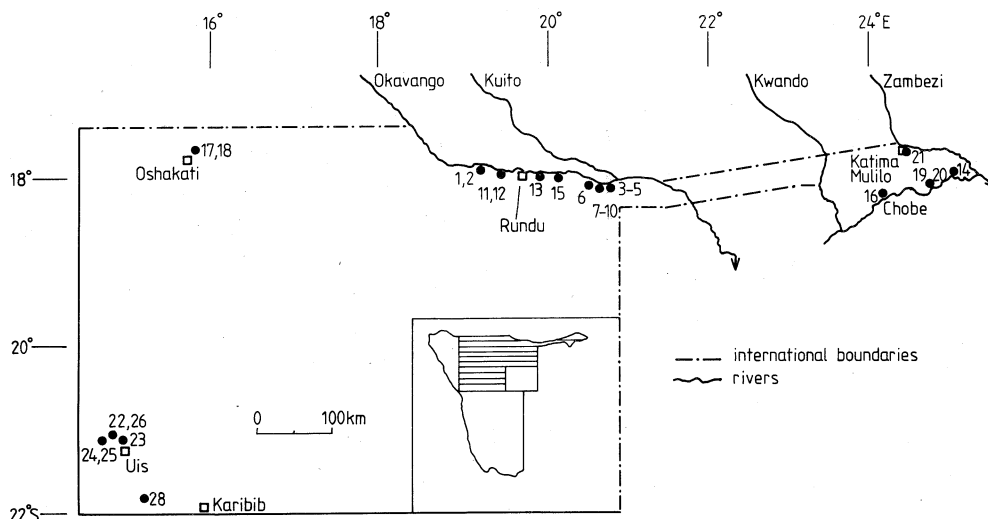


Fig. 1. Map of the northern areas of Namibia showing the sites where samples were taken.

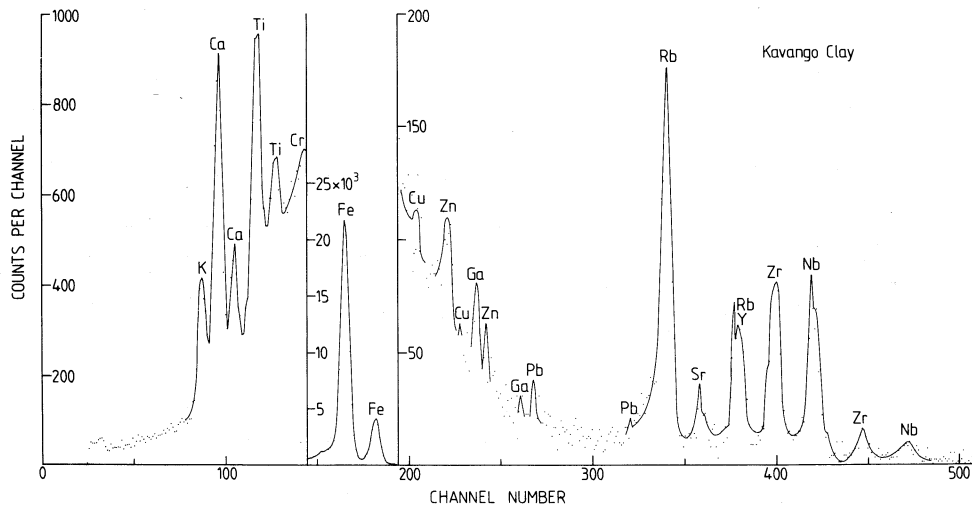


Fig. 2. Typical PIXE spectrum obtained at the external beam facility at Faure, using 4.5 MeV protons.

