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THE BIOLOGY AND BEHAVIOR OF MINING BEES, *ANTHOPHORA ABRUPTA* AND *ENTECHNIA TAUREA.*

BY PHIL RAU

Kirkwood, Mo.

Introduction

This paper deals with the behavior and biology of two species of mining bees, *Anthophora abrupta* and *Entechnia taurea,* with brief notes on *Anthophora raui.* Large colonies of these three bees carried on their mining operations in a sheltered clay bank at Wicks, Mo. All three species were also important factors in the life of this microcosm (the clay bank community), and their relations, interrelations and reactions to environment have been studied and reported in a paper entitled "The Ecology of a Sheltered Clay Bank: a Study in Insect Sociology."[1] In making an ecological study of that kind, one often faces difficulty in deciding just which data to publish under the title ecology, and which rightfully belongs to biology or behavior. Hence I tried to sift out for that paper the data on ecology, and all the remaining material, which more properly belongs to biology and behavior, is published herewith. Since the reader may not always agree with me in my arbitrary classification of data, and since I have tried not to repeat in this paper the data already published under the title "Ecology," I can only recommend that he read the Academy of Science article in connection with the present one.

[1] Trans. Acad. Sci. St. Louis, 25:159-276. 1926.

The clay bank (fig. 2) at which these bees (figs. 5, 6 and 7) were nesting, faced the east, where it received the morning sun, and was protected from the weather by the porch above it.

THE TURRET-BUILDING BEE, *Anthophora abrupta.*

Anthophora abrupta makes no secret of its presence. They are neither timid nor aggressive, but they certainly are self-reliant. Their presence is easily and quickly detected by two prominent indicators, the bees themselves, and the conspicuous nests which they build. A glance at the picture (fig. 5) will convey to the reader some idea of how conspicuous they are as they noisily swing their ponderous bodies to and fro on the wing, arrive home and scramble into their burrows or come tumbling out headlong and dash off into the sunny fields, with all the exuberance of boys just out of school. They have none of the shy, stealthy ways of maneuvering, whereby some of the smaller and daintier varieties of bees and wasps hold their own in a competitive world. They go boldly and fearlessly about their work, and soon construct nests which are likewise prominent. While many species of solitary wasps and bees try in some way to conceal the location of their burrows, these construct large mud chimneys over their nests, made from the clay dug out of the burrows (fig. 1). Since they work in colonies, or more correctly remain to build on the site where they were born, the result is a very conspicuous village, sometimes a very crowded and busy town of these masonry turrets as shown in profile in fig. 8. At a busy season when many of these huge bees are bustling about with very audible hum and zip, the entire village with its many wonderful towers and industrious citizens form a spectacle which is in itself quite capable of overawing any but the most unemotional individual.

In 1917 the *Anthophora abrupta* first appeared on June 25th. In 1918, the spring was warmer and they were out and at work much earlier, and the size of the chimneys indicated that they must already have been at work some days before I discovered them on May 28th.

FIG. 1

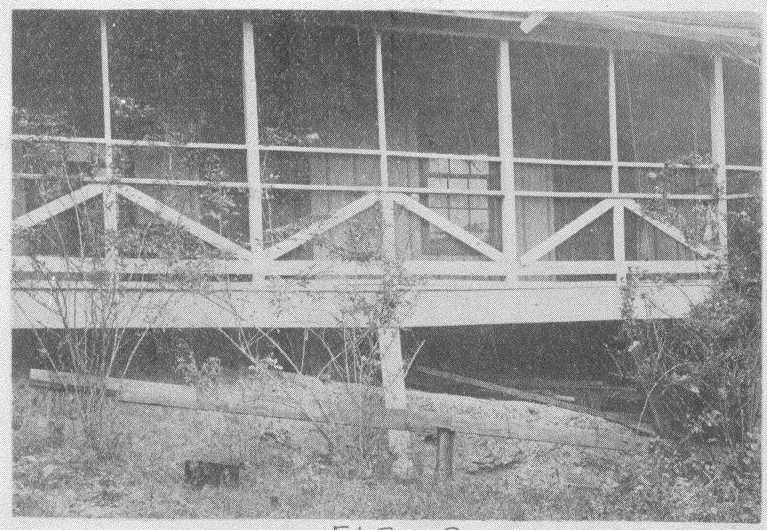


FIG. 2

Fig. 1. The work of *Anthophora abrupta*. Turrets built over their nests.
Fig. 2. The clay bank under the porch where the three species of mining bees nested.

In the spring of 1921 the males were found flying on May 27th, when they were frequently seen on the flower-buds of the rambler roses. Often they seemed to be trying to bite their way into the buds. At evening they were often seen to climb to the top of a grass-blade, grasp the tip firmly in their jaws and go to sleep. Fig. 3 shows a male sipping sugar water from a piece of cotton.

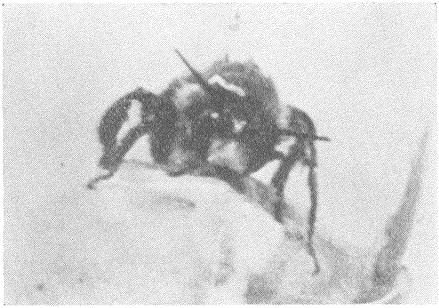


Fig. 3. The male of *Anthophora abrupta.*

I have never seen mating occur at the bank, and I have often wondered if they do not go elsewhere for the purpose of meeting the females. At a point about one hundred yards distant, on a hill side facing the eastern sun, I repeatedly saw a number of males hovering and flitting over a barren spot about three feet square covered with old rusty slag. At first I suspected that this was the place of their courtship-dances, but I failed ever to discover a female there. Instead the males were often found devoting their attention to the rust-covered ashes, to which they clung with their jaws. That reminded me how the females of their species at Manchester, Mo., during the previous summer had shown astonishing persistence in eating the rust from an old iron barrel-hoop and rusty fence-wire. Perhaps these males merely went to this bed of cinders to get their supply of mineral salts while the females were emerging and prospecting for burrows. This habit of licking rusty objects was not merely a casual occurrence but a purposeful and persistent activity; it elsewhere attracted the notice of my companion, who

suggested that carnivouous insects can derive their mineral salts from the blood and juices of their food, but these mining-bees are nectar feeders; hence it is possible that they may need to obtain their necessary mineral salts by some such direct methods as this.

