

THE HABITS OF THE TERMITES OF BARKUDA.

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(Plates V, VI.)

The following notes on the termites of Barkuda are based mainly on collections and observations made in the years 1919, 1920 and 1922, with a few in the early part of 1923. My visits to the island in these years were frequent but never prolonged. Previous to 1919 some specimens were collected, but no special observations were made. For the identification of species and varieties I am indebted to Professor Silvestri, who has described the collection in the preceding pages. Specimens have been examined by him in all doubtful cases.

The habits of the same species of termites living in different circumstances probably differ considerably. When, therefore, my observations differ from those made elsewhere by other observers¹, no actual discrepancy is necessarily implied. Termite ecology, like that of most other insects, can be discussed in a satisfactory manner only in reference to environment. On Barkuda there are several factors of importance in this connection. For a full account of these I must refer to my recent paper² on the island in the *Memoirs of the Asiatic Society of Bengal*, but one or two important facts may be mentioned here. In the first place, the rainfall on the island is small and is concentrated in the few months of the south-west monsoon; in the second, the soil is scanty and infertile, covering the underlying rocks in a thin layer. For the most part it is red and soft, but sandy areas exist. The vegetation is less impoverished than might perhaps be expected in these conditions, but practically all the dead wood on the island, on which it is fairly abundant, belongs to the genus *Ficus* and most of it to the Banyan (*F. bengalensis*). These facts have certainly had a selective influence on the termite fauna of the island.

The termites of Barkuda may be classified biologically in accordance with the structure of their nests, in three categories, viz. (i) Burrowers, (ii) Mound-Builders, (iii) Log-Dwellers. Of the habits of two species, *Odontotermes* (*Euscaiotermes*) *primus* Silv. and *O. oblongatus* Holm., and of one variety, *Capritermes obtusus* var. *abbreviatus* Silv., I have no information. The remaining six species with their varieties fall into the three categories as follows:—

BURROWERS.	MOUND-BUILDERS.	LOG-DWELLERS.
<i>Odontotermes</i> (<i>Odontotermes</i>) <i>fae</i> (Wasm.)	<i>Odontotermes</i> (<i>Cyclotermes</i>) <i>obesus</i> Ramb.	<i>Coptotermes heimi</i> , Wasm.
<i>Eurytermes assmuthi</i> Wasm.	<i>O. (C.) obesus</i> var.	<i>Microcerotermes</i>
<i>E. assmuthi</i> var. <i>modestior</i> Silv.	<i>oculatus</i> Silv.	<i>annandalei</i> Silv.
<i>Microtermes anandi</i> Holm.		
<i>Coptotermes parvulus</i> (Wasm.)		
<i>Capritermes obtusus</i> Silv.		

¹ I would refer here particularly to the valuable notes contributed by Father Assmuth to Holmgren's papers in vols. XXI and XXII of the *Journ. Bombay Nat. Hist. Soc.*, and to the former's own paper on wood-eating termites in the latter volume and vol. XXIII

² *Mem. Asiat. Soc. Bengal* VII, pp. 257—287, pls. vii-xi (1922).

This biological classification does not correspond with any taxonomic one, for species of *Odontotermes* come under two headings; nor is it by any means absolute, for there is no fundamental distinction in habits between the mound-builders and the burrowers and both excavate galleries in logs as well as in the earth. I base the distinction entirely on the position of the royal chamber, or if there is no special royal chamber, on the part of the nest frequented by the queen or queens. With the mound-builders it is above ground, or at any rate almost at ground-level, in or immediately below the mound when the latter is fully constructed; with the burrowers it is under ground, while with the log-dwellers it is in dead logs of wood. I propose to discuss the nests of the three types separately, but before doing so to consider their comparative ecology in such important matters as swarming, the duration of life, the cultivation of fungi and the search for food.

SWARMING.

In most species swarming takes place on Barkuda at the beginning of the rainy season, *i.e.*, at some date in June. In 1920, in which year the rains began about the usual time, *Odontotermes obesus*¹ and *O. feae* swarmed on the night of June 12th-13th; in 1922, in which the rains commenced unusually early, this took place on the afternoon of June 2nd and in the succeeding night. In both years the event was practically simultaneous with the appearance of the south-west monsoon. On the afternoon of June 2nd in 1922 *Microcerotermes annandalei* and *Capritermes obtusus* also swarmed. Winged adults of *Microtermes annandalei* were found with workers and soldiers under the bark of a dead tree, apparently just about to emerge, in June, 1920. *Coptotermes heimi*, however, swarms earlier, in the dry season. Winged adults and a female which had just cast its wings were found in a nest on April 29th in 1922. Apparently *Eurytermes assmuthi* swarms in autumn, after the rainy season, for both young adults which had already cast their wings and winged nymphs apparently just about to undergo their final metamorphosis were taken in October, 1920. I have not observed the actual pairing of any species.

Probably the adults are ready to swarm in suitable climatic conditions some time before these usually occur. I have found male and female nymphs of *Microcerotermes annandalei* with the wings as long as the body but still teneral in February.

In this species, in *Coptotermes heimi* and in *Eurytermes assmuthi*, the communities of all of which are comparatively small, only a few winged adults are produced at a time and they probably issue forth singly or in small parties. The adults of *Capritermes obtusus* crawl out in large numbers from a small hole in the ground while rain is actually falling. They cease to do so when the rain stops and do not appear until it has become heavy. I have seen the process only in the afternoon between 4 and 6 P.M. This is also true of *Microcerotermes annandalei*, except that the hole is in the side of a dead tree-trunk. In the latter species the

¹ In Bombay this species swarms, according to Father Assmuth, after the rainy season.

winged adults issue unaccompanied, but in the former a few workers and one or two soldiers sometimes, but not always, come out of the hole with them. *O. obesus* and *O. feae* swarm only in wet weather and probably do not begin to do so until rain is falling, but they often continue to issue forth for a considerable time, sometimes for a whole night, after it has ceased to fall. In both species the flight is crepuscular or nocturnal, beginning about sunset or later and continuing until about 7 A.M.

