Geophagy in Masked Titi Monkeys (*Callicebus personatus melanochir*) in Brazil

KLAUS-HEINRICH MÜLLER
German Primate Center

CHRISTIAN AHL and GERHARD HARTMANN
University of Göttingen

ABSTRACT. Geophagy was observed 14 times during an 11-month field study on the ecology and behavior of masked titi monkeys (*Callicebus personatus melanochir*). Geophagy took place in 12 cases on the surface of a leaf-cutting ant mound (*Atta spec.*). Analysis of chemical composition and natural features of the soils consumed by the monkeys showed elevated concentrations of several elements. In contrast, a lower concentration of carbohydrates was found in the ant mound sample compared to random non-ant mound soil samples. No difference in the concentration of clay elements, pH-value or percentage of organic matter was found between ant mound samples and randomly collected soil samples. Comparison of used versus not used samples failed to reveal significant clues about function of geophagy. However, chemical and physical properties of soils ingested support previous hypothesis that this behavior may aid in the adsorbtion of plant toxins.

Key Words: *Callicebus personatus*; Masked titi monkey; Geophagy; Chemical properties; Soil properties.

INTRODUCTION

Geophagy, the consumption of soil, have been reported among prosimian (*Lemur*: GANZHORN, 1987) and catarrhine primate species (*Presbytis*: DAVIES & BAILIE, 1988; *Colobus*: OATES, 1978; *Macaca*: INOUE, 1987; *Papio*: HALL, 1962; *Pan*: GOODALL, 1963; *Gorilla*: MAHANEY et al., 1990). Some of these primates spend most of their daily lives on the ground, while others are mainly arboreal. Little is known about geophagy of the arboreal platyrrhine monkeys. IZAWA (1993) reported that soil eating is common in two species (*Alouatta* and *Ateles*) out of 12 that he observed in the Amazon rainforest of Colombia. Furthermore, *Alouatta* has been reported to eat the clay from an oven-bird nest (BICCA-MARQUES & CALEGARO-MARQUES, 1994). Only one species of the callitrichids, *Saguinus mystax*, has been recorded as geophagil (HEYMANN & HARTMANN, 1991). The feeding ecology of *Callicebus* has been the focus of several studies (KINZEY et al., 1977; EASLEY, 1982; KINZEY & BECKER, 1983; WRIGHT, 1985), but geophagy has not been reported on.

A variety of functions have been assigned to geophagy in primates. In a review, DAVIES and BAILLIE (1988) said there is no reason why geophagy should have just one single function: it may serve different functions at different times. The many possible functions of geophagy in primates appear to be associated with an herbivorous diet. In herbivorous primate species, geophagy may have the function of (1) dietary mineral supplementation (CLUTTON-BROCK, 1972; DAVIES & BAILLIE, 1988; GANZHORN, 1987; JOHNS & DUQUETTE, 1991; JOLLY, 1985; SCHALLER, 1965); (2) adjustment of pH level in the stomach (DAVIES

& BAILLIE, 1988; OATES, 1978; POIRIER, 1970); or (3) adsorption of plant toxins such as tannins and secondary compounds (HLADIK & HLADIK, 1972; JOHNS & DUQUETTE, 1991; OATES, 1978; DAVIES & BAILLIE, 1988). Three other hypothesis of geophagy in primates which are not directly related to a herbivorous diet are: (4) tactile sensation in the mouth (HLADIK & GUEGUEN, 1974); (5) physio-chemical effects in the gastrointestinal tract (HLADIK & GUEGUEN, 1974); and (6) relief from infestation of internal parasites (BICCA-MARQUES & CALEGARO-MARQUES, 1994; MAHANEY et al., 1996).

In this paper, geophagy in masked titi monkeys is documented. Chemical composition and natural features of the soil eaten and not eaten will be discussed with respect to the role of geophagy in the mainly frugivorous *C. personatus*.

METHODS

STUDY SITE AND BEHAVIORAL OBSERVATIONS

The study site was a forest segment of about 100 ha at the Estação Experimental Lemos Maia (ESMAI), which is one part of some forest segments of about 400 ha, owned and protected by the cocoa growing authority CEPLAC (Comissao Executiva do Plano da Lavoura Cacaueira). The ESMAI is located in the district of Una, Bahia, Brasil (15°18′S, 39°06′W).