On the next day the persimmon blossoms were beginning to open and already the bees had turned their attention thither; within three or four days more they were intensely active at this new task. In this short time, less than a week, the males had disappeared. Thus in a short while, and in keeping with the rapidity with which this species lives and does things, the males had come and gone, and the females remained buzzing at their new work. They hummed and danced in the sunlight in front of the bank; this activity, however, was not a courtship dance such as occurs in other insect species, but merely the industrious search in flight before the face of the bank as each bee tried to distinguish her own burrow. It was not a simple task at so early a time in the season, and it gave rise to more commotion than later when the bees had had more experience. If one singled out an individual in the crowd and continuously followed it with the eye, one would see that it finally plunged into an opening, sometimes to remain and sometimes to come precipitously tumbling out again and try another. It is little wonder that the returning bees must spend some time in distinguishing their own nest among hundreds or even thousands of burrows, but my observations have substantiated my expectation that later in the season, when the turrets were nearly all built, they would consume less and less time in this orienting dance as they learned more readily to distinguish their own nests among the hundreds in the group. I have stated elsewhere that when these bees came home late in the evening, their hovering in front of the nests was much prolonged, owing to their difficulty in finding their way in the fading light. A number of the larger turrets and their occupants were marked; these were watched in comparison with the rest of the population. It was soon apparent that those with large turrets found their homes with much less hesitation than the turretless ones.

Hence I sometimes wonder, since I have never yet learned

the utility of these chimneys, whether they might not be built to serve as landmarks for the returning bees. The variation in the size, shape and position of these turrets was much more apparent than that of the mere apertures in the bank. The turrets ran in various directions; some were horizontal, some tilted a little downward, others were at various angles toward north and south. There seemed to be no plan or scheme of direction, except that none were seen with an upward tilt, but the points of the compass were utterly disregarded, (see figs. 1, 4, and 8) and so far I have been unable to discover any factor, light, convenience, efficiency, or anything else, that could determine the direction in which these chimneys curved as they grew. Their diameter, (fig. 11) about ½ inch outside measurement, was fairly uniform for the entire colony, but their length varied from nothing to three inches, the greatest number of finished ones measuring about two and one-half inches in length. None of the tubes were found to be closed either at the base or at the orifice of the chimney; the entire channel leading down to the cells was in every case hollow, with an open groove for its full length along the top. The bees did not tear down the chimney and utilize the material for tunnel-filling as do the *Odynerus geminus* wasps,[1] nor did they even seal the tunnel with a thin wall at the surface of the ground. The tunnels were tortuous and hard to follow, owing to the closeness of the nests and the extreme hardness of the clay. One tunnel was opened which slanted downward, then upward, forming a letter "V" with a total length of five inches. Another, which had a two-inch tube, penetrated the bank to a depth of six and a quarter inches, following a zig-zag course, and terminated in the usual pocket. This mother evidently had lost her nest or had become lost herself before the nest had been completed or used. This was not the only case of this failing; in a number of cells we found this same condition.

But these *abrupta* went further than merely to dig a burrow in the ground and provision it, as do so many species of their kind. Deep down within the tunnels in the

[1] Wasp Studies Afield, p. 299-312, 1918.

solid clay they built distinct cup-shaped or thimble-shaped cells in which they placed the store of prepared pollen and the egg, and then individually sealed them, in this way obviating the necessity of sealing the outside or main tunnel to exclude intruders. This method gave excellent protection against injury by violence and the weather, for the cells containing the eggs or larvae were heavier than the little pots which the potter-wasps attach to twigs, and they equalled in thickness and warmth the mud walls of *Trypoxylon politum* and they had in addition the protection of the deep burrow. These cells were oval, ¾ inch in length, placed close together and were varnished on the inside with some special waxy substance. Fig. 12 shows a lump of mud with these brood pots.

The bees continued to extend the tunnels by excavation and enlarge the chimneys by addition. They brought water from a mud-puddle in the road fifteen feet distant, carrying the load in the gullet. With a portion of the water they would wet the hard, yellow clay, remove a mouthful of it, back out and apply it to the last ring in the chimney. The bees would carry the mud under the thorax with the front pair of legs, while the two hind pairs furnished locomotion; as the bee backed out of the nest to the opening, the ball of mud was passed to the hind legs, and she now held her footing with the front legs while with hind legs she slapped the mud onto the last layer and with many active thumps with the tip of the abdomen, punched and beat it into shape. "Punched" is really the right word correctly to describe the gesture. *Entechnia taurea* does similar work with much finer precision; in that species the bee divides the ball of earth into two portions, applies the first part to the center of the tube at the bottom, and carefully smooths and works it on the left side almost to the top; then she applies the second portion in the same way at the base and works it up on the right side. The result of this method is that, either through the builder having insufficient material, or from some other cause, there remains a split or open groove down the full length on the upper median side of the tunnel, where the two halves of the load of mud fail by only a narrow margin to meet.

