Tracing Ivory to Its Origin: Microchemical Evidence

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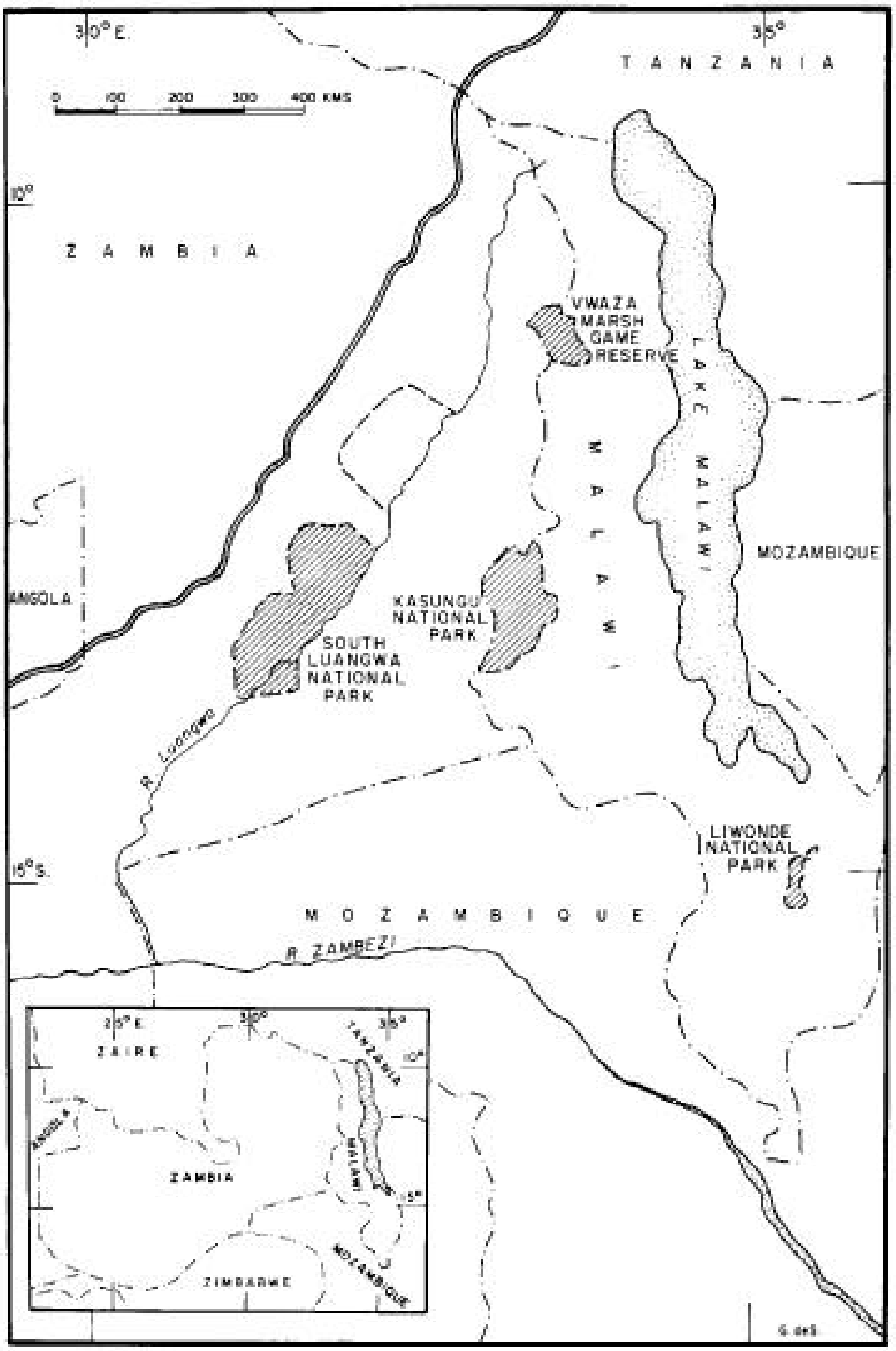

Fig 1. *Map showing the areas from which ivory samples were collected.*

A number of studies have indicated that animal tissues vary in microchemical composition as a result of local differences in geochemistry being transmitted to the animal through the food supply. Efforts have been made to determine the rivers where salmon originate[1], the nesting sites and moulting origins of snow-geese[2], the regional origins of Alaskan moose[3] and the local origins of game animals in Alberta, Canada[4]. There are many other examples, most of which have had moderate success.