The altitude of the study site is about 100m above sea level. The climate is characterized by an average annual rainfall of about 2,000 mm (HOHL, 1993). No distinct dry and wet season were noted. The yearly medium temperature was 23.6°C, with a cold season from June to October and a warm season from November to May. The vegetation of the study area is characterized as evergreen coastal rainforest (VELOSO, 1965). A description of the different forest types is given by RYLANDS (1982). The forest stands on slightly undulating terrain. The soil is relatively poor in minerals and nutritients and has a low cation-exchange capacity (MELO, 1973).

During an 11-month study on the ecology and behavior of masked titi monkeys, *Callicebus personatus melanochir* (Cebidae), two groups were observed from October 1992 to September 1993 during 101 complete days for a total of 1,030 hrs. For details on group composition see MÜLLER (1995). Observations of the study group were conducted from dawn, when the titi monkeys left their sleeping tree, until the late afternoon, when they reached their sleeping tree. Habituation and accompaniment of the group were facilitated by using telemetry (MÜLLER, 1994). Data on the ecology and behavior of masked titis were collected by scan-sampling with 5-min intervals (ALTMAN, 1974). Geophagy and other infrequent behaviors were recorded by ad lib. sampling, with as detailed a description as possible (ALTMAN, 1974). Soil samples were collected at the places where monkeys picked up soil for eating. For comparison, an equal number of samples were collected from the surface of the forest ground (top layer) at randomly selected places (other than ant mounds). Observations were carried out by K.-H. M. and the laboratory analysis by C. A. and G. H.

ANALYTICAL METHODS

Chemical Composition

Soil samples were dried, stored in plastic bags, and kept at 5 – 10°C in a refrigerator until they were analyzed. Most of the elements were measured by X-ray fluorescence (XRF) techniques, using a Philips PW 1480 automated sequential spectrometer. Data processing was controlled by the Philips X 40 software package. Methods, specific details of analytical precision and accuracy are described by HARTMANN and WEDEPOHL (1993).

Physical and Chemical Soil Properties

Particle Size Analysis

Particle-size distribution was measured according to the procedure described by GEE and BAUDER (1986). As a pretreatment to disrupt soil-aggregates, the soils organic matter was oxidized with hydrogen peroxide. Iron- and manganese-oxides were reduced with sodium-dithionite, buffered by 0.3 M sodium-citrate. The samples were washed with distilled water to remove salts. To estimate particle-size distribution, a combined sieving-pipette method was applied to group the particles in size-classes as shown in Table 1.

Table 1. Particle-size distribution in size-classes.

Distribution	μm
Sand	
Coarse	2000 – 630
Medium	630 – 200
Fine	200 – 63
Silt	
Coarse	63 – 20
Medium	20 – 6.3
Fine	6.3 – 2.0
Clay	< 2.0

Chemical Soil Properties

The soils organic matter, expressed as organic carbon (C_{org}), and the total nitrogen, N_t, was analyzed in a Carlo-Erba gas-chromatographer.

The pH-value was measured in distilled water by mixing 10 ml of H_2O with 5g of air-dried soil, waiting 2 hrs before the pH-electrode was placed into the sample. The estimation of total soil carbohydrates was based on a colorimetric method. One gram of air-dried soil was extracted with 2.5 ml 12 M H_2SO_4 and the supernatant solution centrifugated. In this solution, the carbohydrates were analyzed by a slight modification to the method reported by MOPPER and GINDLER (1973).

RESULTS

FIELD OBSERVATIONS

Feeding on soil by masked titis was observed on ocassions in 14 cases during 11 months of observation (102 complete alert periods; CHIVERS, 1972). Twelve times the titis ate soil from ant mounds, one time from the forest floor and one time from a decomposed tree trunk. Soil eating was initiated by the movement of the group down towards the forest