Both in 1920 and in 1922 I was able to observe details of the swarming of *O. obesus* in the same nest, or at any rate in one in precisely the same position, at the base of a large tree of *Ficus infectoria* surrounded by brickwork that had fallen into decay. On both occasions the adults began to issue forth during the night and continued to do so until about 7-30 A.M. The numbers that appeared then became gradually less and the process was completed by 8 A.M. On the previous day the workers had been busy building up little hollow cones of irregular outline on the top of the mound. These were at first completely closed, but their wall was very thin. They varied in size but were never more than six or seven inches high. Before the adults came out, slit-like apertures were formed across the top of these cones on the side furthest from the tree-trunk. These were the vents of egress, and from them both winged forms, workers and soldiers issued in large numbers. As I did not observe the swarming till daylight I do not know whether the soldiers come out as early as the other castes, but they were mingled with them in considerable numbers at that time.

The adults as a rule took flight directly from the edge of the vents, but many fell over as they came out and had no difficulty in rising from the ground. The workers and soldiers wandered about in an apparently aimless way on the surface of the mound, where they were surrounded by hosts of black ants, which every now and then pounced on one of the workers and carried it off. The ants seemed to be wary of the soldiers, but these latter were not drawn up in any particular formation and did not occupy any particular position in reference to the workers and adults. Between 7-30 and 8 A.M. on both occasions all the adults had left the nest, which I opened later in the day; the workers and soldiers had retreated, and the former had in the course of a few minutes closed up the vents with pellets of clay brought from below.

As one of the objects of swarming is believed to be to allow cross-fertilization to take place between different communities, it is important to note how far this is permitted by actual events. On June 2nd, 1922, I observed swarming taking place simultaneously in two nests of *Capritermes obtusus* situated about 50 yards apart. On the night of June 12th-13th, 1920, and again on that of June 2nd-3rd, 1922, communities of both *Odontotermes obesus* and *O. feae* were swarming in different parts of Barkuda, while at Rambha, five miles away, *O. obesus* was swarming in the early morning of the 2nd. Possibly this occurred on Barkuda also on the night of the 1st-2nd, for one of my servants told me that he had seen winged termites in large numbers on that night; but I did not reach Rambha myself till about 6-30 A.M. on the 2nd.

An important question in this connection is that of the power of flight of the different species. In the larger forms such as *O. obesus*

it is certainly much greater than is usually realized. On the morning of June 2nd, 1922, between 7 and 8-30 A.M., I observed large numbers of winged adults of *O. obesus* flying over the surface of the Chilka Lake between Rambha and Barkuda. There was very little breeze at the time, but what there was blew from the S.W. The majority of the termites were apparently attempting to cross the lake at right angles to the breeze or approximately so. In spite of their fluttering and seemingly ill-directed flight, the great majority were progressing steadily in one direction. Many fell by the way and were drowned, but many also persisted and reached land. Some that I saw fly ashore on the island must have flown for at least three miles.

The flight of the smaller species such as *Capritermes obtusus*, *Coptotermes heimi* and *Microcerotermes annandalei*, however, is less sustained. I have already noted that the first and the last of these species only issue forth while rain is actually falling. I find that adults taken direct from the mouth of the nest and kept in a dry cage were unable to co-ordinate the action of their wings or to rise from the ground. In issuing from the nest under natural conditions those of the *Capritermes* run about until they are wet before flying off.

There thus seem to be abundant opportunities for cross-fertilization among the commoner termites even on a small island such as Barkuda. On the one hand it is well within the range of flight of the larger species swarming on the mainland; on the other, some at any rate of the feebler species swarm simultaneously in different communities settled only a short distance apart.

All the communities of the same species do not, however, swarm on the same day, and probably some may produce more than one brood of winged adults in a year. So far as I can ascertain, *Odontotermes obesus* and *O. feae* swarm only once a year and all swarm on or about the same date; but this is not so with *Capritermes obtusus*. Two communities of this species, as I have already stated, swarmed in 1922 on the afternoon of June 2nd, but another in the same proximity swarmed on the 23rd of the same month, while in a fourth nest in another part of the island opened on June 27th, a few winged adults and a large number of sexual nymphs were found. The latter were not all in the same stage of development, some being much smaller and having the wing-pads less advanced than others; but the majority were clearly just about to undergo their final metamorphosis and the wing-pads had already assumed a brownish colour.

In the nest from which adults issued on June 23rd two young wingless queens and two wingless males were found, each pair in a separate chamber. The females had not yet increased in bulk to any appreciable extent, but one of them was already beginning to lay eggs. These young adults probably belonged to one or both of the swarms that appeared from adjacent nests on June 22nd.

DURATION OF LIFE.

My observations on the duration of life in the termites of Barkuda are very incomplete and my conclusions must be largely inferential. Some communities of *Odontotermes obesus* have existed to my knowledge

in the same place for at least five years, but how long any individual lived in them is of course beyond my knowledge. Speaking generally I am of the opinion that the sexual individuals of those species in which the winged adults are small live for a shorter period than those in which they are large, and, indeed, probably survive for only one year. I base this conclusion on the fact that in *Capritermes obtusus*, *Coptotermes heimi* and *Eurytermes assmuthi* only very young wingless males and females were found in nests examined shortly after swarming time. In all these species it is probable that more than one pair of adults inhabits each nest.

The only other termite for which I have any kind of data as regards the winged forms in *Odontotermes obesus*. In *O. obesus* there is only one sexual pair in each nest. This species, as I have already stated, swarms in June. A male and female, the latter already swollen to the full size, were taken from a nest of the typical form in July. In October, 1920, a nest of the var. *oculatus* was excavated very carefully. The royal chamber was removed almost intact and placed with a piece of cotton-wool saturated in chloroform under a bell-jar. When the inhabitants were dead it was removed, opened and examined. Only the female (60 mm. long in spirit) and some workers were found. The male had apparently already disappeared, and no eggs were found anywhere in the nest, though there were a few worker-nymphs. In a young mound of the same form which had only appeared above ground about the middle of June, 1922, a fertile pair was found, the female hard at work laying eggs, on July 24th. The female was only 52 mm. long alive and much less flabby than the one obtained in October. In December, 1922, and January, 1923, however, pairs were found in a nest of the same variety. The female was laying eggs, but was not of the full size in either case.

One large nest was examined on December 25th, and the king and queen removed. The nest, which was rapidly reconstructed on a much smaller scale, was again opened on February 18th. No queen was found and no young larvae were present. Larval workers, however, in their penultimate instar were fairly numerous.