The bee here considered, *Anthophora abrupta* also left an opening along the top of most of the chimneys, (figs. 4 and 11)[1] but here it was not due to the method of building followed by *E. taurea,* for *A. abrupta* applied her load of mud wherever she happened to strike the edge, on the bottom or sides, and the job of spreading it was quickly done. In

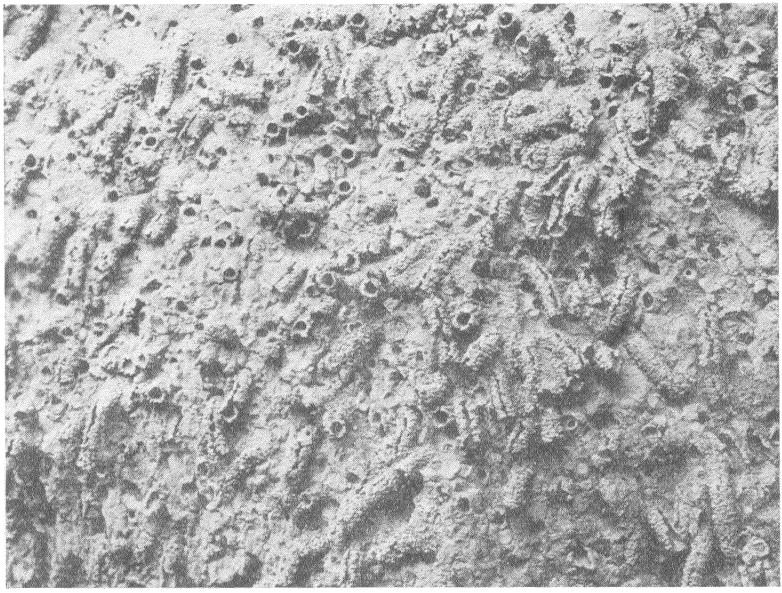


Fig. 4. A close-up view of the turrets over the nests of *Anthophora abrupta.*

this species the chimney was somewhat greater in diameter, and it was rougher on the outside, but the interior surface was very smooth and neat. Sometimes in her hurry to apply the mud, the bee dropped it; at other times she might be seen brushing out loose, moist materials by kicking them backwards, probably the crumbs or scraps that had dropped

[1] Fig. 4 and 1 show these openings very distinctly, while Fig. 11 does not show so many, because in the latter figure they were inverted when the photograph was made. In most of the turrets in Fig. 11 we see the bottom side.

from the walls in the process of biting out the hard clay, or the scraps that dropped while she fashioned her thimble-like cups.

Unlike the homes of some species, this gallery was roomy enough that the owner could turn around in it, for while she always backed out when she emerged with her load of mud, she did just the opposite when she came out for water, for then she always came out head first and dashed away. One singular feature occurred in the great majority of individuals observed; when they had used up the water, and had applied the last load of mud to the turret, they did not realize their need and fly directly out and away for more water, but re-entered the hole as usual, sometimes stayed in a few minutes and then came out head-first and flew away to the watering place. This might be due to the fact that the bee did not know that the water was gone and must have as a stimulus the experience of biting out the dry soil to arouse her inclination to go for more water. On the other hand, it might be that she entered the hole only to turn around so as to leave head-first, instead of tumbling out backwards as when she had applied her mud. The bees, when they had arrived at the water, did not alight upon the surface as do certain wasps, by spreading their legs, but landed on the soft mud on the margin, and with the long tongue protruding lapped it up. They were not bound by instinct even to go to the same place regularly for water, for one year after a rain many were seen availing themselves promptly of the temporary convenience and gathering the drops from the vegetation very near to their doors, instead of going to their customary place.

The round trip for water consumed from one-fourth to one-half minute, and the number of pellets of mud that could be carried out with each mouthful of water was interestingly varied. One bee which was watched for one hour, from 2:03 to 3:05 p.m. made twelve trips for water, and removed forty-seven balls of mud. When one considers that the mud was not only excavated, but was built into the chimney, one feels that this is a good hour's work for so small a creature. One gulletfull of water would remove 2 to 5 balls of earth, the greatest frequency being 4; this num-

ber occurred six times, five loads occurred three times, three loads twice, while in only one instance did she carry only two loads for one mouthful of water.

Another bee working from 2:03½ to 3:01 p.m. made twelve trips, and carried out 2, 1, 2, 2, 3, 5, 2, 5, 5, 2, 1, 2 loads, or thirty-two balls of earth in 57½ minutes; she was not quite as industrious as the first one. A third one also made twelve trips in the same hour, and carried out 1, 7, 2, 2, 0, 4, 3, 2, 2, 6, 2, and 2, totaling 33 loads. This is sufficient to show that there is no regularity in the number of balls removed.

I was unable to ascertain whether the entire amount of water was ejected at one time and the dirt thereby softened, or whether, as in the wasp *Odynerus geminus,* only a little water at a time was disgorged upon the spot, the mud bitten out, and then another spot moistened.

By the middle of July, I found the *Anthophora abrupta* had entirely disappeared, and some of the chimneys were dropping to the ground beneath. When these bees had completed their work, neither the chimney nor the tunnel was plugged up, and, since the former often dropped through disintegration soon after the work was completed, it seemed that they could serve no utilitarian purpose excepting during nidification. Some of the turrets were built so well that they withstood the winter, remaining intact for a year or more.

Chalcid parasites of the genus *Monodontomerus* were abundant about the bank, loitering about the holes, waiting for the provisioning to take place. They were indolent, and did not even evade when one attempted to take them in the fingers. Many of the empty pupal cases of *Anthophora abrupta* harbored several of these live chalcids. In one cocoon I found twenty living pupae of this parasite on June 28th, and since the adults were plentiful there a month earlier, the finding of the pupae at that date indicated a second generation. On June 24, 1920, several cells of this mining-bee were brought indoors. They were not examined until September 2, when several chalcid parasites emerged. To be exact, there were 109 females and 39 males from four cells, or an average of 35 to each cell. Of the other

nine cells collected, three had dead larvae, five contained dried-up balls of food, and one harbored a parasitic cuckoo-bee.

The "open door policy" of this species sometimes brought its trouble too. Not infrequently an animated fight was to be seen between two females, one evidently trying to usurp the burrow that had been made by another, and often dead bees were found at the foot of the bank. Occasionally a dead one was found in the burrow, and in all probability a second mother, in appropriating the nest, cleared the dead body out with the other rubbish. Frequently, however, the fights appeared quite alarming without proving fatal. One pollen-laden mother was seen backing out of her hole with the front leg of an intruder in her mandibles. The visitor showed no fight, but resisted with all her might; at the foot of the hole, every little gain that the rightful owner made was offset by the intruder pulling her back. At last the intruder lost her hold, and as they went tumbling to the ground they engaged in a pugnacious embrace. Needless to say that the rightful owner lost most of her load of pollen, which deluged the face and head of her antagonist. Another pair was locked in deadly embrace for over twenty minutes, and there seemed no probability of their separating soon. They were so intent that they were unaware of the fact that they were being pushed into a test-tube. After five minutes more of violent struggling in this novel place, they lost their grip for a moment and separated, and when they were liberated, they both flew into the air, little disconcerted by the ordeal.

