SOME CONSEQUENCES OF THE SHAPE AND ORIENTATION OF "MAGNETIC" TERMITE MOUNDS

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Abstract

The possible thermoregulatory significance of north–south orientation of "magnetic" termite nests was investigated. Measurements in the nest during three days in early winter showed that a temperature plateau developed between approximately 1000 and 1730 hr each day, at 33–35°C. This contrasted with night-time temperatures as low as 13–15°C. The nest was then sawn off at the base and rotated into an experimental east–west orientation. In this situation no plateau was detected and temperatures rose to daily maxima of 40–42°C. Apparently north–south orientation of the wedge-shaped mound affords rapid warming in the morning, avoids excessive heating by presenting a low profile to the midday sun, and maintains the warmth of the nest late into the day. This finding confirms and amplifies earlier hypotheses. Thermal gradients within the nest support the idea that convection currents may aid air circulation.

An hypothesis is advanced to account for the evolution of the unusual wedge-like shape of magnetic nests. This shape has a larger surface area–mass ratio than a spheroidal one and may be an adaptation to facilitate gas exchange.

I. Introduction

Three closely related species of tropical Australian termites build spectacular epigeous nests that are elongated in section with the elongated axis oriented along a north–south meridian. The nests are wedge-shaped, tapering towards the top, and of large size ranging from 2 to 4 m high and from about 1 to 2 m in length (Figs. 1–3). Their accurate orientation has given rise to the common names, "magnetic" or "compass" termites. The largest and most spectacular nests are built by *Amitermes meridionalis* (Froggatt) and, as far as is known, this species always builds meridional mounds. Two other species, however, *A. laurensis* Mjöberg (north Queensland and northern Northern Territory) and *A. vitiosus* Hill (north Queensland) are known to build meridional nests only in some circumstances, particularly in low-lying ill-drained areas (Gay and Calaby 1970).

Various authors have attempted to understand the biological significance of the shape and orientation of the mounds of magnetic termites. Jack (1897) suggested that elongation of the mound may promote rapid drying of new construction in the wet season, whereas Mjöberg (1920, cited by Hill 1942) considered that the orientation afforded protection from gales. Most prevalent, however, are theories which suggest that the orientation has relevance to temperature control. In the opinion of Hill (1942) north–south orientation would minimize the effects of rapid changes in

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temperature. A thermoregulatory role was also proposed by Gay and Calaby (1970). They recognized that meridional nests present minimal surface area to the sun during the hottest part of the day whereas the eastern and western faces are warmed early and late in the day. They suggested that the thermoregulatory properties of the nest would be most useful in the monsoon season when the soil surrounding the mounds would be waterlogged and the termites unable to seek cool conditions by migrating underground. Another view was offered by Serventy (1967), who opined that magnetic orientation allows efficient air-conditioning of the nest. His hypothesis is that the alternate warmth of eastern and western walls each day would promote circulation of air within the mound.

Shape and orientation of the termitarium have a great influence on the internal microclimate. According to Noirot (1970), the most important factors of the microclimate within termitaria are temperature, humidity, and internal atmosphere. Of these three factors, temperature and internal atmosphere are markedly dependent on the size, structural shape, and position of the nest (Lüscher 1961). Of particular importance is the surface area–mass ratio. Large spheroidal mounds such as those of *Bellicositermes natalensis* (Haviland) show remarkably constant temperatures in the central habitacle (Lüscher 1961). This is a consequence of the large size of the nest coupled with minimal surface area–mass ratio. The wedge-shaped nests of magnetic termites provide a sharp contrast because their surface area–mass ratio is much larger; one may therefore predict larger diurnal fluctuations in temperature than in a spheroidal mound. It seems reasonable, therefore, to propose that the precise orientation of magnetic termitaria may be of thermoregulatory significance as suggested by Hill (1942) and Gay and Calaby (1970). These earlier hypotheses were not based on any data. In the present paper data are presented which allow evaluation of the hypothesis that orientation of magnetic termitaria has thermoregulatory significance.

