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SHORT COMMUNICATION

Geophagia by Mountain Gorillas (*Gorilla gorilla beringei*) in the Virunga Mountains, Rwanda

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ABSTRACT. Mountain gorillas (*Gorilla gorilla beringei*) occasionally eat material from weathered regolith (subsoil) sediments in the Virunga Mountains of northwestern Rwanda. The possible nutritional significance of this behaviour has been investigated by analyzing the geochemistry, primary mineral composition, and clay content of several regolith and surface soil (paleosol) samples. Iron, Na, and Br content may be important in geophagy, and clay present in the soil may also have nutritional importance.

INTRODUCTION

Mammalian generalist herbivores eat foods that vary in quality, and they need to feed selectively on a range of foods in order to satisfy nutritional requirements (WESTOBY, 1974). Deficiencies in essential minerals can arise because of this variability. For example, foliage of terrestrial plants tends to be low in Na, and herbivores in areas with low available Na in soil and water may face Na deficiency (ROBBINS, 1983). Mammals have a specific hunger for Na (ROZIN, 1976) and instances of selective feeding on Na rich foods by herbivores such as moose (BELOVSKY, 1981) and black and white colobus monkeys (OATES, 1978) have been reported.

Geophagia—soil consumption not necessarily associated with mineral licks (ROBBINS, 1983)—occurs commonly in wild herbivores and may help meet mineral and trace element requirements (ROBBINS, 1983; ARTHUR & ALLDREDGE, 1979). Clay particles in ingested soil can adsorb dietary toxins and aid in their excretion and can have an effect on gut pH that is favourable to symbiotic bacteria (OATES, 1978), although they can also chelate metal ions and prevent their adsorption (ROBBINS, 1983). Sodium salts, existing as precipitates on animal bodies or near springs and as encrustations on plants, have served to stimulate licking by African buffalo (*Syncerus caffer* SPARRMAN) (SINCLAIR, 1977; MLOSZEWSKI, 1983).

Mountain gorillas (*Gorilla gorilla beringei*) studied at the Karisoke Research Centre in Rwanda's Parc National des Volcans have been observed to eat sediment that they dig from slightly weathered regolith (mass wasted deposits) (FOSSEY & HARCOURT, 1977; FOSSEY, 1983; WATTS, 1984). Not all study groups or individuals have been seen to eat such sediment. Those groups that eat sediment do so only five to six times per year, so that geophagia accounts for only a tiny fraction of dietary intake (WATTS, 1984). Karisoke Group 5, however, has repeatedly visited several specific subsoil-eating sites in the Hagenia-Hypericum woodland zone at about 3,000 m over many years (FOSSEY, 1983; WATTS, pers. obs.). Indeed, signs of geophagia by bushbuck (*Tragelaphus scriptus*) and black-footed duiker (*Cephalophus nigrifrons*) are regularly found at Karisoke Group 5's digging sites.

Gorilla visits last up to 30 min, and all group members other than small infants excavate and eat sediment (WATTS, pers. obs.). This suggests that geophagia has some nutritional importance to the participating gorillas. Alternatively, it may be a behavioural tradition in this group, with no important nutritional consequences. We analyzed a small but representative regolith (essentially residual mantle of loose, incoherent country rock = basalt) sample suite, to try to identify chemical factors that might play a role in sediment eating.

FIELD AREA AND METHODS

The Karisoke study area is in the central group of Virunga Volcanoes and extends into both Rwanda and Zaire (see Fig. 1). Group 5's sediment eating sites are on the Rwandan side of Mt. Visoke, on steep ravine-edge slopes in Hagenia-Hypericum woodland at about 3,000 m. The material that the gorillas eat comes from regolith (subsoil) that underlies thick reddish-brown paleosols (surface soils) that formed after episodic mass wasting and volcanic activity. These sediments contain a high content of ferromagnetic and feldspathic minerals consisting primarily of anorthoclase, olivine, pyroxene, and hornblende.

The subsoil samples were collected below the surface paleosol cover in exposed outcrops that the gorillas use. The surface paleosols formed from weathering of this regolith over the last 50,000 years.