A. abrupta made nests either with or without turrets, and the turret-making activities were directly correlated with water conditions. They required water in abundance, and when it was plentiful, so too were the turrets; in droughty years they struggled on with few and small or no turrets, and their nesting activities were much reduced. If they had to struggle on with a small drop of water, they consumed much more time in mining than when they could be generous with the water and thoroughly and quickly wet the hard clay. It was pathetic to see the mother back out of her hole with a load of slightly moist soil instead of a load of wet mud;

when she attempted to work it into the turret it would crumble and fall to the ground. The size of the population, it seemed to me, was just as much regulated by the amount of water available as by the number of parasites, for in 1922, when hundreds of bees were at work and the fewest turrets were made, the official statement from the local weather bureau at St. Louis showed that the precipitation for the five months, May to September inclusive, was the least recorded in 85 years.

In another colony, in a different locality, the nests were also built without turrets, but in that case the deficiency was due to lack of clay instead of water. Here the mothers were nesting in the disentegrating mortar of an old stone chimney. Despite the fact that so little turret material was available, and no normal chimneys were made, a good many of the tunnels had a very small ring or collar at the opening.

This bee was almost contemporaneous with *A. raui* (fig. 6) ; however, interbreeding of the two species was not possible. Careful observations in 1922, showed that *A. abrupta* emerged from May 30th to June 2nd, and by June 3rd all the males were dead. *A. raui* did not appear until June 10th, a week after the males of *A. abrupta* were gone. This made it impossible for the males of *A. abrupta* to fertilize the females of *A. raui* and since the females of *A. abrupta* had already been fertilized when the *A. raui* emerged, a second fertilization was improbable. In 1929, the *A. abrupta* population waned on about July 2, and the *A. raui* about July 12.

Since *A. raui* Rohwer is a new species, reported so far only from this particular clay bank, it would be fascinating, if justifiable, to surmise that this habitat is the cradle of the species, an offshoot from *A. abrupta.*

We may cite for comparison some observations on other species of this genus in various localities by different investigators.

Sharp[1] says *Anthophora* is one of the most extensive and widely distributed of the genera of bees. He also points out that Friese has made the discovery that *A. personata*[2] at

[1] Insects. Pt. II, p. 33, 1899.

[2] *A. personata* is now called *A. fulvitarsis* Brulle. (fide T. D. A. Cockerell).

Strasburg takes two years to accomplish the life cycle of one generation. "Some of the species make burrows in cliffs and form large colonies which are continued for many years in the same locality."

Say, in referring to the habits of European *A. parietina,* says that this species digs a hole in a clay bank and that the entrance consists of a cylinder extending downward more than an inch in length and made of small pellets of earth compacted together, rough on the exterior and smooth within.

Hungerford and Williams[1] made note of the nesting habits of *A. occidentalis,* which they call the "larger tube-building cliff bee." The method of nest-building is very similar to that described for *A. abrupta,* for they say: "Their tunnels are 3/8 inch in diameter and extend into the bank about eight inches where they end in several cells. The cells . . are so made that when dug out they come from the gallery as separated urn-shaped nodules of uniform size. The entrance of the tunnel is protected by a curved tube from 3/4 to 2 inches in length. The tubes bend downwards and very often the top or outer curve is split longitudinally." In view of the fact that *Hornia minutifennis* Riley was found to be parasitic on the members of the Wickes colony, it is interesting to learn that these students discovered a new species of beetle, *Hornia gigantea,* parasitic upon *A. occidentalis.*

Frison has discovered a colony of *A. abrupta* near Oakwood, Illinois, and in an interesting paper[2] gives many details of the life history of this species. He finds them nesting in a clay bank, carrying water for mining operations, and on the whole conducting themselves in every way like the bees at our clay bank. His paper includes a valuable review of the American species of *Anthophora.*

Walsh found this species making burrows in the mortar in brick work, and also in the face of a precipitous clay bank. In California, *A. stanfordiana* shows a similar preference for nesting in a steeply inclined surface. They build chimneys over the entrances of their burrows.

[1] Ent. News. 23:258 1912.
[2] Trans. Amer. Ent. Soc. 48: 137-156. 1922.

Latter[1] mentions that *A. pallipes* is abundant in England, and "make their nests in firm banks of sand or clay, if not too wet; their burrows do not extend very deep and contain one or more cells whose outer wall is made very hard, by a cement of sand or clay applied by the female bee after she has completed the commissariat arrangements." We assume that *A. pallipes* does not build turrets at the opening of their nests, for if they do so, it is quite unlikely that so keen an observer would have failed to mention the fact. The same gregarious condition that has been recorded for other species of Anthophora exists in this species, for the author goes on to say that numbers of Anthophora live in the same bank, and on a warm April morning the scene at such a spot is most lively; females are to be seen entering or leaving the burrows intent on business or possibly engaged in a headlong flirtation with males in front of the bank.

Bouvier[2] calls attention to a most interesting point in the behavior of *Anthophora* wherein a species with solitary habits assumes under certain circumstances an attitude ordinarily displayed by social bees, or we might say a step in the evolution from a solitary to a social state. He says that when it is necessary to struggle for the common defense, the European *Anthophora* of the walls becomes singularly aggressive. "Established in sandy, argillaceous soil which it perforates with tubular galleries, this bee comes out in war-like swarms every time one approaches the colonies. Buttel-Reepen relates the misadventure of an entomologist who was pursued a long time by one of these swarms after a badly executed swing of his net; and Friese reports that he himself was attacked for having tried to collect on the walls of a barn where thousands of Anthophora had their nests."