The air-conditioning hypothesis of Serventy (1967) bears on the maintenance of internal atmosphere. Noirot (1970) has emphasized that a termitarium is an enclosed unit having no direct communication with the outside air except briefly during emergence of the alates. Accordingly, gas exchange must occur by diffusion through the walls of the nest and this could be a factor limiting nest (and colony) size. Circulation of air within the nest facilitates gas exchange, and therefore reduces size limitations imposed by diffusion. In this paper the possible genesis of thermal convection currents within magnetic nests will be discussed.

All data presented in this paper were gained during an expedition to the Goyder R., Arnhem Land, N.T., in June 1972.

II. METHODS

The mound selected for study was probably that of *A. laurensis* (Dr A. J. Watson, personal communication) and it is seen in Figures 2 and 3. It was located on a well-drained site on the west side of the Goyder R. (12° 30′S., 135°E.) and was 170 cm high, 100 cm long, and 20 cm thick at the widest part. Temperature was monitored throughout the day at eight sites within the mound as shown in Figure 4. Measurements were made with a thermistor thermometer (Scientific Instruments Co.). Shade temperatures were also recorded. After 3 days monitoring of patterns of temperature change, the mound was sawn off at the base with a bow saw and rotated into an east–west orientation; measurements were then taken for a further 3 days.

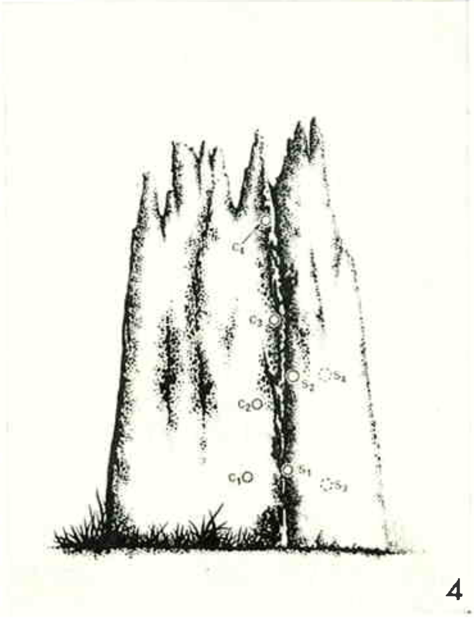


Fig. 1.—Meridional termitarium in low lying poorly-drained area.

Fig. 2.—Eastern face of the termitarium on which the present study is based, at 1400 hr.

Fig. 3.—Western face of the termitarium.

Fig. 4.—Diagram to show the placement of temperature probes. C_1–C_4 were placed in the central column of the mound and were approximately 10, 7, 4, and 2·5 cm respectively from the surface. S_1–S_4 are surface probes placed at a depth of 1 cm. The mound is viewed from the east and S_3 and S_4 are on the western surface.

III. Results

(*a*) *Daily Fluctuations in Core Temperature*

Core temperatures were taken at the four sites indicated in Figure 4, grouped into hourly units, and averaged. Results are seen in Figure 5, for both normal and experimental orientation.

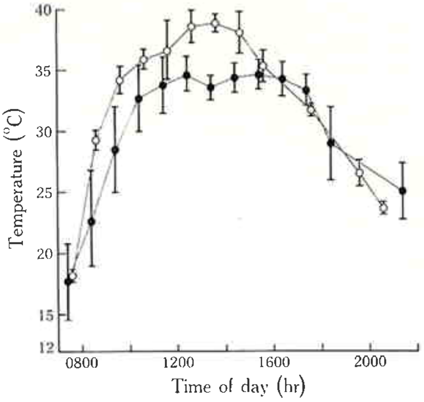
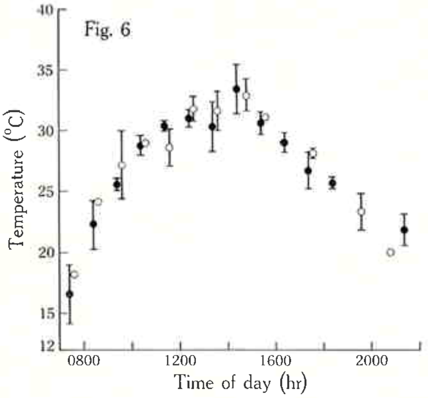