Paleosol and sediment colours were estimated using the colour chips of OYAMA and TAKEHARA (1970). Regolith and paleosol samples were collected and dried after removing the granule and pebble fractions (>2 mm). Each sample was X-rayed using Ni-filtered Cu K_α radiation to determine the mineral content of the <2 μm fraction following procedures outlined by WHITTIG (1965) and MAHANEY (1981). The remaining material of less than 2 mm in average diameter was subsampled and placed in small flip-top vials for neutron activation analysis in the SLOWPOKE Reactor at the University of Toronto (HANCOCK, 1978, 1984).

RESULTS AND DISCUSSION

PHYSICAL PROPERTIES

The samples collected have greyish olive (5Y 5/2), grey (5Y 5/1), dark greyish yellow (2.5Y 5/2), and dull yellowish brown (10YR 5/3) colours (OYAMA & TAKEHARA, 1970). Yellow colours allow estimations of clay content; brown colours relate to Fe and organic (the latter being very small); and grey colours (which dominate) relate to the amounts of essentially unweathered basaltic clasts. The paleosol colour gives the 10YR hue cited above. There appears to be no relationship between the colour of the soil and the gorillas' soil eating habits.

The textures of the subsoil samples studied are 10–15% sand, 77–83% silt, and 13–19% clay. The relative uniformity of particle size distributions apparently provides no rationale for the gorillas' sediment eating, but the high clay content of some sediment samples might