As to the age of workers and soldiers I have little further information. That many die off in the latter part of the dry season I have no doubt. The communities of *O. obesus* and *O. feae* are much reduced in numbers at this season, despite the profuse production of young in early spring. In a nest of *Coptotermes heimi* opened in April I found many dead and shrivelled corpses of workers and soldiers in chambers somewhat remote from those occupied by living individuals.

CULTIVATION OF FUNGI AND SEARCH FOR FOOD.

At least four different forms of termites cultivate fungi on Barkuda. They are *Microtermes anandi*, *Eurytermes assmuthi*, *Odontotermes obesus*, and *O. obesus* var. *oculatus*. I have definite evidence that *Microcerotermes annandalei*, *Coptotermes heimi* and *Capritermes obtusus* are not cultivators, having made a full examination of their nests. The cultivating habit, therefore, is not correlated either with the taxonomic position of the species (except that all cultivating species belong to the family Metatermitidae) or with the nature of its

nest, except that the habit is apparently absent in log-dwellers. It is noteworthy that dead logs on Barkuda contain in the rainy season many species of uncultivated fungi.

Among the cultivating forms there is considerable diversity in the structure of the combs (pls. V, VI). It is, indeed, possible to discover an evolutionary series in those of the four forms, with the combs of *M. anandi* at the base and those of the typical form of *O. obesus* at the apex, those of *E. assmuthi* being a little more advanced in structure than those of the *Microtermes*, and those of the variety of *O. obesus* less advanced than those of the *forma typica* of the same species.

As Professor Bose is discussing the cultivation of fungi by the termites of Barkuda from a botanical point of view in another part of this report, I will merely describe the structure of the combs and of the chambers in which they are situated, with a few notes on other aspects of the culture.

Professor Bose has found that in artificial cultures the same fungus springs up from the combs of all the species, namely, *Xylaria nigripes*, a form only known from termite-mounds. This, however, is apparently only a weed, which the termites prevent from developing.

The communities of *Microtermes anandi* are small and are found in association with those of *Odontotermes*, or at any rate in deserted mounds of the latter. They are not, however, true parasites, for they excavate their own galleries in dead wood or in the earth, side by side with those of the larger species, and form their fungus-gardens in chambers dug out by themselves in the walls of the mound. In well-developed communities the fungus-combs are numerous but isolated and widely separated.

The combs of *Microtermes anandi* (pl. V, fig. 4) are perhaps the most simple in construction of any as yet described. Many of them consist merely of masses of pale yellow globular excretal pellets piled together and very imperfectly agglutinated. In others, which are still extremely fragile, the upper surface has a reticulate pattern of ridges with slight pointed elevations at the nodes, while incomplete cells, either vertical or horizontal are formed in the interior. These often take the form of deep, irregularly curved grooves on the surface. In the most perfect combs the cells are a little more definite, but they are rarely closed at both ends and always vary greatly in shape and size. The general form of the comb is flattened and cake-like. Its size is variable. The largest I have seen, which is not complete but nearly so, is 46 mm. long, 33 mm. broad and 26 mm. deep. Old combs are usually stained black in parts. The mycelia on the combs of this species are always rather scanty and the food-bodies few and less perfect in shape than in the combs of other species.

The largest and most flourishing combs of this species I have seen were dug out in June and July from the walls of deserted mounds of *O. obesus* and its variety *oculatus*. In October I once found a similar, but apparently less flourishing garden, tended by only a few workers, in a similar position. The workers of this species seem to have less con-

¹ For an excellent summary of all that is known on the subject see, Petch, *Ann : Roy. Bot. Gardens, Peradeniya* V, p. 303 (1913).

trol over their cultures than those of the species in which the habit is more highly developed.

In the nests of this species only workers were to be found as a rule in the garden chambers, but a few soldiers are occasionally there.

The fungus-combs (pl. VI, fig. 6) in the nest of *Eurytermes assmuthi* (the communities of which are also comparatively small) and of its variety *modestior*, in which they are still smaller, are very similar, but in some respects a little more complex in structure. In the only nest of the variety (which probably represents no more than a young or impoverished community) examined, only one garden was found, but in those of the *forma typica* there are usually two or three, separated by very narrow passage-ways. The masses of excrement in this species are a little more compact and less fragile than those of the *Microtermes* and they have the form of a comb in a pectinate sense. That is to say, the base is somewhat compressed and from it arise vertical finger-shaped projections, which may coalesce or anastomose in an irregular fashion to form vertical recesses or even partially closed cells. The gardens are not more than about 5 cm. in greatest diameter. They are enclosed in small rounded chambers dug out of the earth a few inches below the surface.

As in *M. anandi*, the soldiers apparently do not as a rule frequent the gardens. I have, however, seen one or two there on several occasions.

There is a considerable gap in complexity between the gardens of *E. assmuthi* and those of the great communities of *O. obesus* var. *oculatus* (pl. VI, figs. 4, 5). These gardens are extremely massive and must have a cubic capacity of many litres, for the whole of the basal part of the mound is occupied by a single large garden, incompletely divided by partitions that hang from the roof or rise from the floor of the large garden-chamber like stalagmites and stalagmites in a cave. The garden nearly fills the chamber, of which it is practically a cast. Sometimes there are two or more tiers of comb. The lower surface of the mass is fairly flat, while the upper surface is produced upwards into numerous little peaks, corresponding to elevations in the roof of the chamber.

The pellets of excreta in both this form and in *O. obesus typicus* remain less distinct than in the two smaller species and are more firmly welded together. Individually they are considerably larger.

It is in the internal structure of the garden that the greatest difference is to be found between the more primitive and the more complex cultures. In *O. obesus* var. *oculatus* there is also a considerable difference in this respect between the older and the younger parts of the garden. The latter are situated at the periphery of the mass. Their external surface is covered with irregular grooves and small circular apertures leading into internal cells or cavities of variable shape and size, but mostly orientated more or less distinctly with their major axis at right angles to that of the whole mass. There is little difference in external appearance between the younger and the older parts of the garden, except that the former are as a rule more rounded on the upper surface, occupying less elevated parts of the garden-chamber, and paler

in colour; but if a section be cut it at once becomes evident that the internal cells in the older parts are more vertical and considerably more regular in size and shape. On an average they are about 12 mm. high and 5 mm. broad. Some others are a little oblique or sinuous, but the vertical orientation of all is well marked.

