FIGURE 1.—NEWLY CLEARED FIELD COVERED WITH MOUNDS OF ANTS NEAR RIO UTINGA, STATE OF BAHIA, BRAZIL

The largest of these mounds have bases of six or seven meters. Photograph by R. Crandall, 1907

FIGURE 2.—MOUNDS OF TERMITES IN AN OLD FIELD NEAR QUELUZ, STATE OF MINAS GERAES, BRAZIL

White spots in the background are the mounds. Photograph by Dr. Gonzaga de Campos, 1909

MOUNDS MADE BY ANTS AND TERMITES: BRAZIL

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GEOLOGIC WORK OF ANTS IN TROPICAL AMERICA¹

BY J. C. BRANNER

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¹ Manuscript received by the Secretary of the Society April 29, 1910.

INTRODUCTORY

In 1900 I published a short paper on the geologic work of ants in the tropics.² Since then a good many additional observations, notes, and photographs have been made, and the most important of them are here brought together in a single article.

There are many brief notes on the work of ants scattered through the writings of travelers in tropical countries, but these notes are for the most part repetitions of rather vague and sensational stories which make no claim to accuracy of statement, so that they would add little or nothing to the value of the article. No attempt has, therefore, been made to use such notes except in so far as they seem to afford new or important corroborative evidence. At the same time it is realized that some of the things that ants do in tropical countries are so remarkable that those who have no personal experience of them may be pardoned for regarding the stories told about them with a certain amount of suspicion. For this reason I have quoted directly, and sometimes at considerable length, from some of our most trustworthy scientific writers, especially from Bates, Belt, and Spruce, all of whom are naturalists to be taken seriously.

The best any one can do who has not seen the work of ants in tropical countries is to turn to what can be seen in temperate regions. But it should be insisted on that the work done by ants in temperate zones is, with a few exceptions, of no geologic importance at all as compared with that done by them in some parts of the tropics.

The work of the ants, in so far as it is of geologic importance, consists chiefly of their nests, habitations, refuse heaps, or mounds, above ground and their burrows, tunnels, passageways, and other excavations beneath the surface, and the opening up of the soil and the subjacent rocks to the various atmospheric influences.

In the United States we have very little evidence of ants making either underground passageways or mounds of sufficient size or extent to have attracted much attention. Indeed, it seems to be generally conceded by entomologists that the ants of the northern part of North America are not as enterprising as those farther south, or even as those of Europe. Forel seems to have found the structures of our North American ants so insignificant that he avoided speaking of them as having mounds at all. Certainly the little ant-hills we have seen in most parts of the United States are too insignificant to attract the attention of geologists. In the South and Southwest they are somewhat more conspicuous, and in the semi-arid portions of western Texas and in Arizona, New Mexico, and parts of California they have attracted not a little attention.

² *Journal of Geology*, vol. viii, pp. 151-153. Chicago, 1900.

The western halves of Oklahoma, Kansas, and Nebraska and the eastern portion of Colorado are inhabited by mound-building prairie ants that are sufficiently abundant and sufficiently pugnacious to have attracted the attention of farmers and entomologists, if not of geologists.³

In the Western States generally ants are more abundant than they are in the East, but a writer on the ant-hills of southwestern Wisconsin says that in that part of the country he knows of at least a hundred so-called ant-hills within a radius of 5 miles, and he appears to regard this number as quite striking. Their mounds, he says, are as much as 75 centimeters in diameter and 40 centimeters in height.⁴ These cases are mentioned simply for the purpose of contrasting the size and number of ant-hills in a region that seems to be regarded as pretty thickly inhabited with some of the typical localities in the tropical portions of South America.

Furthermore, in the tropical parts of America ants are not the simple and easily ignored insects with which we are acquainted in the temperate zones of the earth. Save in the cities, they are almost omnipresent. To the housekeeper they are not only never-sleeping pests, but they are bold and defiant robbers or sneak thieves, as circumstances require, and they can not be ignored. To the planters they are veritable plagues—they destroy the growing crops as completely as if they had been burned over. They do not wipe out a field of grain in a few hours as completely as do the locust swarms of Argentina, and then disappear, but they stay with their work right alongside of the crops, and with time they destroy them no less certainly. Unlike the locusts, they do not come and depart, but they stay right in one circumscribed area all their lives. *Farinha de mandioca*, the meal prepared from the cassava plant, or grain of a size small enough for them to carry, require to be guarded with constant care. I have known bagfuls of *farinha de mandioca* to be carried away by them. In short, the inhabitants have to be constantly on their guard against the ants, both indoors and out of doors, to say nothing of the mere inconvenience of their presence. Nor can their importance be regarded as whimsical in any sense; indeed, I am convinced that they are social, and even national, factors that are not to be ignored.