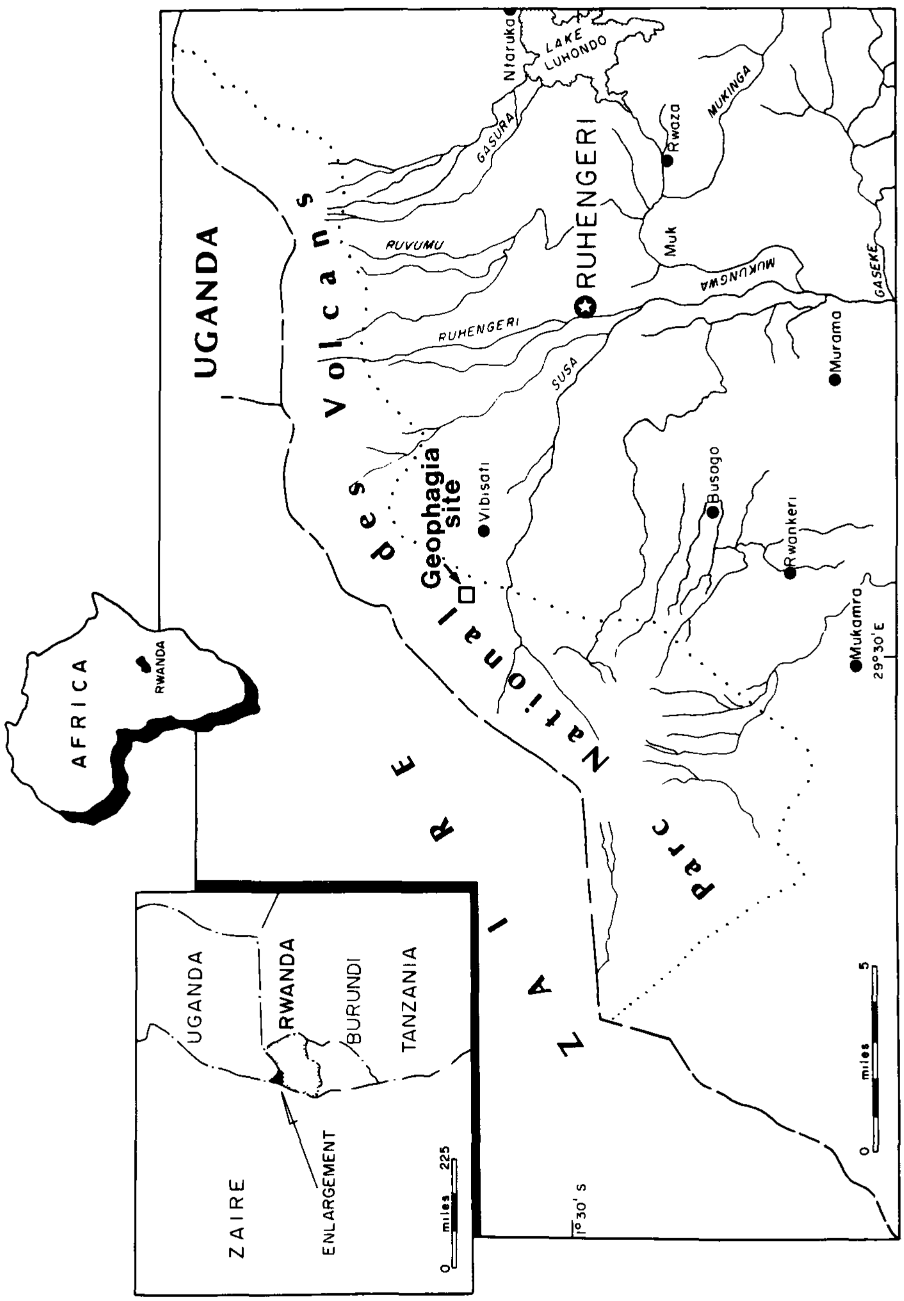

Fig. 1. Location of the gorilla soil-eating site in the Virunga Mountains, Rwanda.

possibly be a factor in geophagia. OATES (1978) reported that black and white colobus monkeys in the Kibale Forest, Uganda, regularly eat soil high in chlorite clay minerals. Although this soil is also rich in several elements (e.g. Na, Cu), there was no evidence that the rest of the diet was low in these nutrients. OATES suggested that the lattice structure of the clay might function to adsorb and help excrete plant toxins and/or help regulate the pH of the monkeys' ruminant-like fore-stomachs. Mountain gorillas, like colobines, are folivores that rely heavily on symbiotic gut bacteria to obtain adequate nutrition. They should need to maintain a favourable environment for these bacteria and to protect both their own and the bacterial enzyme systems from the disruptive effects of compounds such as tannins.

Abrasion pH's are high (10–11) as would be expected from the rock-forming mineral composition. These highly alkaline materials can be expected to contain very low levels of *p* (even though it was not measured in this study), eliminating a search by the gorillas for this biologically important element as an explanation for geophagia.

GEOCHEMISTRY

Table 1 shows the concentrations of 34 elements for the upper surface soil (paleosol), and

Table 1. Geochemical analyses of a paleosol and regoliths near the Karisoke Research Centre, in the Hagenia Woodland, Virunga Mountains, northwest Rwanda.*

Elements	Paleosol	Regoliths
Na%	2.27	0.78±0.06
Mg%	2.0	1.1±0.2
Al%	7.8	10.0±0.2
Cl	440	≤200
K%	4.1	1.5±0.2
Ca%	5.0	2.1±0.3
Sc	15.2	18.4±0.3
Ti%	1.8	1.5±0.1
V	270	190±10
Cr	122	170±110
Mn	1480	1500±200
Fe%	8.1	7.5±0.2
CO	33.0	26±5
Ni	28	≤34
As	1.9	3.2±0.6
Br	6.0	11±1
Rb	122	49±3
Sr	1040	490±50
Sb	0.17	≤0.22
Cs	1.1	0.9±0.1
Ba	1260	1400±100
La	98.2	130±10
Ce	171	260±40
Nd	50	67±6
Sm	9.6	13.0±0.7
Eu	2.7	3.2±0.2
Tb	1.1	1.5±0.2
Dy	3.4	5.4±0.9
Yb	2.2	3.3±0.2
Lu	0.30	0.54±0.03
Hf	7.14	10.9±0.4
Ta	9.1	12.7±0.5
Th	21.4	32.3±1.2
U	3.8	5.8±0.3

*Data in ppm unless otherwise indicated.