Chemical differences can be measured by a variety of techniques and we used two, fluorescing X-ray spectroscopy and electron beam microprobe. Ivory samples from three protected areas in Malawi and one in Zambia, were analyzed and the concentrations of a number of elements were determined. The preliminary results reported here indicate that the microchemical differences found are related to the place of origin; scatter diagrams for values of some pairs of elements exhibit non-overlapping clusters for the four areas. The present findings show promise that the technique may well have ecological applications, say in providing information on the degree of interchange of elephants between areas, and on long term vegetation trends; it may assist in archaeological and historical research on the trade in ivory, an approach under investigation by Harbottle and Silsbee (unpublished); and finally, the method might be used in law enforcement, particularly in detecting smuggling and documentation abuse. The technique may also become relevant to other wildlife products such as rhino horn, turtle shell and crocodile skin.

The Experimental Material

Twenty-seven samples of ivory, each from a different elephant, were collected from the Vwaza Marsh Game Reserve, Kasungu National Park and Liwonde National Park in Malawi and the South Luangwa National Park in Zambia. The areas are separated by settlement and there is no movement of elephants between them except possibly for Kasungu and Luangwa. (Fig 1.) The sample tusks were taken from elephants shot on control on the area boundaries, and most were from adult males between 25 and 40 years old killed in 1980 and 1981.

A rectangle of about 3 sq cm and up to 0.5 cm thick was hacksawn from the thin ivory surrounding the pulp cavity at the base of the tusk. The sampling location was chosen because this thin ivory has no commercial value and is the most recently laid down in the life of an elephant obviating uncertainty due to possible movements during earlier existence.

Prior to analysis samples were cleaned in an ultrasonic cleaner containing detergent and then washed in distilled water and alcohol to remove the stains of blood, soil and vegetable matter which characteristically form a crust on raw ivory.

The Experimental Method

Eighteen samples, five each from Kasungu and Liwonde National Parks, and eight from Vwaza Marsh Game Reserve, were analyzed by the X-ray fluorescing spectrometer using the method described by Kelsall and Burton[5]. Three different sets of instrumental conditions were needed: Condition 'A' to maximize the calcium and phosphorus signals; Condition 'B' to minimize calcium and maximize zinc and strontium; Condition 'C' to obtain the otherwise undetectable barium signal. (See Table 2).

The three conditions theoretically permit analysis of all elements between atomic numbers 12 (magnesium) and 92 (uranium) at the parts per million level. However the ability of the instrument to detect specific elements varies largely and some contained in ivory and detected by other methods have not been found by this instrument.

The Experimental Findings

The results of the X-ray spectroscopy are shown in Table 1, and scatter diagrams of three pairs of elements are shown in Figs 2-4. In these scatter diagrams, the data clusters from the three different areas in Malawi are in some cases distinct and non-overlapping. The distinguishing scatter sets are:

Kasungu Vwaza	:Calcium(B)/Zinc(B)
Kasungu – Liwonde	:Calcium(B)/Zinc(B) and Calcium(B)/Barium(A)
Vwaza- Liwonde	:Strontium (B)/Barium(C)

Results from the electron beam microprobe are summarized in Table 3 and a scatter diagram showing calcium (potassium-alpha) ratios against phosphorous and magnesium is shown in Fig *5.* The data clusters for Kasungu and South Luangwa are distinct and non-overlapping on this basis.