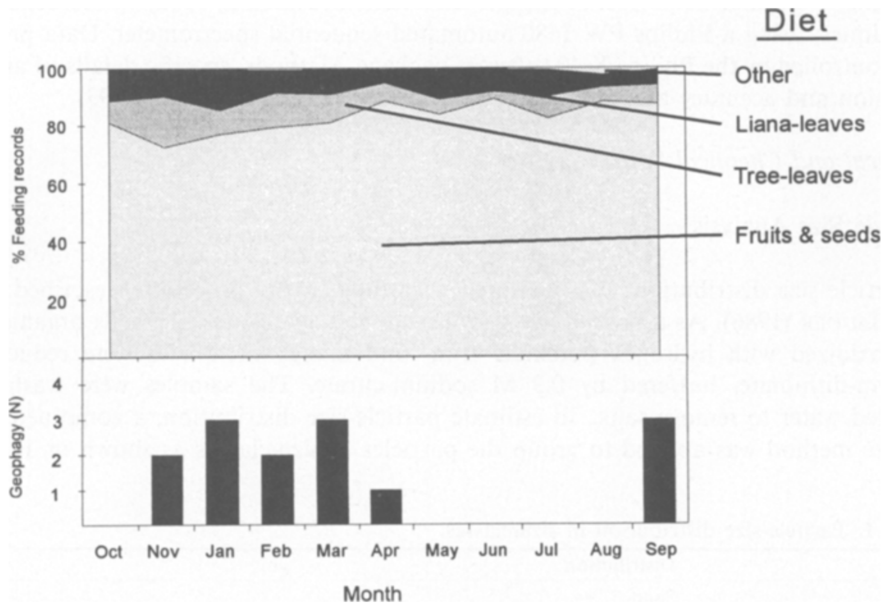

Fig. 1. Seasonal variation in the frequency of geophagy in *C. personatus* in relation to diet.

floor to a height of about 3 to 7m. One member of the group would begin to climb downwards if a leaf-cutting ant mound (*Atta spec.*) was close by. While climbing down the animal would give a very low level vocalization; a special type of intra-group communication (KINZEY, 1981). The other members of the group would rest near the mound, observing the forest floor surrounding the ant mound. When the moving animal was near the forest floor at a height of about 50 cm, it jumped on the ant mound. The titi broke an aggregate of soil from the mound by hand or mouth and picked it up. The monkey then moved rapidly back towards a nearby tree and climbed to a height of about 2 to 3m before eating the soil. (The piece of soil picked up by the monkey was usually and naturally round, with a diameter of 6 to 9 mm and a weight of about 5 to 10g.) The procedure of picking up an aggregate of soil was then repeated once or twice more. After soil-eating, the monkey climbed back up to a height of about 3 to 7m above the ant mound. Another member of the group then climbed down. The other group members scanned as before. If one of the scanning group members perceived a potential risk, it uttered a short vocalization (alarm call) and the monkey on the ground climbed rapidly upwards without looking for the source of the alarm. When there was no threat, he climbed back to the floor to continue consuming soil.

Hourly variation in geophagy was noticed. Masked titis ate soil only after 10:00 and before 16:00. Within this period, there was no preference for any hour of the day that could be noted. Seasonal variation in geophagy was observed (Fig. 1). Geophagy has previously been associated with a folivorous diet. The proportion of leaf intake of masked titis varied throughout the year (MÜLLER, 1995), thus we tested the relationship between leaf consumption and geophagy. There was no significant correlation between the monthly frequency of geophagy and the monthly percentage of leaf intake (Spearman rank correlation test: $r_S=0.29$, $p=0.37$, $N=11$).

Table 2. Average soil compositions and standard deviations of the soils consumed and randomly collected soil samples not consumed by *C. personatus*.

	Average composition		
	Soil consumed $n=6$	Random soil samples $n=6$	Mann-Whitney U-test probability
wt.%			
SiO_2	62.8±4.4	65.5±8.8	0.2
TiO_2	3.4±0.6	2.6±0.4	0.04
Al_2O_3	14.0±1.7	9.7±1.8	0.004
Fe_2O_3	7.1±0.7	5.3±1.0	0.01
MnO	0.051±0.016	0.035±0.008	0.08
MgO	<0.005	<0.005	0.93
CaO	0.16±0.26	0.052±0.011	0.47
Na_2O	<0.005	<0.005	0.33
K_2O	0.043±0.02	0.025±0.008	0.04
P_2O_5	0.039±0.006	0.031±0.005	0.02
Sum	87.4±3.3	83.2±7.1	0.2
ppm			
Sc	8±3	7±2	0.5
V	171±16	124±20	0.008
Cr	89±12	70±14	0.04
Co	4±2	3±1	0.4
Ni	10±3	5±2	0.02
Zn	21±4	16±3	0.02
Rb	4±1	4±1	0.5
Ga	23±4	17±4	0.05
Sr	20±4	16±4	0.06
Y	26±3	22±4	0.04
Zr	1847±277	1565±313	0.2
Nb	62±5	49±5	0.005
Ba	7±9	4±3	1.0
Pb	19±4	15±3	0.06

Mineral Analysis

The mineral composition of six samples of soil consumed by titi monkeys (mound of leaf-cutting ants) were compared to six soil samples (non-ant mound) not eaten by the monkeys. Samples from the ant mound are characterized by an aggregate structure formed by soil particles being cemented together by the ants.