These European Anthophora have, according to this, progressed in their behavior further toward socialization than the American *A. abrupta* and *A. raui.* Here at various times I sat among their nests for days at a time, and these bees did not at any time show a concerted attack, as described

[1] Bees and Wasps, p. 74. 1913.

[2] Psychic Life of Insects, p. 317. 1922.

above. One may even swing the net or otherwise disturb them or even handle them with impunity. They possess stings, but they seem not to know how to use them when taken in the fingers.[1] Thus we see that our American *Anthophora,* while gregarious, are very primitive in the scale of socialization.

THE WHITE-BANDED BEE, *Entechnia taurea* SAY (J. C. Crawford)[2]

While the mining-bee *Anthophora abrupta,* would build only horizontally in the face of the clay bank in the bright sunlight, the species now considered, her nearest neighbor, whose nesting-habits were in general very similar, built vertical burrows in the top of the bank. Sunlight was not a factor in their choice of a site, for most of their burrows were far back in the shadow of the porch where the amount of light was much reduced.

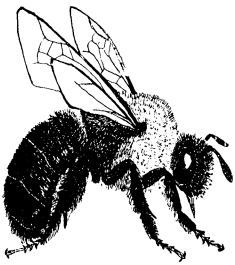


Fig. 5. *Anthophora abrupta.*

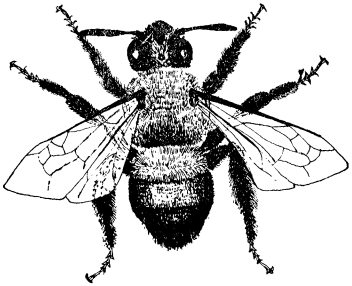


Fig. 6. *Anthophora raui.*

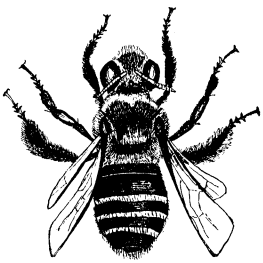


Fig. 7. *Entechnia taurea.*

These white-banded mining bees, *Entechnia taurea* (fig. 7) worked energetically through a much longer season than the *Anthophora* bees. They were out and buzzing about the holes in the clay bank as early as July 12th, 1917, and a few were still to be seen on October 3rd, although many dead

[1] Many of these bees were taken in the fingers and marked before being taken on homing flights (Journal Comp. Psychology, pp. 35-70. 1929) but they never retaliated with a sting.

[2] This identification was verified by Mr. S. A. Rohwer, who calls it *(Entechnia) Melitoma taurea.*

ones then lay about, which showed that their season was practically over, and the remaining few had not long to live.

The first of the bees were active on the clay bank (fig. 2) on July 12th; by the 16th, about twenty-five were present in a state of agitation but doing nothing definite; most of them were in a group at the extreme south end of the bank.

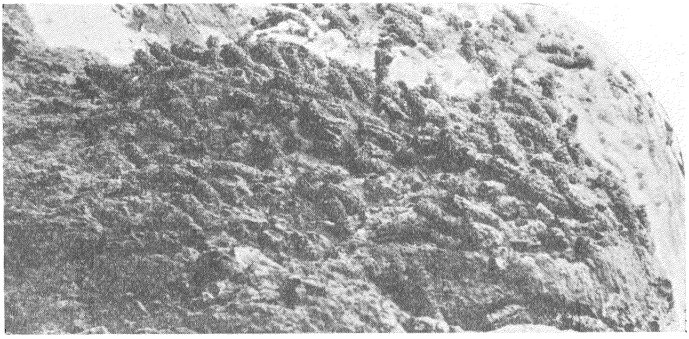


Fig. 8. A view in profile of the turrets made by *Anthophora abrupta*.

Occasionally some of them would get into the empty holes and quietly remain there, but the great majority spent their time buzzing and fussing about one another, often quarreling. One shallow burrow and its occupant attracted particular attention; the bee was within with its head to the wall and the tip of its abdomen near the orifice. This bee was the object of much conflict; often five or six bees would crowd about the opening and attempt to drag it out by main force; when one would attempt to get the inmate out, and had partially succeeded, then two or three would actually fight furiously in the doorway to get its place in the cell. They would grasp one another by the legs, and often a pair locked in combat would roll down the embankment and struggle in battle on the ground, holding a tight grip of one another's legs with their mandibles. Sometimes the one in possession

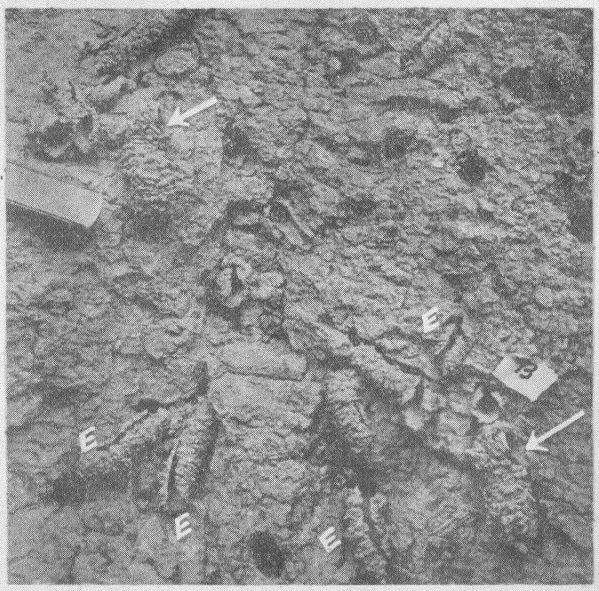


FIG. 9

FIG. 10

Fig. 9. The turrets of the white-banded bee, *Entechnia taurea* indicated by letter "E." The two arrows point to the upturned turrets of *Anthophora raui.*

Fig. 10. The upturned turrets of *Anthophora raui.* A wad of cotton is placed in the opening of some of the turrets to show their upturned position.

of the burrow would come out and fight with the intruder.[1] On one occasion the occupant grabbed the leg of the intruder in its mandibles and held on so tenaciously that the bee in attempting to pull the leg away, dragged the occupant a great distance from the hole, thus giving opportunity to a bee nearby to enter and take possession of the coveted place. Often throughout the conflict the legs were gripped so fiercely in the mandibles that I thought surely they would be snipped off, but this never happened.