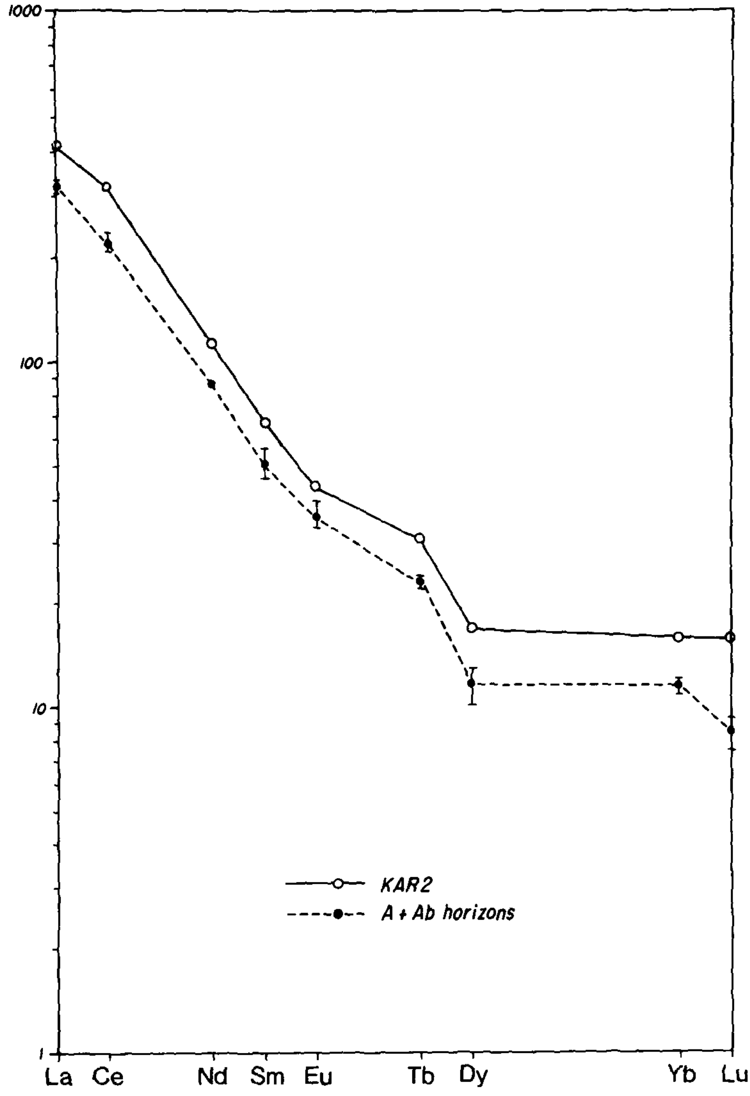

Fig. 2. Chondrite-normalized plots of rare earth elements of KAR2 (subsoil samples) and surface soil samples from nearby.

the group mean levels ±1 standard deviation for the same elements in the four regolith samples. Concentration levels in the two sample sets overlap or are close for many of the elements. Also, chondrite-normalized plots of the rare earth elements (Fig. 2) are remarkably consistent in form, indicating that the surface soil and the regolith samples are geochemically very similar. Some trends distinguish the two data sets, however: concentrations of Al, Sc, Cr, As, Br, and the heaviest elements (the rare earth elements, Hf, Ta, Th, U) are higher in the regolith; some elements (Mn, Fe, Ba, Co) are about the same; and the alkali and alkali-earth elements and others (Na, Mg, K, Ca, Ti, V, Rb, Cs) tend to be depleted in the regolith.

Table 2 gives complete data on ten elements that are of particular interest. Nine are essential nutrients (Robbins, 1983). The tenth, Br is not known with certainty to be essential. Data

Table 2. Geochemistry of regolith samples mined by mountain gorillas at Karisoke in the Virunga Mountains, Rwanda.*

	Elements									
Sites	Na	Mg%	Al%	Cl	K%	Ca%	Mn	Fe	Co	Br
KAR2-1	8320	1.2	10.3	≤240	1.6	2.5	1350	7.40	24.6	11.4
KAR2-2	9460	1.1	10.1	≤140	1.7	2.1	1420	7.31	24.1	9.2
KAR2-3	8170	0.9	10.4	≤170	1.3	1.8	1840	7.94	31.3	11.9
KAR2-4	7890	1.3	9.9	≤120	1.3	1.8	1380	8.08	25.3	10.3

*Data in ppm unless otherwise indicated.

on the gorilla's intake of three of these (Ca, Mg, and K) from plant food sources are available (WATTS, 1983; WATERMAN et al., 1983).