All samples were tasted by the observer after collection, but no particular taste (sweet, acid, salty, or bitter) was apparent.

Mineral composition of the soil consumed and not consumed by the titi monkeys with the mean and standard deviation of the concentration of each element are presented in Table 2. Concentrations of the following elements were significantly higher in the samples consumed by titi monkeys: TiO_2, Al_2O_3, Fe_2O_2, K_2O, P_2O_5, Nb, Y, Zn, Ni, Cr, and V (Mann-Whitney U test: $p<0.05\%$).

Physical and Chemical Soil Analyses

Some physical and chemical characteristics of the soil samples are shown in Table 3. If these characteristics are important for ingestion by *C. personatus*, it can be argued that they should display significantly different values either in the soil's organic content (C_{org}, N_t), by its flavor (pH, carbohydrates), or by improved digestibility (clay content). No

Table 3. Soil-physical and -chemical characteristics of soils consumed by *C. personatus* and random soil samples.

		Soil consumed $n=5$	Random soil samples $n=6$	Mann-Whitney U-test probability
$\% C_{org}$		3.52 ± 1.83	4.36 ± 0.57	0.2
$\% N_t$		0.23 ± 0.11	0.28 ± 0.02	0.41
C_{org}/N_t		15.3 ± 1.2	15.6 ± 1.4	0.85
pH (H_2O)		4.10 ± 0.28	4.03 ± 0.19	0.71
Carbohydrates (mg/g)		2.33 ± 1.09	3.53 ± 2.79	0.07
Particle-size distribution (μm)				
Sand	>63	47.5 ± 5.5	52 ± 7.9	0.2
Coarse silt	$63-20$	8.1 ± 2.3	6.5 ± 1.4	0.52
Medium silt	$20-6.3$	5.0 ± 0.8	5.9 ± 1.6	0.39
Fine silt	$6.3-2.0$	2.3 ± 1.4	3.8 ± 1.25	0.13
Clay	<2.0	37.2 ± 4.5	31.8 ± 5.8	0.13

statistically significant differences were found among these measures between consumed and non-consumed soil samples (Mann-Whitney U test: $p<0.05\%$).

One interesting trend in the consumed soil was a slight tendency towards a more greasy textured soil which falls within the particle-size distribution having higher clay and lower sand content. However, this result is not statistically significant.

DISCUSSION

Several studies on the ecology and feeding behavior of *Callicebus* have been carried out, but geophagy has never been reported in this genus (KINZEY et al., 1977; EASLEY, 1982; KINZEY & BECKER, 1983; WRIGHT, 1985). Geophagy is reported here for the first time in a species of this genus.

Normally masked titi monkeys do not go on or near the forest floor (MÜLLER, 1995). Masked titis were observed moving below a height of 5m in less than 1% of their daily activity period. One reason why they move for only a small proportion of their daily time budget near the forest floor may be the risk of predation by snakes (*Bothrops* or *Corallus*). Foraging on the forest floor for insects or small vertebrates was never observed. If masked titis must eat soil, and soils from different places may not differ markedly in quality (top soil with ground litter), it would be advantageous for them to pick up the soil from an ant mound rather than from the forest floor because: (1) at the top of an ant mound titis will have more security as they can easily survey their surroundings by scanning; (2) it is easier for them to pick up an aggregate of soil, cemented together by the leaf-cutting ants, than topsoil of the forest floor; and (3) ant mounds are normally covered with less vegetation or litter, which may obviate clearing the litter and so diminishing exposure on the forest floor.

Functions of geophagy, such as relief from internal parasite infection, physical or chemical effects, tactile sensation in the mouth or tradition were excluded from the analysis because no data are available to test these hypotheses.