Nothing in the way of a biologic or systematic study of tropical ants is attempted in the present paper. However valuable such a study might be, it is the number of individuals, rather than the number of species, that concerns the geologist, though it is recognized, of course, that some

³ T. J. Headlee and George A. Dean: The mound-building prairie ant (*Pogonomyrma occidentalis* Cresson). Bull. 154, Kansas Agricultural Experimental Station. Manhattan, 1908.

⁴ Hermann Muckermann: *Psyche*, vol. ix, pp. 355-360. Boston, 1902.

species are much more active agents than others. We need concern ourselves with only two large orders: the true ants belonging to the *Hymenoptera*, and the termites, or so-called white ants, neuropteroid insects which belong to the *Isoptera*, and are known all over Brazil by the popular Indian name of "cupim." And nothing is attempted in the way of a study of the architecture of their nests and underground passages, save in so far as such details will give a better idea of the geologic bearing of these matters.

The monumental work of Dr. Auguste Forel, "Les Fourmis de la Suisse," published at Zurich in 1874, will naturally be consulted by any one especially interested in ants themselves and in their habits and structures.

It may be useful to suggest in this connection, however, that though the ants of Switzerland and of temperate regions generally exhibit the same ingenuity and intelligence as those of tropical countries, as geologic agents they are very tame indeed in comparison with those of the tropics.

In studying the work of ants in the tropics one is constantly reminded of Mr. Darwin's studies of the work of earthworms. Mr. Darwin was able to give the quantitative results of his studies. In the case of the ants, unfortunately, quantitative results have not been possible. The time occupied by them in doing a given amount of work varies so much that quantitative observations, in order to have any value, would have to be carried on upon many colonies and for a long period of time. The results given at page 469 are an attempt at quantitative determination, but it will be observed that it is not known how many individuals took part in the work, while the time element involved in the calculation is entirely lacking. It is hoped that observations may be undertaken by geologists living in tropical countries with a view to settling these interesting points.

To illustrate this article especial pains have been taken to get as many photographs and sketches as possible of the above-ground structures of ants and termites, and the accompanying illustrations have been carefully made by Mrs. Starks from photographs, most of them taken in Brazil by myself or by my former assistant, Mr. Roderic Crandall, now geologist of the Geological Survey of Brazil (Serviço Geológico do Brasil). It seemed better to have the drawings made rather than to use the original photographs, in spite of the evident suspicion of exaggeration or alteration, whether intentional or accidental, to which all drawings are open. This redrawing was the more necessary because the photographs were taken hastily and under many unfavorable circumstances, and they are therefore often not good, or they are not available for reproduction as photo-

graphs, besides being of various inconvenient sizes. The illustrations are given because it is felt that they are the most impressive and most trustworthy witnesses one can put in evidence regarding the subject.

THE TRUE ANTS

ABUNDANCE

Although ants are not everywhere equally abundant in tropical South America, their numbers are so large on an average as to promptly attract the attention of travelers, even when they do not excite their wonder. Residents, who might be expected to have conservative views on the subject, often speak of them as the owners of the land. Such a remark is at first regarded as merely facetious, but the character of some of the writers who make it entitles it to serious consideration. As long ago as 1648 Piso said that the Portuguese not inappropriately called the ant the "king of Brazil."⁵

One naturalist who spent some time in the country says, "Brazil is one great ants' nest."⁶

Belt says, "They are one of the greatest scourges of tropical America."⁷

A Brazilian traveler, speaking of the region of the upper Rio, Paraguay, says, "The ant and the different kinds of termites own the land."⁸

Another puts it in this fashion: ". . . ants . . . deserve to be considered the actual owners of the Amazon Valley far more than the red or the white man."⁹

Another writer says of them: "One seriously asks whether they are not the real conquerors of Brazil."¹⁰

These characterizations are all so sweeping that, taken alone, they are open to the suspicion of being merely picturesque and extravagant ebullitions rather than serious and truthful statements of fact. If they are based on some knowledge of the ants, these expressions seem to spring from more or less personal animosity toward those insects. And yet this very animosity, if it really exists, must come from a pretty uniform per-

⁵ *Formicæ autem hæ (Rey do Brasil Lusitanis non immerito dictæ, quod perpetuam tyrannidem exercent) aliquæ Europæarum plane similes, aliquæ triplo majores & alatæ, omnivoræ sunt.*

De Aeribus, Aquis, & Locis. Gvillelmi Pisonis Historiæ Naturalis & Medicæ, p. 9. Amsterdam, 1658.

⁶ Rev. H. Clark: *Letters home from Spain, etc.*, pp. 131, 173. London, 1867.

⁷ Thomas Belt: *The naturalist in Nicaragua*, p. 79. London, 1874.

⁸ Dr. Joao Severiano da Fonseca. *Vlagem ao redor do Brazil*, vol. 1, p. 352. Rio de Janeiro, 1880.