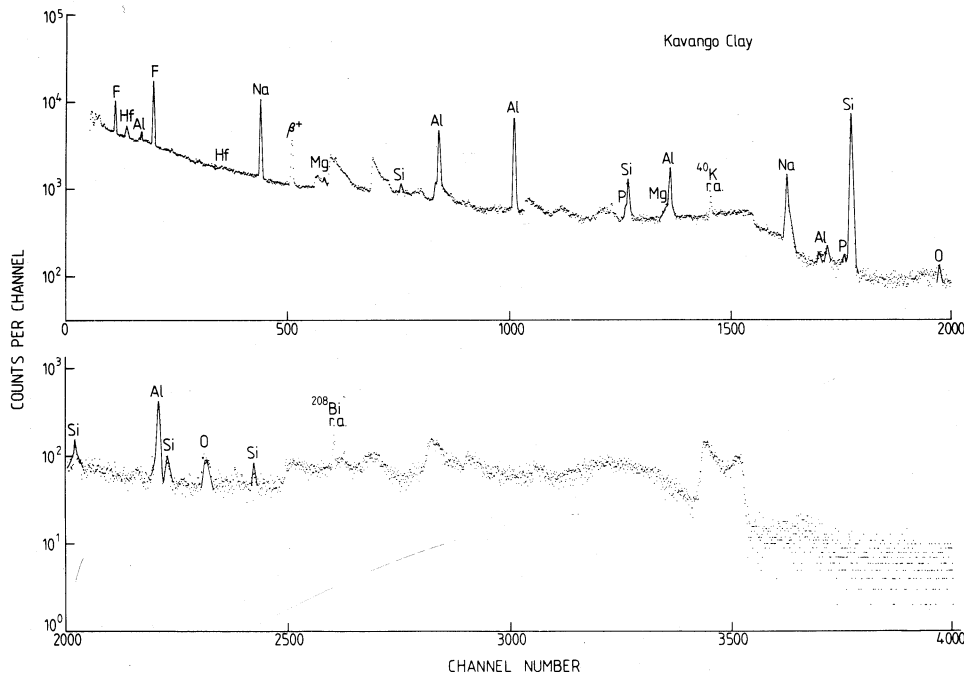


Fig. 3. PIPPS spectrum obtained simultaneously with that of Fig. 2.

are those which had been collected by the potters themselves and regarded by them as being suitable for the making of pots. A number of rejected samples were also included. The pottery samples included those made and fired by traditional methods from the aforementioned clays as well as specimens from archaeological sites. The control samples were collected from archaeological sites in the field (by L.J. and the O.F.S. sample by C.G. Sampson).

The term 'grog' refers to crushed sherds mixed with the clay. All specimens are known to have originated from the stated sites. The locations of the sites, except for sample 27, are indicated on the map in Fig. 1. The sampling sites represent simply those areas which were accessible and where research is currently being undertaken with the help and cooperation of the local inhabitants.

Each specimen was crushed and ground to a powder in an agate mortar. Samples of about a gram were compressed to tablets measuring 12 mm in diameter and 2-3 mm thick, using a pneumatic press operating to pressures of 10 tonnes. The tablets were protected from contamination and damage by paper rings and discs on both sides.

The methods of analysis used were particle-induced X-ray emission (PIXE) and particle-induced prompt photon spectroscopy (PIPPS). The former is an atomic method which makes use of the prompt X-rays emitted under charged particle bombardment.

The passage of an energetic charged particle may transfer sufficient energy to target atoms in its path to expel inner shell electrons. When these vacancies are filled, X-rays, characteristic of the target atoms, are emitted and the whole PIXE energy spectrum can be measured using energy-dispersive methods with a Si(Li) detector. In this way a sensitive multi-elemental analysis can be carried out non-destructively. A complementary method is PIPPS, which can be carried out simultaneously using a Ge(Li) detector during a single proton irradiation with the two detectors viewing the bombarded target. This latter method is based on the fact that when a nuclear reaction occurs the heavy product nucleus is usually formed in an excited state. To attain its most stable configuration the nucleus decays promptly, within a period of femtoseconds to nanoseconds, emitting gamma-rays characteristic of the energy level structure of the product nucleus. Since the gamma-rays are a result of the nuclear reaction, prompt radiation is emitted even if the product nucleus is not itself radioactive. The measurement of these emissions thus has to take place during the bombardment of the specimen. This is in contrast to techniques such as activation analysis where the delayed radiation from radioactive decay may be measured long after the irradiation.

The major advantage of both PIXE and PIPPS is that all the data are available at the end of the irradiation, and the rate of data accumulation is a function of the irradiation conditions, so

that the duration of an analysis may be extended to achieve improved precision. In addition, the amount of radioactivity in the sample after analysis is negligible.

Whilst PIPPS can measure major and minor components down to a concentration of the order of milligrams per gram, PIXE extends the analysis to trace components at a concentration of micrograms per gram.

The sample tablets were mounted in a ladder for use with the external beam facility at the 6 MV Van de Graaff accelerator at Faure.⁹ In order to measure the spectra of the emitted prompt X-rays and prompt gamma-rays simultaneously, the energy of the bombarding proton beam was chosen to be 4500 keV, somewhat higher than is generally used for prompt X-ray excitation. This beam lost about 300 keV in passing through a thin beryllium window at the end of the vacuum beam tube. The window-to-sample distance in air was about 20 mm and the collimated beam at the window had a diameter of 3 mm. The beam current was monitored on the Be window and irradiations lasted for about 30 min with beam currents of about 1.5 nA.