Geophagy has been described for several largely herbivorous primate species. Foliage of terrestrial plants tend to be low in sodium. The consumption of soil could be a sodium supplement to the diet (ROBBINS, 1983), but both the geochemical analysis of the soils eaten and not eaten by titi monkeys showed very low concentrations of sodium. The soil consumed by *C. personatus* showed, however, an enrichment of several chemical elements compared with the random soil sample. Nearly all investigations on geophagy, where the soil eaten was compared with random soil samples, reported similar results (DAVIES & BAILLIE, 1988; MAHANEY et al., 1990; HEYMANN & HARTMANN, 1991). In contrast to these findings, HLADIK and GUEGUEN (1974) concluded that the minerals contained in soil are not nutritionally significant in the diets of primates. *C. personatus* ingested soil on only 14% of complete observation days and the amount of ingested soil was very small. It seems that mineral supplementation is not the most important function of geophagy in *C. personatus.*

In some folivorous primate species, geophagy may serve as an antacid function for digestion (POIRIER, 1970; OATES, 1978). Our soil analysis showed that no significant differences of pH-level between the soil consumed and the random sampled soil were observed. The pH-values of soil in this study were relatively low, compared to investigations in which soil eating has been suggested as an antiacid function (DAVIES & BAILLIE, 1988). It seems that in the mainly frugivorous *C. personatus*, geophagy was not principally used for buffering the pH-level of the stomach.

In primates, it has also been suggested that, soil rich in clay has been ingested because of its capacity to adsorb plant toxins such as tannins and secondary compounds (HLADIK, 1977; JOHNS & DUQUETTE, 1991; OATES, 1978). The clay molecule has because of its flat structure a large surface with a great capacity to adsorb plant toxins (affinity) and carry away the toxic components of the diet. MÜLLER (1995) described that *C. personatus* ingested fruits in 76.6% of the feeding records, leaves in 17.2%, and other food categories in 1.8% (food category was not identified in 4.2% of the feeding records). Seeds were ingested in 28.6% of the frugivorous portion of the *C. personatus* diet. Various studies on primate diet demonstrated that 5 to 13% of seed drymatter were tannins (DAVIES & BAILLIE, 1988; WRANGHAM et al., 1991; HAMILTON & GALDIKAS, 1994). Furthermore, BATE-SMITH (1972) pointed out that a bitter taste of food is an indication of plant toxin content. Forty-seven percent of the fruits ingested by *C. personatus* had a bitter taste (MÜLLER, 1995). Unfortunately, the diet of *C. personatus* was not chemically analyzed. None the less we think that the bitter taste of fruits ingested by *C. personatus* is an indication that titi monkeys may also benefit from the adsorptive capacity of clay to detoxify certain food items in their diet. Our analysis showed no statistically significant difference in the proportion of clay between soil samples consumed by the titis and random soil samples. We observed the same proportion of clay in consumed and non-consumed soil samples as found in other studies, in which geophagy was referred to as having the function of detoxifying otherwise nutritions foods.

There were no detectable chemical or physical revealed in our analysis for why termite mound versus ground soil samples were preferred. This may be influences by non-ingestive related factors such as predator avoidance.

To examine further the function of geophagy in *C. personatus*, experiments in captivity under standard conditions need to be carried out. Under such conditions only one parameter (for example: type of diet: folivorous – frugivorous, acid – non acid; type of soil: pH-level, clay content) can be changed at a time to test each of the above mentioned functions of geophagy in primates.

Acknowledgement. This research was supported by Deutscher Akademischer Austauschdienst, Deutsche Forschungsgemeinschaft and Deutsches Primatenzentrum Göttingen. Field work was authorized by Conselho Nacional de Pesquisa (CNP_q) and Comissão Executiva do Plano Lavoura

Cacaueira (CEPLAC). I am (KHM) particularly grateful to Prof. Dr. HANS-JÜRG KUHN for supporting the project and PD Dr. JÖRG GANZHORN for the stimulating discussion on the subject of geophagy. The soil analysis was carried out very carefully by Mrs. INGRID OSTERMEYER. We thank Dr. ALCIDES PISSINATTI (Centro de Primatologia do Rio de Janeiro, CPRJ) and Dr. JOSÉ INACIO LACERDA (Estação Experimental Lemos Maia) for their helpful advise in Brazil. Finally I am (KHM) very grateful to my field-assistant, CLÉA SERRA-MÜLLER, for her generous help in the field and to Dr. MAUVIS GORE for revision of English language.