Fig. 5.—Comparison of core temperatures of the termitarium in normal north–south orientation (●) and experimental east–west orientation (○). Each point is the result of combination of all core temperatures (C_1–C_4) over each 3-day measurement period, in hourly groups. The mean, standard deviation, and number of observations is shown in each case. Each day the nest was in sunshine from 0700 to 1730 hr, although broken cloud conditions often developed in the afternoons.

(1) *Normal North–South Orientation.*—In the undisturbed mound, average core temperature rose rapidly from when the sun's rays fell on the mound until about 1000 hr. Throughout most of the day (1030–1730 hr) core temperatures were fairly constant at approximately 34°C, until temperatures fell when the mound became shaded.



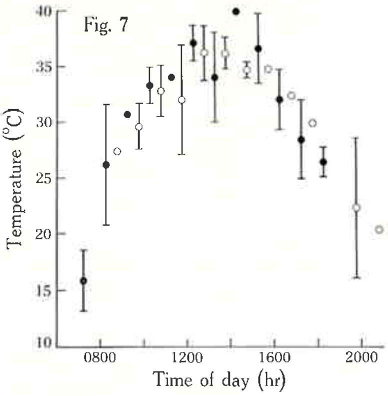


Fig. 6.—Comparison of shade temperatures for each 3-day measurement period. ● North–south orientation. ○ Experimental east–west orientation. Data are grouped as in Figure 5.

Fig. 7.—Comparison of black bulb temperature for each 3-day measurement period. Symbols as in Figure 6.

(2) *Experimental East–West Orientation.*—In the experimental orientation, core temperatures increased as before but no plateau was reached; temperatures climbed to about 6°C higher than those recorded before the mound was rotated.

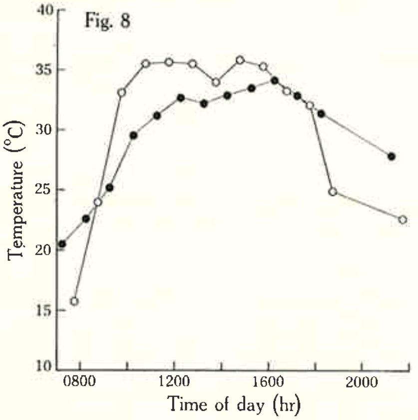
(3) *Shade and Black Bulb Temperatures.*—These were similar before and after rotation (Figs. 6 and 7), which indicates the validity of ascribing the observed

alteration in thermal behaviour to the alteration in orientation and not to differences in thermal characteristics of the two time periods.

(*b*) *Thermal Gradients within the Mound*

(1) *Core Gradients.*—Daily reversals of the thermal gradients in the core of the mound were detected (Fig. 8). During the night, temperatures at C_1 and C_2 were warmer than at C_3 and C_4 by up to 5·0°C. This situation was reversed during the day, when the upper parts exceeded the lower by up to 5·0°C.

(2) *Surface Gradients.*—In normal orientation, morning surface temperatures (measured 1 cm below surface) were higher on the eastern side while those on the western side were higher in the afternoon, as predicted (Fig 9).



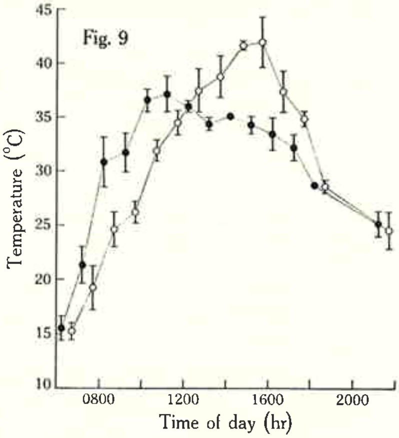


Fig. 8.—Daily cycle in upper (C_4, ○) and lower (C_1, ●) core temperatures with the termitarium in normal north–south orientation. Data grouped as in Figure 5.