The PIXE X-ray spectrum was measured with a Si(Li) detector situated 103.6 mm from the face of the sample and normal to the incident direction of the bombarding beam. The detector was shielded with a lead collimator to reduce the effects of gamma-radiation. To prevent secondary excitation of lead X-rays, the surface of the collimating aperture was covered with a pipe of perspex. The PIPPS gamma-ray spectrum was measured with a Ge(Li) detector situated 150 mm from the target and 135° to the beam. Spectra from both detectors were recorded simultaneously in a multichannel analyser and stored on magnetic tape for off-line computer processing.

Because the matrix of all samples was essentially of constant composition, it was not necessary to introduce corrections for the stopping power of the beam or absorption characteristics of the radiations. Comparison of and differences between samples could thus be deduced directly from observed count rates.

As 13 elements were counted for each of 28 samples, multivariate statistics were used to reduce the data matrix to a two-dimensional representation which could be evaluated visually. The method chosen was correspondence analysis,¹¹ which is based on principal component analysis and involves the mathematical decomposition of the original analytical data matrix into axes in such a way that the groups of objects which are most distinct as well as the variables (in this case elemental concentrations) that separate them are at the extreme of the first axis. Increasingly less important separations are displayed on the second and subsequent axes. Any two axes plotted against each other yield a two-dimensional display in which both objects and variables (chemical elements) are featured. Although it is not permissible to interpret object-element distances, nevertheless their relative coordinates

are related in such a way that an object with a high value for any element is attracted towards the point representing that element and, conversely, a low value is repelled away from that point. Each axis accounts for a percentage of total inertia or variability and is labelled in decreasing order of importance.

Results and discussion

Typical X-ray and gamma-ray spectra are shown in Figs 2 and 3 respectively. The integrated counts under the respective peaks were calculated by a modified form of the program SAMPO¹⁰ at the UNIVAC-1100 computer of the University of Cape Town. From these counts, numerical values, proportional to the elemental concentrations, were calculated for the elements K, Ca, Ti, Cr, Fe, Cu, Zn, Ga, Rb, Sr, Zr, Nb and Pb. Counts were normalized to Fe and the resulting 28 × 12 data matrix was submitted for multivariate statistical processing by correspondence analysis.¹¹ This enabled the complex multidimensional relationships to be reduced to two-dimensional representations, one of which shown in Fig. 4, a plot of the first two axes. Both the samples analysed as well as their relationship to the analysed elements shown in boxes are plotted in the figure. The element, Nb, is not shown in the plot as its coordinates lie beyond the range of the axes of Fig. 4. Axes 1 and 2 account for 82.8% of the total inertia and hence little can be gained by considering other axes as well. Table 2 summarises the eigenvalues and inertia content calculated for the more important axes.

The results were quite surprising, particularly in view of what had been hypothetically expected, i.e. that the different clay sources would have very different trace element signatures. The representative points of all the clay and pottery samples from northern Namibia form a single, apparently interrelated, cluster which is shown in greater detail in Fig. 5. No sub-clusters are obvious as there is an overlapping of samples from different sites. For example, sample 19 from the east has its representative point between those of 17 and 18 from the west. Thus the pattern of trace element composition is, within experimental error, the same for all samples from the northern areas, i.e. from Oshambo in the west, along the Kavango river to the Zambezi-Chobe confluence in the east. The control samples show a very different representation, as was expected because they came from quite different source areas. The small number of samples does not merit detailed discussion except to comment that sample 24, a potsherd found in the Brandberg, is apparently quite different from the local Brandberg clays and could indicate that it was brought into the area from elsewhere. Further investigation of this and other outliers is currently being followed up.