Both the arrangement of the gardens and their internal structure are very different in the typical form of *O. obesus* (pl. V, figs. 1, 2; pl. VI, figs. 1-3). As we shall see later, the difference in arrangement is correlated with a difference in the form and structure of the nest. In the mounds of *O. obesus typicus* there is no single large fungus-garden, but there are many (sometimes as many as twenty or thirty) small gardens, each contained in a single chamber of almost spherical form. The largest chambers are rarely more than 9-10 cm. in diameter and the gardens in them a few centimetres less, but both vary considerably in size. In regularity of internal structure these gardens are almost comparable to honey-combs. They are never quite spherical but as a rule slightly convex above and flat or concave below. Occasionally they have the form of a mushroom with a bulbous head and a slightly narrower stem. I have found specimens in which the upper part was separated from the lower and fitted over it like a cap. Such combs were, however, abnormal and probably owed their peculiarity to some defect in the culture. The cap was always drier and of a darker colour than the remainder of the comb and bore comparatively few food-bodies. The upper part of normal combs often differs from the lower in the same way but to a less extent.

The upper surface of the comb of this termite as a rule contains a few large circular openings, which are approached by short, broad, irregular grooves. The lower surface also bears a few apertures, but they are smaller. Most of the entrances are on the sides.

The internal cells differ from those of the comb of the variety *oculatus* in their regularity, and in being transverse instead of vertical. They are also more uniform in size and are arranged in regular transverse rows in which the separate cells often alternate. Each cell is from 6 mm. to 15 mm. in length, from 3 mm. to 5 mm. in height, and from 10 mm. to 20 mm. in breadth.

The combs of this form thus closely resemble those of *O. redemanni* as figured by Petch.¹

The combs of *O. obesus* are compact from the first and even when very small have a distinct "cellular" structure (pl. V, fig. 1).

In the four forms of fungus-garden here described we may note, as I have already pointed out, an evolutionary series. There is a gap between the structures produced by *Eurytermes assmuthi* and *Odontotermes obesus* var. *oculatus*, while the resemblance between the comb of the former species and that of *Microtermes anandi* is on the whole closer than that between those of the *forma typica* of *O. obesus* and its variety. Probably the latter's single big garden resembles the garden of *O. bangalorensis* as figured by Assmuth in Holmgren's paper.²

¹ Petch, *Ann. Roy. Bot. Gardens, Peradeniya* III, pl. VII (1906).

² *Journ. Bombay Nat. Hist. Soc.* XXII, pl. E, fig. 3.

As to the actual culture of the fungi and their utilization by the termites I have few observations to offer, but there are one or two interesting facts of a collateral nature that have impressed themselves on me. First as to the removal of the combs by *O. obesus*. If a mound of that species be opened in February the upper garden-chambers, which are situated well above ground, will be found to be empty. If this is done in April or May, all the garden-chambers in the mound are empty. In both months the interior of the empty chambers is perfectly clean, and no trace of the gardens can be discovered. If, on the other hand, a mound be opened in which the termites have for some reason died out, as is often the case, dry and shrivelled remains of the gardens will be seen in abundance. I believe, therefore, that in the dry season, and especially when the weather is hot as well as dry, the workers remove the gardens bodily underground. In order to test their power to do so, I exposed three garden-chambers in a mound of *O. obesus typicus* on the evening of August 5th. By the next morning new roofs had been built over two of the chambers, but the third, which was very deep, remained open. The comb had completely disappeared. The passage leading to the chamber from the other parts of the nest had been blocked up.

There are probably two reasons for this removal, viz., (i) the impossibility of maintaining the correct temperature and moisture for the growth of the fungi above ground in hot and dry weather and (ii) the danger to the community if the upper parts of the nest are occupied too near the surface at such times. In descriptions of termite-mounds apertures in the walls, sometimes called "chimneys," are frequently mentioned, and it has even been suggested that these apertures are ventilation-shafts. They are common enough in the mounds of *O. obesus typicus* on Barkuda, but I believe that they are due entirely to accident and constitute a serious danger to the termites. They will always be found on examination to lead into unoccupied chambers or passages completely walled off from the nest. Most frequently they are due to the collapse of the roof of a garden-chamber. This comes about from several causes, both climatic and biological. In great heat, when the mound is dry, its walls are apt to crack, and naturally do so most readily where thinnest. A heavy rainfall then produces a funnel-shaped aperture in the roof of a hollow cavity. But the mound is weakened not only by heat and rain but also by the attacks of many boring or burrowing animals, ranging in size from the monitor lizard *Varanus bengalensis*, which is often as much as 4 feet long and sometimes hollows out the interior of a mound to form itself a safe retreat, to certain trap-door spiders¹ and the larva of a tiger-beetle (*Cicindela haemorrhoidalis*), which habitually constructs their burrows in the mounds of *O. obesus*.

The danger to be apprehended (if they have the faculty of apprehension) by the termites when the mound is breached is not only that of flooding in heavy rain but also that of a massed attack by predaceous ants. Such ants are almost invariably to be found in the immediate vicinity of termite-mounds, and they lose no opportunity

¹ See Gravely, *Rec. Ind. Mus.* XXII, pl. xvii, figs. 4-6 (1921).

of carrying off workers and even, when larger species are the aggressors, soldiers. It is very common for empty garden-chambers which have accidentally received a "chimney," to be occupied by colonies of some Pomerine or Campanotine ant which would quickly depopulate even the great communities of such a termite as *O. obesus*, if an entry were given them.

If I am right in thinking that the workers of *O. obesus* remove their combs, the question naturally arises, how do they reconstruct them, for they must take them to pieces in order to remove them? In order to throw some light on this question I opened several mounds a few days after the rains had commenced in June, 1922. In all but one, which was apparently occupied by a young community just starting house-keeping, the combs were already fully formed in chambers in the upper part of the mound. They only differed from gardens examined later in the season in being extremely soft and friable. An artificial culture from them produced *Xylaria nigripes* in an exceptionally short time. It looked as though the combs had been hastily constructed or reconstructed and had not yet become consolidated or been completely weeded.