After capturing many of the bees, I ascertained, by the absence of pollen baskets, that they were males, and I promptly wondered if they did not crowd around certain burrows that were about to give forth members of the opposite sex. There was one hole in particular about which they crowded thus in clamorous competition, so I decided to open the burrow with my knife. The contestants, however, were not to be pushed aside; they persisted there, even though the blade nearly severed them, and excitedly buzzed about the tool; it seemed they could scent the female within, and could not be driven from the spot. Again and again I tried to penetrate the mass to remove the few little clods of dirt which hid the secret prize, but it could not be done without dismembering the bees. Another cocoon was unearthed elsewhere in the bank, however, and with a knife it was carefully opened; within was a bee, fully developed but all wet and soggy and with wings uninflated. It was in my forceps but a few seconds before a half a dozen males were clinging to it, displaying every evidence of a great eagerness to mate. The excitement continued for some minutes, when one male and this immature one succeeded in making their escape.

Since at the beginning of the season only one female was seen at work burrowing, and some twenty-five males were about, it appears that in this species, as in many other cases of the insect world, the males enjoy a priority of emergence, and await the coming of the females.

[1] I do not know whether or not they used their stings on one another; when females were taken in the fingers, they did not hesitate to use the sting freely. The pain, however, was not severe, lasting only a few minutes. In this they differed from *Anthophora abrupta*.

Following these first busy days, the population of *Entechnia taurea* seemed to disperse, for on several occasions during the remainder of July, only a few at a time were seen about the place. They, of course, were females, busily coming and going about the burrows they were rapidly digging and the clay chimneys which they were building

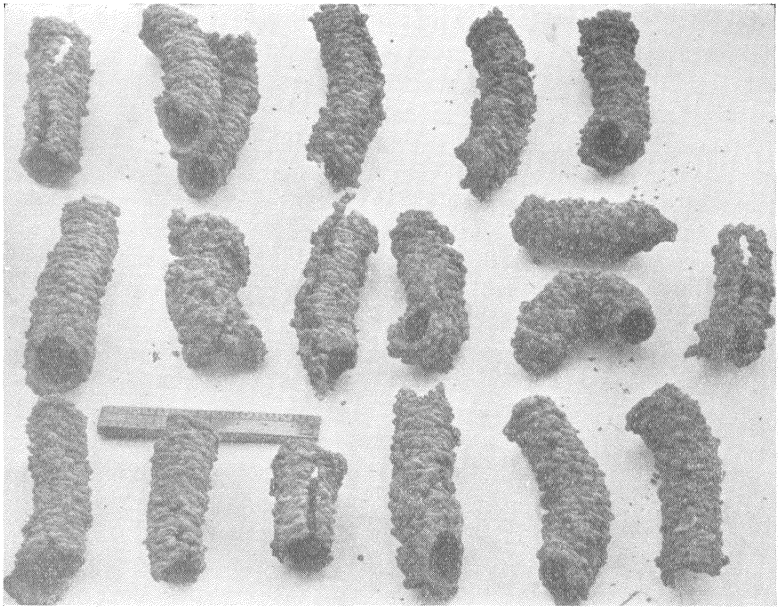


Fig. 11. A collection of turrets of *Anthophora abrupta* to show details of construction.

over them. A few males were there too. The bees were divided into two groups, one at either end of the bank, while the center which bore an abundance of old burrows of *Anthophora,* had no bees. Enormous numbers of parasites lurked about this portion, which would indicate that only those at the extreme ends had escaped their ravages. At the north end, some half dozen males were playfully buzzing about, keeping strictly to the confines of their own

neighborhood. Moreover there were then in this immediate area no females, nor were any nests in construction. This was conspicuously different from the south end, where activities were occurring, in small numbers to be sure, but further advanced, since there the males had departed and the females were nesting. This playfulness of the males at the north end seemed to be merely a repetition of the male frolics at the south end some ten days before.

A visit to the bank on August 14th showed that the females and their burrows were becoming more numerous. At the south end, the males were again in abundance, buzzing, flying, dancing about and repeating the performance of leg-pulling and leg-biting. The females were still burrowing in the top surface of the bank; none had as yet gone into its vertical face. Few of the females would work after the sun had left the bank at about noon, and the males too were most active in the sunlight.

The method of digging and building was in most of its details similar to that of *Anthophora abrupta,* previously described. The *Entechnia taurea* female carried water with which to moisten the clay before she bit off a mouthful. One mother was observed to begin her burrow at 11 a.m. She stood on her head in a vertical position, with the abdomen waving in the air, and worked the soil, often leaving the work to go for water. At 2:30 p.m. the hole went down to a considerable depth, and over its top was a little turret about three-fourths inch in length. There was much loose, wet soil about and under this turret, showing that not all of the mud carried out had gone into the tube. The bee was at work within, and every few seconds she appeared walking backwards and pushing up a pile of moist, fine-cut soil. Many turrets had beneath them a similar accumulation of clay which had been dumped out of the burrow, (fig. 9E) so that one may say that only the portions first removed go into making the chimney, and the remainder of the clay that comes out of the burrow is loosely pushed out.

One mother had been busily occupied at nest building for three hours, when suddenly a male appeared upon the scene, hovering over her. Quick as a flash she quit her work, and her precipitous haste in attempting to clean her-

self and primp (this female rubbed the powdery dust off) was really uproarously funny; but little details of appearance seemed to make no difference to him, and he urged his attentions without delay. Immediately after their separation a half minute later, she went into the hole and the male followed. Soon both came out; then they went in again as though prospecting, she leading and he following her all the time. After a few minutes, both came out, danced and fluttered about each other before her doorway for two minutes, then she went back to her work and he continued the dance for many minutes before the burrow, during all the time going no more than two feet away.