The relatively tight clustering of the representative points from northern Namibian samples has some interesting implications. Firstly, the clays and the pottery made from them overlap. This

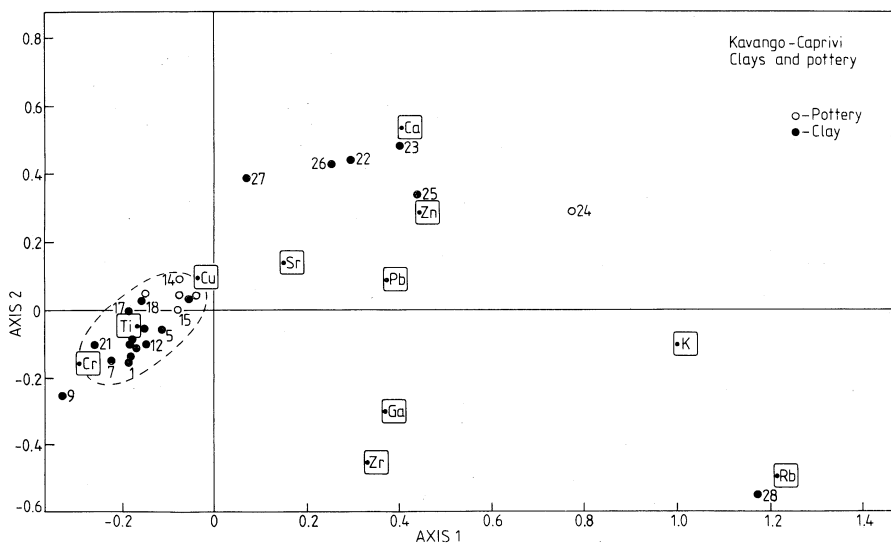


Fig. 4. Plot of first two axes from correspondence analysis showing the close clustering of samples from the Kavango area. Elements are shown boxed. Data for the element Nb were included in the calculations, but the coordinates of the element point (2.28, 1.44) are beyond the range of the above plot.

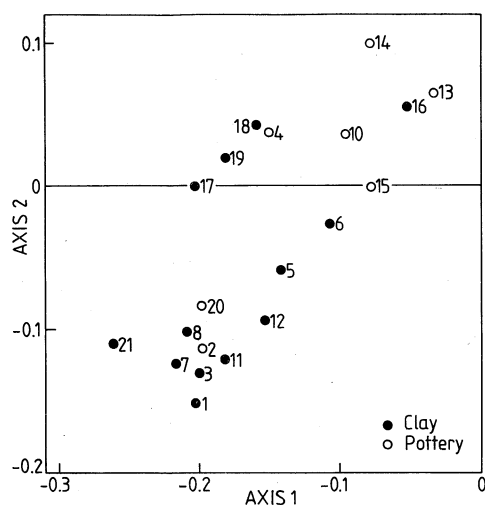


Fig. 5. Detail of the Kavango area samples from Fig. 4.

implies that the trace element composition of the clays is retained in the pottery, thus satisfying the first requirement for provenance studies.

Secondly, the overall similarity in trace element composition of the clays over a broad region means that it will be difficult, if not impossible, to differentiate clays from different localities within the region. It remains to be shown that this close relationship is retained if other trace elements, such as the rare earths, are included in the composition profile. Experience from other investigations has shown, however, that the clustering of specimens into groups with similar composition is not critically dependent on the choice of trace element,^{6,9} provided the number of elements determined is sufficiently large. It is thus likely that the addition of other elemental data will not appreciably alter the groupings of the samples. Hence provenance studies within this region will be problematic if based on composition profiles. Pottery from outside this area will be recognisable, but for the time being, localised trade or exchange practices will remain undetected.

Lastly, the apparent elemental uniformity of clays over such a large area remains to be explained. The surface geology of the region is referred to as Kalahari Beds. These are sands, gravels and clays which have been transported, laid down and reworked

Table 2. The scores of the first 6 eigenvalues showing the amount of variability they account for.

Axis	Eigenvalue	Percentage	Cumulative percentage
1	0.140560	60.72	60.72
2	0.051171	22.12	82.84
3	0.023034	9.95	92.79
4	0.009146	3.95	96.73
5	0.003299	1.43	98.16
6	0.001827	0.79	98.95
Total inertia	0.23147823		

over millions of years by wind and water.¹² The major rivers flowing southeastwards through the study area originate in central Angola and have their source in the anorthosites of this region.¹³ It is likely that this source material provided the background trace element signature for those portions of the Kalahari Beds which stretch from southern Angola through to Namibia and Botswana, particularly the areas which were formerly floodplains of the major Angolan rivers. This could result in an apparently uniform elemental composition. It will thus be necessary to test the geographical extent of this apparent uniformity and to define its boundaries. A search could then be made for any stringers of sediment originating within a different geological drainage system which might have retained the identity of its elemental composition and thus be relevant to provenance studies.

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