In one small mound which had just appeared above ground the comb-chambers were already constructed but void of comb. In one such chamber I found a little pile of minute fragments of wood and bark. Do the workers collect material for the formation of excrement and devour it to produce the excrement *in situ*? The point is worth investigating further.

As to the utilization of the food-bodies produced by the fungi in the combs, I have no direct observations to record; but I think it evident they do not provide the bulk of the food consumed by the workers and soldiers. Even in communities in which the garden-chambers are very large or numerous, they could hardly do this for the enormous number of individuals in each community; while in small communities such as those of *Eurytermes* or *Microtermes*, the gardens themselves are small. In the nests of *O. obesus* both soldiers, workers, and young of all castes are found in the gardens. The royal chamber is apart and if the adult males and females feed on fungus-products, they must be brought them by the workers. The eggs, however, are carried by the workers to the gardens, in which both they and the young are often found in large numbers, and I have little doubt that the young eat the food-bodies there produced. Possibly the workers and soldiers do so also in times of stress, but in damp weather they make long excursions outside the nest to feed on dead wood, dead leaves and other dead organic matter. I once traced a foraging party of *O. obesus* from a mound under a fig-tree for over 80 yards to a mass of dead weed thrown up by the lake on the shore. In whatever way the excrement² out of which

¹ See Annandale and Dover, *Rec. Ind. Mus.* XXII, p. 337 (1921) and Horn, *Deutsch. Ent. Zeits.*, 1899, pp. 234, 395. In April, 1922, I found the adults of this beetle abundant in burrows in termite-mounds on Barkuda. Their exuviae were also present and they were evidently waiting to emerge as soon as the rains began. At the beginning of June, after the first heavy showers, Dr. Kemp and I found only exuviae in the burrows, but the beetles were common outside.

² Petch, *Ann. Roy. Bot. Gardens, Peradeniya* III, p. 200 (1906).

the gardens are constructed be produced, it cannot be produced unless bulky food containing much woody matter be devoured.

In the gardens of *Eurytermes assmuthi* and *Microtermes anandi* only workers (young and adults) and young soldiers have as a rule been found. Eggs and newly hatched young are piled up together in empty chambers. The *Microtermes* accompanies its larger companion (*O. obesus*) on foraging expeditions in dead logs, in which it eats its own tunnels. They are smaller than those of the *Odontotermes*, too narrow, indeed, for the latter to penetrate. Both this species and *E. assmuthi* also keep their sexual adults apart from the fungus-gardens and even the winged nymphs are isolated in separate chambers. The habitual food of the *Eurytermes* workers is probably the rootlets of trees and other vegetable matter found in the soil. Conditions are, therefore, much the same as in the larger cultivating communities, and probably in the smaller communities also fungus-products are reserved mainly for the young and for adult sexual individuals. They certainly do not form the bulk of the food of the workers and soldiers, at any rate in damp weather.

In December, 1922, I excavated a large nest of *O. obesus* var. *oculatus* with the help of several friends. The ground was very hard and dry at the time. We found the general structure of the nest normal (see p. 245), but the fungus-garden was very bulky and in three tiers. It and its surrounding walls were still damp. The workers and soldiers, although apparently quite active, had almost deserted the galleries and were, indeed, quite absent from the upper vertical galleries, but were found in considerable numbers inside the combs and also in and around the royal chamber. Apparently excursions were not being made from the nest, and the only apparent source of food was the fungus gardens. The "food-bodies" in these were found to be less abundant in winter than in the wet season and to be practically absent from the inner part of the combs in which the workers and soldiers were congregated possibly because they were being devoured by the community at large as soon as they were formed.

THE NESTS OF THE BURROWERS.

Much the simplest and probably the most primitive nests are those of the burrowers. In many species the community is comparatively small and the amount of earth excavated in constructing the nest not of sufficient bulk to form a mound above ground. To this *Odontotermes feae* is an exception, but I will deal with that species last in this section, because its habits provide a transition to those of the mound-builders.

Simplest of all the Barkuda species in the construction of its nest is *Microtermes anandi*, the communities of which are also probably the smallest. It excavates a number of small rounded chambers connected by very narrow passages in the walls of a mound of *Odontotermes obesus*.

The chambers are numerous and each contains either a fungus-garden or a mass of eggs. They are widely separated one from another. Those that contain eggs have an arched roof and a flat floor, while the fungus-garden are more irregular in shape. I have not found a royal chamber. The sexually mature adults probably only live a short time. They have certainly been absent in several nests I have examined both

in the rainy season and after its conclusion, while masses of eggs were found in February. The number of soldiers present is small. Large or elaborate excavations are, therefore, unnecessary in the nest.

Although this species, so far as I know, always makes its nest in the mounds of *O. obesus*, it does not confine its excavations to the walls of the mounds, for I have found it, as already stated, constructing very narrow galleries in dead wood side by side with those of *O. obesus*. Such galleries, however, can hardly be regarded as part of the real nest. The workers, accompanied by a few soldiers, make their way underground to dead logs lying prone and enter them from below to feed on the decaying wood. Neither sexual individuals nor nymphs are found there.

The nests of *Eurytermes assmuthi* are not more extensive, but perhaps a little more complex. They are formed in vegetable mould at the base of trees and take the form of narrow horizontal passages a few inches below the surface of the soil and of small rounded chambers not more than 5 cm. in diameter and situated at the same level as the passages. The latter branch and anastomose sparingly over an area of many square feet and the chambers, which contain the fungus-gardens or provide accommodation for a royal pair or for groups of sexual nymphs, are situated toward the periphery of the whole. It is difficult to follow the exact arrangement of the complex as it is formed in soft earth which collapses at a touch; but there appears to be no exit to the outer air and I have never seen workers or soldiers above ground.

The nest of the variety *modestior* of this species is just like that of the *forma typica* but of less extent and perhaps less complex. The only community observed lived in close proximity to one of the latter form under a tree of *Hemigyrosa canescens*.