Of interest is that the X-ray spectroscopy data scatter diagrams show that the ivories from Kasungu and Liwonde exhibit the greatest differences. The variation between ivories from either of these and that from Vwaza is not so marked. Kasungu and Vwaza produce dentine with a high degree of overlap in most parameters and the degree of relationship corresponds to the gross geochemistry of the areas themselves. Both are situated on the central African plateau and are underlain mainly by gneiss rocks of the precambrian basement . Elephants in the two areas eat a similar range of grass species and the woodland is dominated by species of the genus *Brachystegia.* Liwonde, by contrast, is situated on the floor of the Malawi rift valley and its soils are mainly recent alluvium with outcrops of nepheline

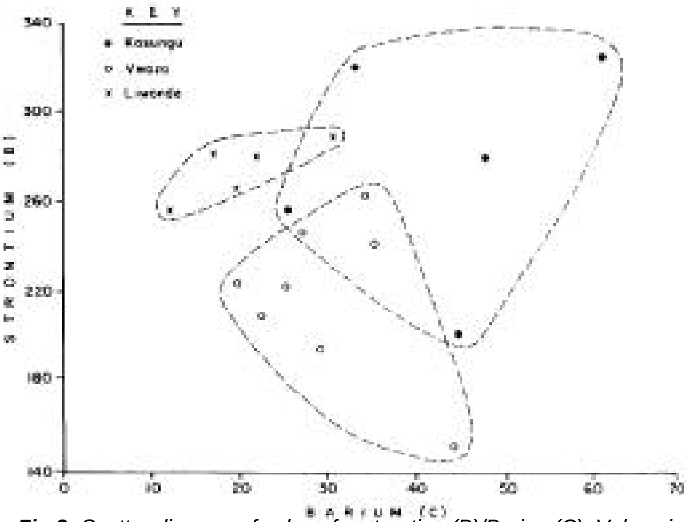

Fig 2. *Scatter diagram of values for strontium(B)/Barium(C). Values in X-Ray intensity, counts/sec.*

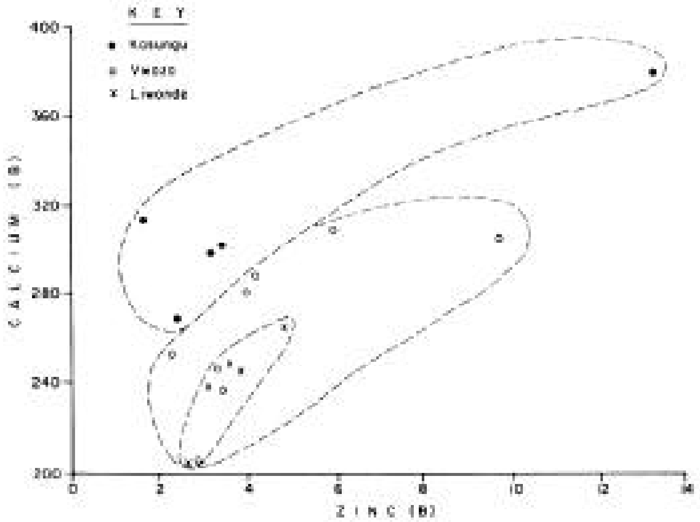

Fig 3. *Scatter diagram of values for Calcium(B)/Zinc(B). Values in X-Ray intensity, counts/sec.*

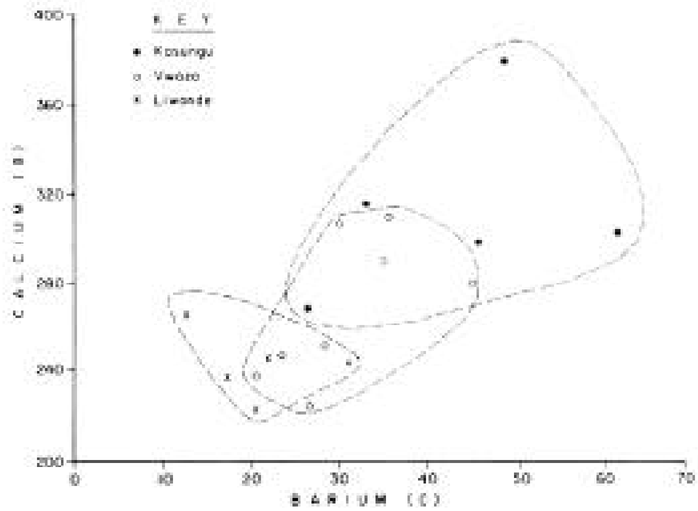

Fig 4. *Scatter diagram of values for Calcium(B)/Barium(C). Values in X-Ray intensity. counts/sec.*