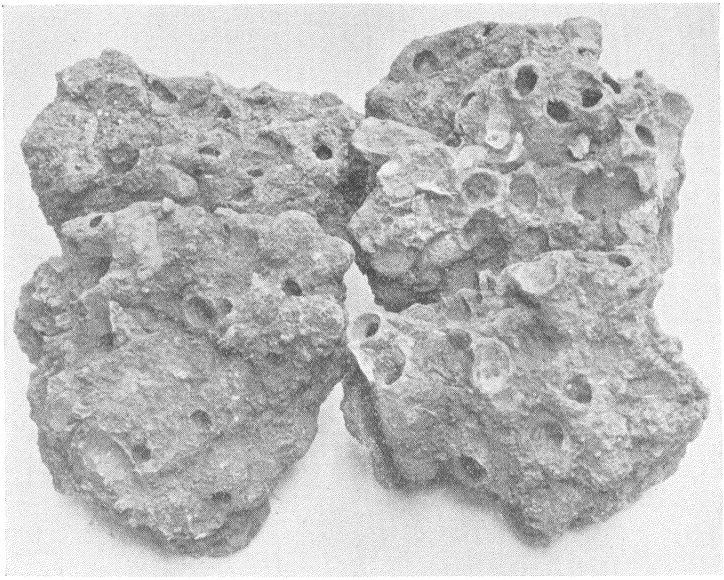
At the rear of the house on its west side was another clay embankment, of similar soil, but not protected by a porch, and neither did it receive the morning sun. No bees were burrowing there, but the area bore many plants of bindweed, with the large white morning-glory-like flowers. Here the females sought pollen, and on one autumn day, when only six blossoms were open, each flower was occupied by an idle male, while dozens of others were trying to find places. They would most persistently sit within the cup for hours at a time, and would bob up and fight away any bee that attempted to enter. All that I examined were males. The only explanation that I can think of to justify such conduct is that they were lying in wait here for the females. Yet I cannot have full confidence in even this supposition, for on a few occasions I saw these dogs-in-the-manger fight away even the females who came in earnest quest of pollen. The same leg-pulling behavior that was seen on the clay bank was practiced within the blossoms whenever a second male attempted to usurp the place of the first. When the males entered the flowers they did so head first and then turned themselves around and faced the outside, so they could watch what was going on out in the world. It will be noted that while the length of life of adult males of the two species of Anthophora bees is only a few days, in *E. taurea* the males live all summer.

When the females came in from the fields pollen-laden, it appeared at first that they carried the pollen under the abdomen, with great masses bulging out at the sides and

back. In reality, however, the pollen-baskets were overflowing, and masses of pollen adhered to the underside of the body, while the legs were held close to the body, probably holding the abdominal masses in place, with the result that the little bee had the appearance of being very fully laden indeed.

Up to August 20th, most of the white-banded bees were still making their burrows and chimneys on the surface plane, and only about ten per cent of them were beginning to dig into the vertical face of the bank. In the case of this species, probably as soon as one nest was completed another was begun.

Most of the turrets made by this species (figs. 9E and 13) had a longitudinal split extending almost the full length of the upper side along its center. The purpose of this, as well as the purpose of the whole chimney, has often puzzled me. I have wondered whether the cause of this was mechanical or psychological, but after having observed the method of making the chimney, I have concluded that the opening along the middle of the chimney may be accounted for as mechanical. The bee backs out with a large ball of mud under her throat; with the forelegs she divides this load in half and passes one portion backward under the body until it reaches the tip of the abdomen. This is applied to the edge of the turret, commencing at the bottom and working toward the top. This amount of wet clay is usually about enough to make half a ring. Then likewise the second half is passed beneath the body to the rear legs, the bee begins at the bottom again, joins this wet mass to the end of the first half of the ring and works upward in the opposite direction, perhaps with the intention of completing the ring, but rarely doing so. Since the second portion does not quite reach the first, there is a discrepancy, and the result is that layer after layer of this leaves an open groove on the top of the turret. It is possible that this is done purposely, and that the insect could just as easily carry out a little more mud or stretch what she has so as to complete the circle if she wished to do so. It may be that it is of advantage to build the nest so that it will admit the light, and this peculiarity of construction has become a habit. It is very pretty



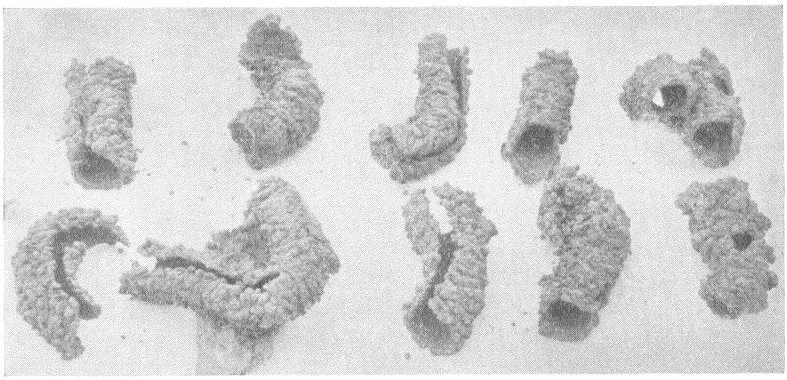


Fig. 12. (Above) A clump of earth containing cells of *Anthophora abrupta* (¾ natural size).

Fig. 13. (Below) The turrets of the white-banded bee *Entechnia taurea* (slightly enlarged).

to see the bee's abdomen extending just beyond the last ring of the turret, and then applying the two portions of mud deftly to the last layer. She cannot see what she is doing, since during this work her head is always inside the chimney.