The communities of *Capritermes obtusus* are larger than those of either of the two preceding species, but in order to realize the fact it is necessary to excavate the whole nest. This it is by no means easy to do in the scanty soil of Barkuda, for the excavation is usually found among stones or rocks and penetrates downwards for a considerable distance. The species, therefore, though common, is very liable to escape notice. The only nest of which I succeeded in exploring the greater part was dug in a somewhat exceptional position, namely, in the wall of a deserted mound of *O. obesus*, and even in this nest I did not find the royal chamber, though eggs were observed in abundance. The nest consisted of narrow passage-ways and comparatively large but very flat round or oval chambers 10 cm. or more in diameter. These were situated at different levels. The total depth of space occupied by the whole nest must have been about 3 feet and the superficial area about the same. The upper chambers were occupied by large numbers of workers with a much smaller number of soldiers. Those lower down, at about ground-level, contained workers, immature workers and soldiers, sexual nymphs and eggs all together. A few winged individuals were also discovered in the same position: This was on the 29th of June.

The only external orifices I have seen are those through which swarming was taking place.

Odontotermes feae lives in still larger communities and probably excavates much larger and more complex underground passages and

chambers ; but I have never succeeded in exploring a nest of this species. The amount of earth it excavates is certainly considerable. Sometimes this earth is piled up in an amorphous mass among the roots of trees, more often it is utilized in filling up the cavities eaten in dead tree-trunks. In these cavities a complicated series of oblong vertical chambers is often constructed, having thick earthen walls formed of small pellets carried up from underground by the workers. The bulk of these earthworks, which often fill the greater part of dead but still upright trunks, is sometimes almost as great as that of small mounds of *O. obesus*. *O. feae*, however, always works under cover, while the mounds of its congener are built more or less in the open.

The real nest of *O. feae* is always underground and even when the excavated earth is piled up among the roots of trees, the pile contains only passage-ways and small irregular chambers.

The habits of *Coptotermes parvulus* are apparently similar to those of *O. feae*, but I have only once taken this species, in an upright hollow trunk of *Ficus bengalensis*. It was in very hard, dry wood.

THE NESTS OF THE MOUND-BUILDERS.

The mounds constructed above ground by many species of termites (on Barkuda by two varieties of *Odontotermes obesus* only) are not mere rubbish heaps, as has been stated, but highly organised structures containing not only the gardens of the community but also its royal palace, its public nurseries and its communal dwelling-place. Nevertheless, they must be regarded as a development from the almost structureless rubbish heaps piled up by such species as *Odontotermes feae* outside their burrows, and are in some respects analogous to the coarse and irregular chambers constructed by the same species in hollow tree-trunks and such situations.

The two varieties of *O. obesus* (the *forma typica* and *oculatus*) that occur on the island construct very different mounds. This is curious, for the only anatomical difference that Professor Silvestri has been able to find between the two forms is that the eyes of the female are much larger in *oculatus* (v. fig. II, p. 224). There is apparently no difference between the workers which build the mounds. At one time I thought that the difference in the mounds was due to a difference in the earth out of which they were built and that the var. *oculatus* only lived in sandy soil ; but I have recently found mounds of just the same construction among bushes of *Glycosmis pentaphylla* in the red soil in which those of the *forma typica* are usually built, and also mounds of the typical *O. obesus* in sandy soil. The mound (fig. 1) in which the type female of *oculatus* was taken, was situated in a thicket growing on sandy soil on the east side of the island and was excavated completely by Dr. Baini Prashad and myself in October, 1920. It was about 6 feet high, as a whole nearly cylindrical and about 3 feet in diameter, but was rendered very irregular in cross-section by the fact that numerous laterally compressed buttresses projected all round, running up from the ground almost to the highest point and ending in separate little peaks. There was no external aperture. What appears like one on the figure was merely a depression. Several dead leaves and a small fragment of dead wood were attached to the surface.

In this mound, as I have already stated, almost the whole of the basal part at and a little above and below ground-level was occupied by a single large, incompletely divided chamber enclosing the single fungus-garden of the community. The incomplete partitions were mostly vertical, but others were horizontal. Their consistency was softer than that of the other parts of the nest, probably because they were kept in a continual state of moisture. A little to one side of the garden, at about ground-level, and communicating with it by means of complicated narrow galleries, occupied chiefly by soldiers, was the royal chamber, in which were a single fully developed queen and numerous

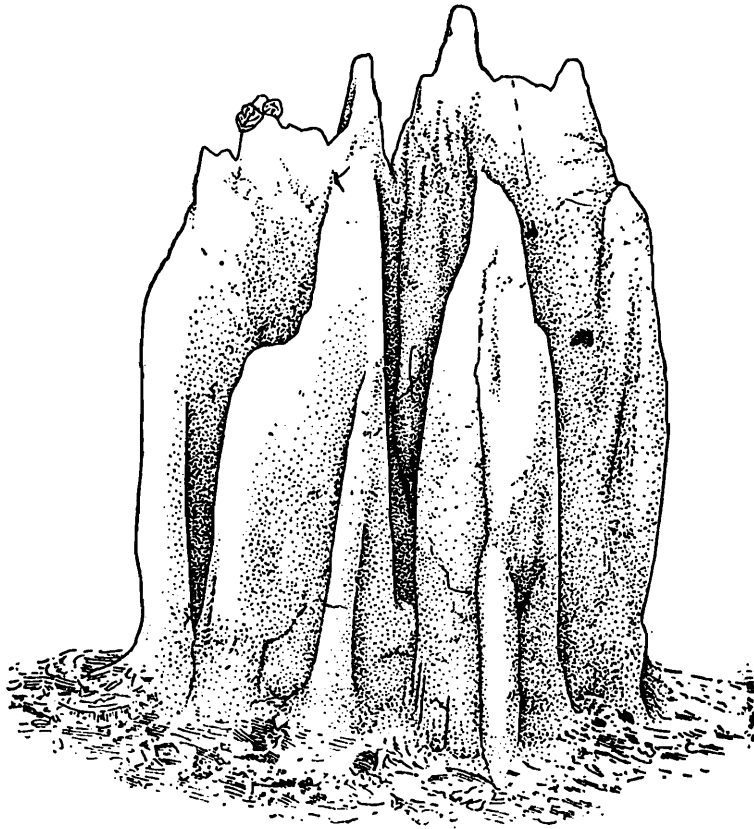


FIG. 1.—Mound of *Odontotermes obesus oculatus* from which type-specimens were obtained. From a Photograph.

workers. It was 17 cm. long, 7 cm. broad and 3 cm. high in the middle, the floor being flat and the roof somewhat irregularly arched. No male or eggs were found, but nymphs of both asexual castes were fairly abundant in the comb. The upper part of the mound consisted internally of compressed vertical galleries joined together by numerous narrow horizontal passages, the buttresses and narrow central core being hollow. These were occupied by a few workers and soldiers.