cyanite. The grasses tend to be of higher quality and the woodland is dominated by *Colophoopermum mopane.* The data from Liwonde appear to be more homogeneous than those from either Kasungu or Vwaza. This may be because the fewer elephants in Liwonde are usually confined to a smaller and ecologically more homogeneous area.

Sample KU-12-79 from a 41 year old bull shot on control in Kasungu National Park shows some very anomalous values for a number of parameters. Post-mortem examination showed that, some years before its death, this animal had suffered a severe gunshot wound in the lower jaw causing a complete fracture of the right ramus. Although the wound had healed, the bone of the lower jaw did not unite and that this probably affected the animal's feeding was indicated by extensive malformation of the teeth. It is possible that the anomalous chemistry of this elephant's ivory may be related to the wound either through its effect on feeding or dental metabolism.

A Reference Library for Ivory

On the basis of the limited analyses carried out to date it is clear that the microchemistry of ivory differs in relation to origin and that differences may be sufficiently consistent to be used as the basis of a system for identifying the source against a library of reference samples. The first requirement is to analyze a large enough number of samples to allow a multivariate analysis to be made. The chemical variation within individual tusks due to movement and vegetation change, the distinction among different age and sex classes of elephants and the extent of chemical overlap between ivory from different areas must all be determined if the method is to be of value. If this can be done then we will be able to determine the provenance of ivory more simply than oil paintings - an ability which many conservationists would consider worth a Picasso or two.

TABLE 1
X-RAY INTENSITY IN COUNTS PER SECOND

	'A'		'B'			
'C'						
WAZA MARSH GAME RESERVE						
TUSK SERIAL NO.	**P**	**Ca**	**Ca**	**Zn**	**Sr**	**Ba**
MZ-03-78	739	3,564	304	9.7	195	30
RU-20-79	806	2,941	288	4.2	241	35
RU-27-79	772	3,162	279	4.0	150	45
RU-04.80	933	3,244	309	5.9	264	35
RU-21-80	295	2,489	236	3.4	221	20
RU-24-80	871	2,914	252	2.3	246	28
RU-29-80	377	2,644	222	2.8	223	26
RU-30-80	336	2,732	245	3.3	197	23
LIWONDE NATIONAL PARK						
TUSK SERIAL NO.	**P**	**Ca**	**Ca**	**Zn**	**Sr**	**Ba**
U-01-80	549	2,953	265	4.8	257	12
U-03-80	508	2,679	247	3.6	282	22
U-04-80	465	2,574	238	3.2	281	17
U-06-80	500	2,712	245	2.7	291	31
01-10-80	485	2,560	223	2.6	267	20
KASUNGU NATIONAL PARK						
TUSK SERIAL NO.	**P**	**Ca**	**Ca**	**Zn**	**Sr**	**Ba**
KU-17-79	1,322	3,801	377	13.2	281	48
KU-03-80	491	2,785	312	1.6	323	33
KU-21-80	951	3,694	301	3.4	331	61
KU-26-80	451	2,925	267	2.4	255	26
KU-41-80	868	3,860	297	3.2	202	45

'A''B''AND 'C' are separate analyses, each done under different instrumental conditions.