REFERENCES

ALTMAN, J. 1974. Observational study of behavior: sampling methods. *Behaviour*, 49: 227–267.

BATE-SMITH, E. C. 1972. Attractants and repellents in higher animals. In: *Phytochemical Ecology*, HARBORNE, J. B. (ed.), Academic Press, London, pp. 45–56.

BICCA-MARQUES, J. C.; CALEGARO-MARQUES, C. 1994. A case of geophagy in the black howling monkeys *Alouatta caraya*. *Neotrop. Prim.*, 2 (1): 7–8.

CHIVERS, D. J. 1974. *The Siamang in Malaya. Contributions to Primatology, Vol. 4.* S. Karger, Basel.

CLUTTON-BROCK, T. H. 1972. Feeding and ranging behaviour of the red colobus monkey. Unpublished Ph.D. thesis, Univ. of Cambridge, Cambridge.

DAVIES, A. G.; BAILLIE, I. C. 1988. Soil-eating by red leaf monkeys (*Presbytis rubicunda*) in Sabah, Northern Borneo. *Biotropica*, 20 (3): 252–258.

EASLEY, S. P. 1982. The ecology and behaviour of *Callicebus torquatus*, Cebidae, Primates. Unpublished Ph.D. thesis, Washington University, St. Louis.

GANZHORN, J. U. 1987. Soil consumption of two groups of semi-free-ranging lemurs (*Lemur catta* and *Lemur fulvus*). *Ethology*, 74: 146–154.

GEE, G. W.; BAUDER, J. W. 1986. Particle-size analysis. In: *Methods of Soil Analysis. Part 1: Physical and Mineralogical Methods* (2nd ed., No. 9 in the Series Agronomy), KLUTE, A. (ed.), Amer. Soc. Agronomy, Soil Science Society of Amer. Madison, Wisconsin.

GOODALL, J. 1963. Feeding behavior of wild chimpanzees. *Symp. Zool. Soc. Lond.*, 10: 39–47.

HALL, K. R. L. 1962. Numerical data, maintenance activities and locomotion in the wild chacma baboon, *Papio ursinus. Proc. Zool. Soc. Lond.*, 139: 181–220.

HAMILTON, R. A.; GALDIKAS, B. M. F. 1994. A preliminary study of food selection by the orangutan in relation to plant quality. *Primates*, 35: 255–263.

HARTMANN, G.; WEDEPOHL, K. H. 1993. The composition of peridotite tectonites from the Ivrea Complex, northern Italy: residues from melt extraction. *Geochim. Cosmochim. Acta*, 57: 1761–1782.

HEYMANN, E. W.; HARTMANN, G. 1991. Geophagy in moustached tamarins, *Saguinus mystax* (Platyrrhini: Callitrichidae), at the Río Blanco, Peruvian Amazonia. *Primates*, 32: 533–537.

HLADIK, C. M. 1977. A comparative study of the feeding strategies of two sympatric species of leaf monkeys: *Presbytis senex* and *Presbytis entellus*. In: *Primate Ecology: Studies of Feeding and Ranging Behaviour in Lemurs, Monkeys and Apes*, CLUTTON-BROCK, T. H. (ed.), Academic Press, London, pp. 324–354.

HLADIK, C. M.; HLADIK, A. 1972. Disponibilitiés alimentaires et domaines vitaux des primates à Ceylan. *Terre et Vie*, 26: 149–215.

HLADIK, C. M.; GUEGUEN, L. 1974. Géophagie et nutrition minérale chez les primates sauvages. *C. R. Acad. Sc. Paris, Serie D*, 279: 1393–1396.

HOHL, A. 1993. Wiederherstellung der Artenvielfalt in den Agrarzonen tropischer Regenwälder. Unpubl. Doc. thesis, Universität Hohenheim, Hohenheim.

INOUE, M. 1987. Soil-eating of Japanese macaques (*Macaca fuscata*) at Arashiyama, Kyoto. *Prim. Res.*, 3: 103–111. (in Japanese)

IZAWA, K. 1993. Soil eating by *Alouatta* and *Ateles*. *Int. J. Primatol.*, 14: 229–242.

JOHNS, A. D.; DUQUETTE, M. 1991. Detoxification and mineral supplementation as functions of geophagy. *Amer. J. Clin. Nutr.*, 53: 448–456.

JOLLY, A. 1985. *The Evolution of Primate Behavior* (2nd ed.). Macmillan Publ., New York.