On June 24th, 1922, I opened a young nest of this form that had appeared above ground about six weeks before. It was situated in a *Glycosmis* thicket in red soil and had the shape of a sugar-loaf cone a little irregular at the base but without buttresses. It was about 2 feet high and slightly broader at the base. Internally the upper part consisted of vertical galleries of wide calibre joined together by rather narrower horizontal ones. These galleries seem useless to the community.

Possibly they assist in some way in regulating the temperature or moisture of the lower part of the mound, for they are always present. The whole of the base of the mound was occupied by a single large fungus-comb with relatively high vertical pinnacles, the largest of which was about 25 cm. high from base to apex. As in the older nest previously described, the comb was incompletely divided by clay partitions, but these all arose from the floor of the cavity. The royal chamber, containing a male and a mature but not fully swollen female, lay just under the comb a little to one side. This is its normal position.

In a third, very large nest of this form excavated in December, at least three large fungus-gardens, resembling those in the other nests, had been constructed one above the other. A fourth, much smaller nest, examined in January resembled the second.

The structure of the mound of *O. obesus* var. *oculatus* thus resembles that of *O. bangalorensis* as figured by Father Assmuth¹ in Holmgren's paper.

On Barkuda the mounds of the typical form of *O. obesus* (fig. 2) are usually built either in thickets of the shrub *Glycosmis pentaphylla* or



FIG. 2.—Typical mounds of *Odontotermes obesus typicus*, showing artificial apertures. From a Photograph.

round the base of the trunks of fig-trees such as *Ficus infectoria*. They are usually constructed in groups the different members of which communicate underground and are as a rule only a foot or two apart but sometimes a yard or even more. Each mound is a small conical elevation, rarely more than 3 feet high and having about the same maximum diameter at the base. It is frequently compressed in one plane so as to be less than a foot thick and is as a rule pointed at the apex. The different mounds of each group are sometimes arranged in a straight line and sometimes scattered irregularly. I have not been able to correlate their orientation with any factor in the environment. When the surface is fresh and in good condition there is no external aperture, except the temporary slits made to permit of the exit of the adults and then closed after swarming has taken place; but in old mounds there are always large funnel-shaped openings due, as I have already pointed out, to

¹ In Holmgren, *Journ. Bombay Nat. Hist. Soc.* XXII, pl. F. There is some confusion about the name "bengalensis" on this plate, but I understand that it is really, despite the legend, a mistake for *bangalorensis*.

accidental causes. When a group of mounds is very flourishing the different mounds are sometimes enlarged to such an extent that they meet and coalesce, thus forming a single large mound of irregular shape. In very old mounds it is often only the central parts that are inhabited by *O. obesus*, with colonies of *Microtermes annandi* in the walls of the outer parts.

The internal structure of the nest is very different from that of the var. *oculatus*, the main differences being due to lack of buttresses and of an empty upper storey and to the fact that there are many fungus-gardens situated in separate chambers. These are contained both in the mounds and in the earth below them. The highest are often at the very top of the mound within a few inches of the surface. The chambers are almost spherical and perfectly smooth, almost polished internally. They are connected by narrow passage-ways and communicate in the same manner with vertical shafts that run down the mound. These are as a rule circular in cross-section instead of being compressed. In old mounds which have coalesced the royal chamber is situated near the centre some distance above ground. In younger nests, however, it is situated underground, at the base of one of the mounds. In form it resembles that of the var. *oculatus*.

The internal structure of old nests thus closely resembles that of those of the allied species *O. redemanni* as figured by Petch.¹

The mound of *O. obesus* is built or repaired only in damp weather. If at other times it suffers any injury that causes a breach to be formed, a partition is as a rule hastily constructed, completely closing the internal galleries and chambers. If an accident of the kind occurs when the air is very dry a considerable part of the nest may be deserted and the partition formed well below ground, but even a slight shower is sufficient to encourage activity in building and if a nest is completely destroyed an attempt may be made to reconstruct it on a small scale even after a heavy dewfall. In the hot weather, *i.e.*, in the latter part of the dry season, the mounds are practically deserted in any case, the community having retired underground, and if the intact part of the mounds be opened, only an occasional patrol of workers and soldiers will be encountered. Immediately the rains commence, however, the workers become active and repairs and new constructions are started with great vigour. In 1922, after a prolonged drought, the first heavy rain fell on the evening of June 1st. Repairs were already in full swing on the 3rd, the work being done chiefly at night and in the early morning before the sun became hot. A few days later a break in the rains took place. The new half-built chambers were partitioned off and the working parties retreated underground to wait for more favourable conditions. As soon as rain fell again work recommenced.

A great deal of reconstruction evidently took place in the inner parts of the nest, but all that could be observed directly was the work on the outer parts. This consisted in re-roofing chambers in which breaches had been formed accidentally and in the construction of new pinnacles to the mound. The mode of operations was the same in both

¹ *Ann. Roy. Bot. Gardens, Peradeniya* III, p. vi (1906).

structures. A very thin, porous roof was first formed, its shape, whether flat, arched or conical, depending on the needs of the case. The workers surged up in large numbers and at the same time a line of soldiers took up their position, with their heads outwards, round the edge of the aperture, taking care that their soft bodies were well inside. When a new chamber was to be built, the workers ate away the roof of the old one below it. Each brought up from below a little pellet of clay, which it deposited, apparently haphazard, at the edge of the cavity, at the same time secreting a drop of saliva to cement it in place. There seemed to be no co-ordination between the work of different individuals and those which had deposited their pellets wandered about in an apparently aimless way, but the disorder was apparent rather than real, for when the chamber was too broad to be arched over in one span, other workers simultaneously built up pillars from the floor. These pillars were never too high to do more than just support the new roof.

