Graduate Research Fund. We thank Dr Neil Croll for encouragement in this study.

M. R. SAMOILOFF
S. BALAKANICH
M. PETROVICH

Department of Zoology,
University of Manitoba,
Winnipeg, Manitoba

Received August 13, 1973.

1 Samoiloff, M. R., McNichol, P., Cheng, R., and Balakanich, S., *Expl. Parasit.*, **33**, 253 (1973).
2 Lee, D. L., *J. Zool., Lond.*, **169**, 281 (1973).
3 Ward, S., *Proc. natn. Acad. Sci. U.S.A.*, **70**, 817 (1973).
4 Cheng, R., and Samoiloff, M. R., *Can. J. Zool.*, **49**, 1443 (1971).

Calcium Carbonate in Termite Mounds

THE presence of appreciable quantities of calcium carbonate in termite mounds on non-calcareous soil has intrigued pedologists for many years. Milne[6], for example, found a termite mound with 7% calcium carbonate and estimated that it contained about 2 t of calcium carbonate excluding the hard limestone (53% $CaCO_3$) base of the mound. The soil below the base of a termite mound may also be calcareous. The soil underneath one termite mound in an area of non-calcareous soil was found to have a mean of 1.7% calcium carbonate to a depth of 6 m, or about 20 t of calcium carbonate[9].

The task of finding the primary methods of calcium carbonate accumulation has been hindered by the fact that termite mounds are complex systems involving biological and physical processes. Milne[6] and Pendleton[7] suggested that the most probable biological method was the collection of food by termites and formation of calcium carbonate from the mineralised residues. Other biological methods of calcium carbonate accumulation that have been advanced are as follows: (1) exchangeable calcium in soil collected incidentally by termites with their food[6]; (2) exchangeable calcium in soil collected purposely by termites requiring an alkaline environment[6]; (3) calcareous material collected from below the depth of soil said to be non-calcareous[3,7]; and (4) calcium-containing groundwater brought up by termites[2]. The physical methods proposed all involve evaporation of water containing calcium bicarbonate from a termite mound as the means of accumulating calcium carbonate, but they differ in the source and mode of entry of water into the mound. Thus Milne[6] suggested that water moves upward into the termite mound by capillary action. Den Doop[4] considered that the water evaporating from the mound was derived from surrounding land in the wet season. Boyer[2] too describes how water from perched water tables drains laterally and collects underneath mounds of *Macrotermes subhyalinus*. Finally, Hesse[5] found an association between calcareous *Macrotermes* mounds and poorly drained soil which led him to state that saturation of the base of a termite mound by groundwater was a prerequisite of calcium carbonate accumulation.

The early ideas on the mode of accumulation of calcium carbonate in termite mounds were considered by Pendleton[7] who said of some of them that they "seem too fantastic to repeat". He came to the conclusion that there was no known method by which termites or pedological processes could bring about the observed accumulation of calcium carbonate in termite mounds. There seems therefore to be a need for a different approach to the problem. A weakness of all proposals made hitherto is the long time that it would take to accumulate large amounts of calcium carbonate.

I have constructed a hypothesis that could account for more rapid accumulation of calcium carbonate in a termite mound.

The hypothesis (Fig. 1) is that calcium carbonate can accumulate in termite mounds by means of a two-stage process.

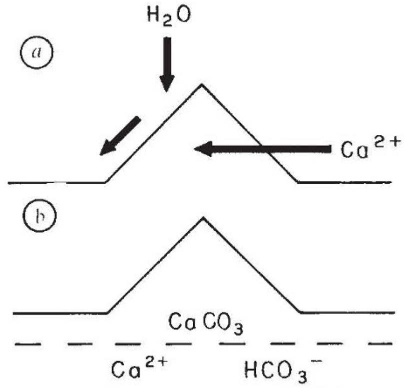

Fig. 1 Two stages in the accumulation of calcium carbonate in a termite mound. *a*, Elevation of the *p*H of the termite mound. This is brought about by termites carrying vegetation into a mound, aided by the fact that a mound sheds rainwater; *b*, precipitation of calcium carbonate as a result of contact between a termite mound of high *p*H and groundwater of low pH_c.

(1) Elevation of the *p*H status of the termite mound above that of the pH_c of the groundwater. An increase in the *p*H of a mound is brought about by termites importing vegetation which is decomposed to release exchangeable bases. Retention of exchangeable bases in the termite mound is facilitated by a low degree of leaching because a mound sheds water[9].

(2) Saturation of the base of the termite mound by groundwater containing calcium bicarbonate which precipitates as calcium carbonate according to the equation

$$Ca^{2+} + HCO^-_3 \longrightarrow CaCO_3 \downarrow + CO_2 \uparrow$$

The tendency for calcium carbonate to precipitate from irrigation water on contact with soil is a well known alkalinity hazard of irrigation schemes, and it has been found by Bower[1] to be related to a modified Langelier saturation index:

$$\text{Modified saturation index} = pH_s - pH_c$$

where pH_s is the *p*H value of the soil and pH_c is the theoretical *p*H value that the water would have if in equilibrium with calcium carbonate. Bower states that precipitation of calcium carbonate occurs if the index is positive. Moreover, the percentage of the applied bicarbonate that precipitated was found to be highly correlated with the value of the index.

This *p*H-dependent precipitation of calcium is related to the presence of bicarbonate and carbonate ions and does not occur with other common anions in groundwater, namely, chloride and sulphate. Formation of calcium carbonate in termite mounds in some regions and not in others may therefore, perhaps, be explained by differences in the anion composition of the groundwaters.

The rate of accumulation of calcium carbonate by means of the *p*H-bicarbonate process outlined here could be relatively fast in situations where groundwater of low pH_c flows past the base of a *Macrotermes* mound of high *p*H value. Consequently, if this hypothesis is correct, it will be unnecessary to assume that termite mounds have existed for the thousands of years that it would take to accumulate large amounts of calcium carbonate by evaporation of water.

J. P. WATSON

Agriculture Department,
University of Rhodesia, Salisbury

Received August 20, 1973.

1 Bower, C. A., in *Proc. UNESCO Arid Zone Symposium, Teheran, Iran, 1958*, 215 (UNESCO, Paris, 1961).
2 Boyer, Ph., in *La Vie dans les Sols* (edit. by Pesson, P.), 279 (Gauthier-Villars, Paris, 1971).
3 Burtt, B. D., *J. Ecol.*, 30, 125 (1942).
4 Den Doop, J. E. A., *E. Afr. agric. J.*, **4**, 89 (1938).
5 Hesse, P. R., *J. Ecol.*, **43**, 449 (1955).
6 Milne, G., *J. Ecol.*, **35**, 192 (1947).
7 Pendleton, R. L., *Thai. Sci. Bull.*, **3**, No. 2, 29 (1941).
8 Watson, J. P., *J. Soil Sci.*, **13**, 46 (1962).
9 Watson, J. P., *J. Ecol.*, **57**, 441 (1969).