TABLE 2
INSTRUMENTAL CONDITIONS FOR THE ANALYSES IN TABLE 1

Instrumental Condition	'A'	'B'	'C'
Tube voltage*	7 kev	35 kev	47 kev
Is current*	0.25 ma	0.35 ma	0.55 ma
Filter	None	Ag	Cu
Vacuum	Yes	No	No
Per cent dead time	30	30	30
Counting time	100 sec	250 sec	250 sec

***pulsed tube mode

TABLE 3
ELECTRON BEAM MICROPHOBE RESULTS

CALCIUM (K-ALPHA) RATIOS	**Phosphorus**	**Magnesium**
KASUNGU NATIONAL PARK		
KU 6	0.641	0.018
KU 12	0.646	0.015
KU 25	0.803	0.049
KU 53	0.581	0.022
SOUTH LUANGWA NATIONAL PARK		
LU I	0.561	0.009
LU 2	0.569	0.016
LU 3	0.557	0.000
LU 4	0.568	0.010
LU 5	0.519	0.004

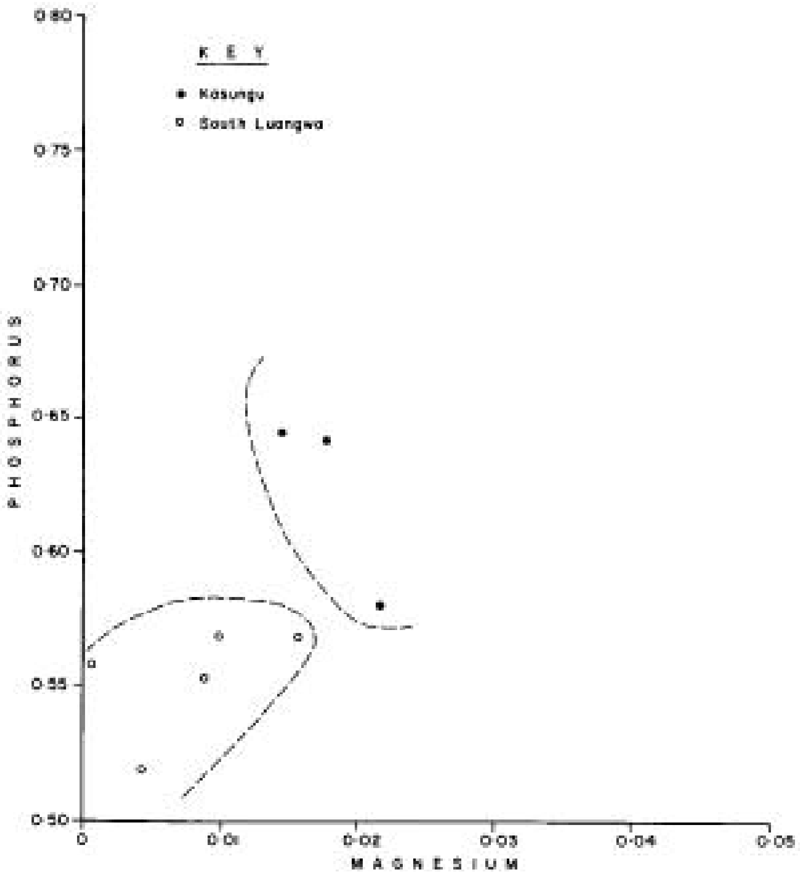

Fig 5. *Scatter diagram of values of Calcium (K-alpha) ratios, Phosphorus/Magnesium*

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References

1. LA. Lapi and T.J. Mulligan, "Salmon stock identification using a microanalytical technique to mesaure elements present in the fresh-water growth region of the scales", 1981, Journal of the Fisheries Research Board of Canada.
2. J.P. Kalsall and R. Burton, "Some problems in identification of origins of lesser origins of lesser snow-geese by chemical profiles", 1979, Canadian Journal of Zoology, 57(12), pp.2292-2302.
3. Frenzmann, Flynn and Arneseon, unpublished.
4, Personal communication with Wishart and McClymont
5. J.P. Kalsall and R. Burton, "Identification of origins of lesser snow geese by X-ray spectrometry, *Canadian Journal of zoology*, 54 (4), pp.718-732.