KINZEY, W. G. 1981. The titi monkey, genus *Callicebus*. In: *Ecology and Behavior of Neotropical Primates*, COIMBRA-FILHO, A. F.; MITTERMEIER, R. A. (eds.), Academia Brasileira de Ciencias, Rio de Janeiro, pp. 241–276.

KINZEY, W. G.; BECKER, M. 1983. Activity pattern of the masked titi monkey, *Callicebus personatus. Primates*, 24: 337–343.

KINZEY, W. G.; ROSENBERGER, A. L.; HEISLER, P. S.; PROWSE, D.; TRILLING, J. 1977. A preliminary field investigation of the yellow handed titi monkey, *Callicebus torquatus torquatus*, in Northern Peru. *Primates*, 18: 159–181.

MAHANEY, W. C.; HANCOCK, R. G. V.; AUFREITER, S.; HUFFMAN, M. A. 1996. Geochemistry and clay mineralogy of termite mound soil and the role of geophagy in chimpanzees of the Mahale Mountains, Tanzania. *Primates*, 37: 121–134.

MAHANEY, W. C.; WATTS, D. P.; HANCOCK, R. G. V. 1990. Geophagia by mountain gorillas (*Gorilla gorilla beringei*) in the Virunga Mountains, Rwanda. *Primates*, 31: 113–120.

MELO, A. O. D. 1973. *Solos do núcleo colonial de Una.* Boletim Técnico No. 26. Ceplac-Cepec, Itabuna, Bahia, Brasilien.

MOPPER, K.; GINDLER, E. M. 1973. A new noncorrosive dye reagent for automatic sugar chromatography. *Anal. Biochem.*, 56: 440–442.

MÜLLER, K.-H. 1994. Capture and radio-telemetry of masked titi monkeys (*Callicebus personatus melanochir*, Cebidae, Primates) in tropical rain forest. *Neotrop. Prim.*, 2 (4): 7–8.

MÜLLER, K.-H. 1995. Langzeitstudie zur Ökologie von schwarzköpfigen Springaffen (*Callicebus personatus melanochir*, Cebidae, Primates) im atlantischen Küstenregenwald Ostbrasiliens. Verlag Shaker, Aachen, Germany.

OATES, J. F. 1978. Water-plant and soil consumption by guereza monkeys (*Colobus guereza*): a relationship with minerals and toxins in the diet? *Biotropica*, 10 (4): 241–253.

POIRIER, F. E. 1970. The nilgiri langur (*Presbytis johnii*) of South India. In: *Primate Behaviour: Developments in Field and Laboratory Research, Vol. 1*, ROSENBLUM, L. A. A. (ed.), Academic Press, New York, pp. 251–383.

ROBBINS, C. T. 1983. *Wildlife Feeding and Nutrition.* Academic Press, New York.

RYLANDS, A. B. 1982. The behaviour and ecology of three species of marmosets and tamarins (Callitrichidae, Primates) in Brazil. Unpubl. Ph.D. thesis, Cambridge.

SCHALLER, G. B. 1965. *The Mountain Gorilla: Ecology and Behavior.* Univ. Chicago Press, Chicago.

VELOSO, H. P. 1965. *Atlas Florestal do Brasil.* Rio de Janeiro, Serviço de Informação Agrícola: 82.

WRANGHAM, R. W.; CONKLIN, N. L.; CHAPMAN, C. A.; HUNT, K. D. 1991. The significance of fibrous foods of Kibale Forest chimpanzees. *Phil. Trans. R. Soc. Lond.*, B334: 171–178.

WRIGHT, P. C. 1985. The cost and benefits of nocturnality for *Aotus trivirgatus* (the night monkey). Unpubl. Ph.D. thesis, City University of New York, New York.

—— Received: *September 5, 1995*; Accepted: *September 13, 1996*

Authors' Names and Present Addresses: KLAUS-HEINRICH MÜLLER, *Travessa 1. de Janeiro 16, App. 3, Ilheus-Centro, CEP 45650-000, Brazil*; CHRISTIAN AHL, *Institute of Soil Science, University of Göttingen, von-Siebold-Strasse 4, D-37075 Göttingen, Germany*; GERHARD HARTMANN, *Geochemical Institute, University of Göttingen, Goldschmidstrasse 1, D-37077 Göttingen, Germany.*