Only Br (nearly twice as abundant in the regolith samples, which were eaten) stands out as a potentially significant factor in geophagia in comparison between the two sets of samples. Many of the other elements were actually more abundant in the paleosol, which was not eaten.

The Na content is high in both data sets, resulting from the volcanic origin of the surface soils (paleosols) and the regoliths, and although the Na content of the regoliths is lower than the paleosol, it still may be nutritionally important. The low Cl concentrations preclude the Na being in the form of NaCl.

The Fe content is of potential interest because the mountain gorillas range primarily between 2,400 and 3,500 m and reach as high as 3,800 m. They may require relatively large amounts of Fe for the erythrocyte production, as is true of high altitude human populations (STICKNEY & VAN LIERE, 1953; MATTHEWS, 1954). African buffalo at 2,000–3,000 m above sea level on Mt. Kenya apparently replenish blood Fe levels through geophagia (MAHANEY, 1987). Iron levels in both the paleosols and regolith are, like Na, higher than normal because of their volcanic origin, and may therefore be a source of Fe replenishment.

The Ca content of several important gorilla foods is comparable to, or higher than, the Ca content of the regolith samples. For example, *Galium ruwenzoriense*, *Carduus nyassanus* leaves, and *Laportea alatipes* leaves, staples that contribute about 50% of the gorilla's diet (WATTS, 1984) contain 1.92%, 2.80%, and 2.95% Ca by dry weight, respectively (WATTS, 1983). *Peucedanum linderi* stems, another staple, contain 5% K by dry weight. Weighted mean dietary values for these two elements in the diet of one gorilla group were 3.77% of the total dry weight intake for K and 1.80% for Ca (WATTS, 1984). It therefore appears unlikely that either element is an important factor in geophagia.

The subsoil Mg content is relatively high in comparison to the weighted mean dietary value for this element (0.24% of the total dry weight intake; WATTS, 1984), but is much lower than the paleosol content, and is a doubtful factor in geophagia.

Manganese and Co concentrations are relatively high in both the paleosols and regoliths, again because of their volcanic origins, but their availability from gorilla plant foods is unknown.

Although Al is one of the few elements to increase in concentration from paleosols to regoliths, there does not appear, at this time, to be a nutritional requirement for excess Al.

CONCLUSIONS

Geophagia may provide mountain gorillas with an important source of essential minerals or trace elements. Sodium and Fe emerge as possible candidates: both are abundant in the ingested materials. The gorillas may have a special need for Na because the montane vegetation tends to be Na depleted (Robbins, 1983) and for Fe because of the altitude of their habitat. Data on dietary Ca and K rule out the possibility that the regoliths may provide these nutrients. Geophagia may supplement the overall intake of Mg and Br.

A second possible nutritional explanation for sediment eating by gorillas is that the clay fraction of the ingested material may help adsorb and excrete toxins, or may help maintain a gut pH favourable to bacteria on which the gorillas depend for some of their nutritional needs, as suggested for black and white colobus monkeys by Oates (1978). Chimpanzees at Gombe also regularly eat small amounts of clay-rich soil (that also contains substantial amounts of K, Mg, and Ca) from termite mounds (Goodall, 1986). Clay composition does not appear to be important in explaining why gorillas repeatedly use particular sites, because there are no crystalline clay minerals present in the samples studied.

A third possibility is that sediment eating is a behavioural tradition that has no real nutritional significance, or that at least does not correct nutritional deficits. Harcourt and Stuart (1977) have made this suggestion for coprophagy, which occurs very infrequently in all research groups. Watts (1989) has similarly suggested that ant eating which like geophagia is restricted to certain groups/individuals, is an acquired taste that supplements the intake of certain nutrients but is not nutritionally essential. Given the infrequency of geophagia, it is a real possibility that it has almost no essential nutritional role.

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