Fig. 9.—Surface temperatures on eastern (S_1, S_2, ●) and western (S_3, S_4, ○) faces of the termitarium in normal north–south orientation. Data grouped as in Figure 5.

IV. DISCUSSION

(*a*) *Thermoregulatory Significance of North–South Orientation*

From Figure 5 it can be seen that during north–south orientation of the long axis there is a more or less stable thermal situation in the mound during much of the day but, when the mound was rotated into an experimental east–west orientation, not only did this plateau fail to develop but the maximum recorded temperatures were up to 6°C higher. Clearly north–south orientation, in presenting the mound's lowest profile to the sun at the hottest time of the day, reduces the mound's maximum temperature, and the hypothesis outlined by Gay and Calaby (1970) is confirmed.

(*b*) *Thermal Gradients*

Convection currents derived from thermal gradients within the mound may be important in circulation of air. The data indicate gradients both in the core of the mound and between eastern and western faces.

(1) *Core Temperature Gradients.*—Thermal gradients within the core of the mound reverse twice daily (Fig. 8). This occurs because the summit of the nest is

thinner and less massive than the base, and is therefore more responsive to changes in ambient temperature. It is likely that during the night the warmth of the base may lead to a stream of upcurrent air.

(2) *Face-to-face Gradients*.—Daily reversals of the thermal gradient between eastern and western faces occurred (Fig. 9), confirming Serventy's observation. It is probable that air moves upwards in the eastern side of the mound in the morning and in the western side during the afternoon. However, this circulation is more likely to be a side-effect of the north–south orientation than a "reason" for it.

(*c*) *Some Speculations*

Previous discussions of the significance of construction of meridional nests have suffered from lack of data and from a failure to realize that two separate questions are involved. These are:

1. What is the significance of building a wedge-shaped nest, rather than one which is spheroidal?
2. What is the significance of the north–south orientation of the wedge?

This paper offers an answer to the second question by showing that north–south orientation is an adaptation of thermoregulatory significance. Some speculation about the first question is possible. The most thermostable termitaria are those with massive spheroidal dimensions such as *B. natalensis* (Lüscher 1961). This thermostability results from their small surface area–mass ratio. The wedge-shaped mounds of compass termites have a larger surface area–mass ratio, which renders them more responsive to fluctuations in ambient temperature. Hence the importance of their orientation, which leads to a degree of thermostability during the day. It is unlikely that the wedge-like shape of the nest *per se* is an adaptation related to thermoregulation.

The dependence of the mound's gas exchange on diffusion through the walls has been referred to in Section I. A consequence of the larger surface area–mass ratio in compass mounds is that the surface area available for gas exchange is relatively large, so that gas exchange will be facilitated. The mounds of *Amitermes* have no ventilatory pipes or chimneys such as are seen in mounds of *B. natalensis* (Lüscher 1961), and yet very large compass mounds are common. Interestingly, other large termitaria often have structural features which lead to an increased surface area. In some parts of Australia, for example, the large nests of *Nasutitermes triodiae* (Froggatt) are strongly fluted, the surface being thrown into many vertical ridges resulting in increased surface area.

It seems reasonable to propose that the wedge shape of the nest of *Amitermes* has evolved as a device to increase the surface area–mass ratio, thereby facilitating gas exchange and reducing diffusion-related limitations on colony size. North–south orientation of the nest is seen as an adaptation to counter the potential thermal instability of a wedge-shaped mound. These interpretations may have some oblique support from the observation by Gay and Calaby (1970) that meridional mounds are built by *A. vitiosus* and *A. laurensis* on poorly drained areas only. This may now be explained in terms of gas exchange. In such areas, particularly in the monsoon season, dampness would decrease the porosity of the walls and put surface area considerations at a premium. If the factors controlling the type of mound built by these facultatively compass species can be determined, then some answers to these speculations will emerge.

V. ACKNOWLEDGMENTS

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