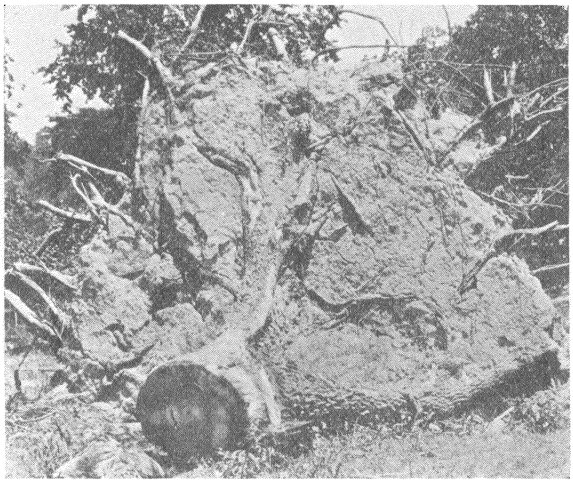


Fig. 14. An uprooted tree, both sides of which contained nests of *Entechnia taurea.*

Since I wished not to demolish the bank, I opened only a few burrows. The first consisted of a gallery one inch in length, terminating in a pocket in which were two neat, thimble-shaped cells.[1] One of these was sealed; when opened, it was found to be crammed full of white pollen (or perhaps bee-bread, since part of it was moist and might have been mixed with nectar or water), and on a dry portion of the mass and securely attached to it was the elongated egg. The lower cell contained the same. The lower part of the mass of bee-bread was very moist and soggy, while the

[1] These cells were not made by merely partitioning the tunnel, but each was a solid mud cup built inside the burrow and snugly fitted into it. When these nests were opened the surrounding earth could merely be picked off leaving a complete cup as illustrated in Fig. 15.

upper part was dry, powdery pollen. There were also many drops of moisture condensed on the walls of this cell. Whether the pollen had been put in dry, and the moisture that we found in the cell was due to nectar or water which the mother may have added, or whether the pollen was moist and the moisture which I found upon opening the cell was that which had come out of the pollen and condensed on the walls, is matter for conjecture.

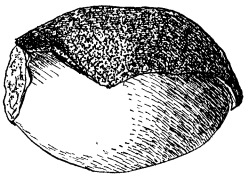


Fig. 15. The brood cup of *E. taurea,* with the mud wall cut away to show the intact papery lining.

Another nest was opened which had a three-and-one-half inch gallery leading down to the cell. This cell was half filled with pollen, and the bee itself was within, with her pollen baskets full to overflowing. The nest was obviously far from complete. These bees do not seal the mouth of the turret; neither do they seal the burrow at the surface of the ground, but leave it open its full length. The cells at the bottom are sealed securely enough to afford sufficient protection when they are hidden within the tunnels chiseled out of the hard clay. Sometimes one does find one of these turrets sealed, but this work is done by a *Trypoxylon* wasp which takes possession of the place for her own nest.

These white-banded bees varnished the interior of their brood-cups with some waterproof substance, as did the two species of *Anthophora;* but these supplied an added protection to the young bees, in the form of a thin, papery wall which completely lined the cells. While it is brittle, it is strong enough that one may pick away the mud from the outside and leave this lining intact, as shown in fig. 15. At first I thought that this lining had been placed there by the mother, but since those cells in which the eggs had failed to hatch did not have this lining, it seemed reasonable to

attribute it to the work of the larvae. An examination of this material under the microscope does not show a structure of spun silk; hence it is probably made of the contents of the alimentary tract, which are completely emptied at the time of pupation. It is a known fact that in certain aculeate Hymenoptera, the excrementary material of the larva is retained until pupation time when it is emptied and fashioned into a cocoon. Here in the white-banded bee is a similar condition, with the slight change of using the material for caulking purposes instead of cocooning.

That *Entechnia taurea* attains gregariousness is due just as much to the fact that the clay bank is protected as to their community instincts. In 1917 I noticed a sickly colony in a clay bluff about one-quarter mile south of the bank. These burrows went horizontally into the bank at a road, and had no protection from the weather. Only three turrets and their builders were seen. This colony did not become established, and in 1918 no progeny were there. In 1918, two turrets were found at the side of a foot-path on a hilltop in the shade of an old oak. In the same season, the dirt about the base of an uprooted tree at a point about fifteen miles distant from the bank had twelve turrets of this species. The knotty roots served as protection from the weather, so the colony there was able to grow. The fact that the bees of the Wickes clay bank became colonized under the protection of the porch is no mere accident, but the following notes made at various distant localities, show that the habit of seeking protected places is general for this species, or, to put the explanation in other words, those bees which nest in sheltered areas grow into colonies and those which do not, either they or their progeny fall victim to the elements, landslides, etc.

At Keys Summit, Mo., a clay embankment by the roadside and facing the western sun, had forty or fifty of these turret-topped nests, penetrating the slope horizontally, scattered along the slope for about a hundred and fifty yards. This bank was about ten feet high, and some vegetation and a few trees were growing there whose roots held the earth firm and made protecting niches in the bank. All of these nests were found in the protected spots, and none

in the exposed portions. One can readily see how landslides or rain would demolish the work of these little builders, and do damage to their tunnels as well. Three small colonies were seen, also, in roadside banks in situations similar to the above except that the soil was crumbly and exposed. Much of their work has been lost; they did not become established in these exposed sites. Others were seen at Wesco, one hundred twenty miles southwest of St. Louis. Some were in banks, others in level ground, and in three different places they had chosen for their home-site the soil in the roots of some trees which had been torn up by a tornado three years previously. Here again they enjoyed the protection of the roots, and throve. One of them (fig. 14) had twenty-five nests on one side of the base of the upturned tree, and thirty on the opposite side.

The colony of bees during the five years, had decreased in size. In 1922 about forty members were building and two-thirds of them were far back on top of the clay bank where the darkness was indeed conspicuous; the turrets were pointing in every direction. During this same period its neighbor *Anthophora abrupta* had reached great proportions. The causes for the rise of one species and the decline of the other, are fully discussed in the St. Louis Academy of Science paper already referred to.