I have said that the new roof when first constructed was porous. Beneath each little pore or aperture a soldier was on guard. If any object was brought within a couple of inches of the new roof, the soldier opposite it thrust out its head with a convulsive movement and widely opened its jaws, influenced, I suppose, either by movements in the air or by a change of temperature, for the soldiers of course are blind. If a hand was waved over the structure its movements were followed by a kind of shudder as each soldier in turn executed this manoeuvre. The object of the guard was evidently to protect the workers against the attack of black predaceous ants, of which large numbers were always on the watch for an opportunity to carry off the workers. The soldiers they could not attack, for their soft bodies were protected by the wall and only their hard head and jaws were exposed. The ants, therefore, which ran about the surface of the mound, avoided those parts of it that were still porous. The little pits in which the sentries were on guard can often be seen on the inner surface of the wall in completed mounds (pl. V, fig. 3). These, except where the wall is very thick, provide evidence that the soldiers remain on guard while the wall is thickened round them and that it is only when it has reached its maximum thickness that the external holes are filled up. The stoppers are sometimes so thin as to be translucent.

No attempt was made to thicken the roof until the whole of the outer layer had been completed and the thickening was carried out entirely from within. The thin outer layer of the roofs of the new or reconstructed chambers was comparable to the temporary shelters made by the workers when on a foraging expedition, except that the latter are not porous. They are, however, extremely thin and fragile. The only occasions on which the workers of *O. obesus* appear in the open are when the adults are swarming and when they themselves are constructing the external parts of the mound, and these events only occur at night or in the early morning or late evening. When fungus-combs are removed from the nest with workers inside, the workers attempt to fill up the external apertures of the combs with their excrement. Food-supplies outside the nest are usually approached from underground and the burrows for this purpose may be many yards in length. In the

instance I have mentioned in which a party made its way for over eighty yards to a mass of dead water-weed, the stony nature of the soil rendered this method of approach impossible in places, and the termites had also apparently come up to the surface from time to time to devour dead twigs that lay in their way on the ground. At such places they had constructed temporary galleries of clay pellets consisting of an arched unpaved passageway. Such lengthy excursions, however, only take place in damp weather. In the hot season foraging rarely extends beyond the immediate vicinity of the nest. When actually feeding, even in the interior of a mass of dead leaves, the workers make a fragile roof of the same kind but of irregular shape to shelter themselves, while under the bark of dead trees they construct irregular chambers of the same substance but much less massive than those constructed by *O. feae*. These temporary earthworks, however, can hardly be regarded as part of the nest. Their object probably is to conserve the moisture of the air as well as to protect the workers from ants and other enemies.

The amount both of "original works" and of repairs undertaken in the mounds of both forms of *O. obesus* varies greatly in different years, apparently in correlation with the rainfall. In the wet season of 1922, in which the rainfall was abnormally low at Barkuda, hardly any new mounds were built on the island, while the repairs executed in old mounds were reduced to the minimum compatible with security.

NESTS OF THE LOG-DWELLERS.

Comparatively few species of termites, on Barkuda at any rate, live exclusively on dead wood. Indeed, *Coptotermes heimi* and *Microcerotermes annandalei* seem to be the only species that do so. The only wood in which I have found these log-dwellers was that of the Banyan (*Ficus bengalensis*). They occur most frequently in rotten trunks lying prone on the ground. In one such trunk I have taken no less than five species of termites, namely, *Odontotermes feae*, *O. obesus*, *Microcerotermes annandalei*, *Microtermes anandi* and *Coptotermes heimi*. Only the two species previously mentioned, however, were true log-dwellers.

The nests of the *Coptotermes*, of which there were many in this log, are confined to those parts of it that remain damp. During the hot weather the insects retire to the heart of the trunk, where this condition persists, but in the rains they may be found immediately under the bark. The real nest can be readily distinguished from the "flings", as Father Assmuth calls them, produced where the termites are feeding on wood. Although the species does not cultivate fungi, it produces for its dwelling-place a structure superficially not unlike the fungus-comb of some species. This structure, of a fragment of which a good photograph is reproduced by Father Assmuth,¹ is formed of wood covered with the excrement of the workers (pl. V, fig. 5). It has as a rule a bluish black colour and varies in size with the numbers of the community. In a large nest it has a capacity of several litres. The cells are narrowly oval with their long axis in the same direction as that of the fibres of the wood, i.e. parallel to the length of the trunk.

¹ Assmuth, *Journ. Bombay Nat. Hist. Soc.* XXII, p. 382, pl. iii, fig. 1, pl. iv, fig. 1.

Their walls consist of very thin layers of wood strengthened by the covering of excrement. Occasionally, where the tree-trunk is in contact with the earth, they are further strengthened by a thin layer of clay. They can, however, always be distinguished readily both from the thick-walled, irregular chambers of *O. feae* in a similar position and from the temporary and much more fragile galleries of *O. obesus*.

The chambers in this nest are eaten out from the wood by little bodies of workers, which crowd together for the purpose and are apparently so intent on their work that they can be dissipated only by violence. As they eat away the wood they secrete some substance that dyes it black to a depth of about a millimetre. Possibly this substance may guide another body working independently to form the other side of the partition, by means of some flavour or of a peculiar consistency it imparts to the wood. The excrement must be spread on the walls in a liquid or semiliquid condition after they are completed. The flattened pellets can be distinguished by the naked eye. Father Assmuth points out that the workers of this species spread their excrement on any body over which they crawl. He figures a bottle thus adorned and suggests that it may form an easy path-way for the workers, but I am convinced that my interpretation of its original function is correct, for the partitions between the cells are often so fragile, especially where the wood is rotten, that they would collapse unless strengthened.

In a nest opened in April I found some of the cells, always at a considerable distance from those occupied by living individuals, filled with the dead and shrivelled bodies of workers and soldiers. The occupied cells always contain large numbers of soldiers and workers. Immature individuals of the neuter castes are often found with them and I have not been able to distinguish any particular royal chamber.

The nests of *Microcerotermes annadalei* seem to me precisely like those of *C. heimi*. Indeed, it is possible that the former species merely occupies deserted nests of the latter.

The foregoing observations, incomplete and imperfect as they are, may, I hope, provide suggestions for those who are in a position to investigate the habits of termites more fully than I have been able to do. My notes are based, except where it is otherwise stated, on the examination of many nests of each species and on such field observations as I had time to carry out in the midst of much other work and on short visits to the island. They have been put together as a supplement to Professor Silvestri's systematic description of my collection and to Professor Bose's account of the fungi cultivated by certain species. Both these papers are published simultaneously with my own and in the same part of this volume.