⁹ Richard Spruce: *Notes of a botanist on the Amazon and Andes*, vol. II, p. 366. London, 1908.

¹⁰ Adolph d'Assier: *Revue des Deux Mondes*, vol. xlix, p. 582. Paris, 1864.

sonal experience of them. It therefore seems best to quote directly a few more detailed statements regarding the abundance and habits of ants in Brazil. Certainly no one will be taken more seriously than Dr. Auguste Forel, who says that "the ant fauna of South America is perhaps the richest in the world from the systematic point of view."¹¹ In the paper cited 440 species of true ants are noted as inhabiting Brazil, out of a total of 2,000 known in the world.

But though it is with the number of individuals rather than the number of species that we are concerned, it is worth remembering that in many considerable regions a single species may occupy about all the ground space that it is possible for ants to occupy. A single species may thus fairly swarm and do a vast deal more work than several different species.

The true ants, evidently of a large number of species, are so abundant and are such serious pests in some places that the land is practically preempted by them. Travelers passing the night in the open have to be constantly on their guard against colonies of ants. Fighting such colonies under the circumstances is simply out of the question. When one finds himself in disagreeable proximity to them, the only thing to be done is to move at once and leave the ants masters of the situation.

Bates, speaking of a certain species, says (page 354) :

"These Ecitons are seen in the pathways of the forest at all places on the banks of the Amazons, traveling in dense columns of countless thousands."

On the Rio Tapajos, in the Amazon Valley, Bates noted the

"quantity of drowned winged ants along the beach; they were all of one species, the terrible *formiga de fogo* (*Myrmica savissima*), the dead or half-dead bodies of which were heaped up in a line an inch or two in height and breadth, the line continuing without interruption for miles at the edge of the water. The countless thousands had been doubtless cast into the river while flying during a sudden squall the night before, and afterwards cast ashore by the waves."¹² . . . "I was told that this wholesale destruction of ant-life takes place annually, and that the same compact heap of dead bodies which I saw only in part extends along the banks of the river for 12 or 15 miles" (op. cit., p. 206).

I have seen similar accumulations of dead female ants on the lower São Francisco and the Rio Paraguay, near Corumba, and at two places on the shores of estuaries near Aracaju, in the State of Sergipe.

Bates says the *formiga de fogo*, or fire ant, was so abundant at one

¹¹ A. Forel: A fauna das formigas do Brazil. Bol. do Museu Paraense, vol. 1, p. 89. Pará, 1895.

¹² H. W. Bates: The naturalist on the River Amazons, 4th ed., p. 201. London, 1875.

place on the Tapajos that there was scarcely a square inch of ground free from them. (Op. cit., p. 202.)

The only figures I am able to give in regard to the sizes of ant colonies are the estimates given by Azevedo Sampaio, a Brazilian entomologist who has studied the *saúbas*. He estimates the colonies at from 175,000 to 600,000 individuals.¹³

DESTRUCTIVENESS

In speaking in general terms of the destructiveness of ants in tropical America, Humboldt says:¹⁴

"Those who do not know the immense quantity of ants that infest every country within the torrid zone, can scarcely form an idea of the destruction and of the sinking of the ground occasioned by these insects. They abound to such a degree on the spot where Valencia is placed that their excavations resemble subterranean canals, which are filled with water in the time of the rains and becomes very dangerous to the builders. Here recourse has not been had to the extraordinary means employed at the beginning of the sixteenth century in the island of St. Domingo, when troops of ants ravaged the fine plains of La Vega and the rich possessions of the order of St. Francis. The monks, after having in vain burnt the larvæ of the ants, and had recourse to fumigations, advised the inhabitants to choose by lot a saint, who would serve as an *abogado contra las hormigas*. The honour of the choice fell on St. Saturnin, and the ants disappeared as soon as the first festival of this saint was celebrated. Incredulity has made great progress since the time of the conquest, and it was on the back of the Cordilleras only that I found a small chapel, destined, according to its inscription, for prayers to be addressed to Heaven for the destruction of the *termites*."

The destruction wrought by the true ants is confined chiefly, but not entirely, to agricultural products. It is no uncommon thing to find spots where certain ants are so abundant and so destructive that the planters simply leave them alone. Sometimes it happens that after clearing a piece of land, and beginning their planting, the farmers find the ants so destructive that those particular fields are abandoned. In the coffee regions certain ants, popularly known as the *saúbas*, are so destructive that a systematic and unceasing war has to be waged upon them in order to save the coffee trees. But their attacks are not confined to coffee trees by any manner of means.

The following description of the *saúbas* is given by Gabriel Soares de Souza, one of the earliest writers on Brazil (1587).¹⁵

¹³ Azevedo Sampaio: *Sauva ou Manhu-uára*, pp. 50, 54. S. Paulo, 1894.

¹⁴ Alexander de Humboldt and Aimé Bonpland: *Personal narrative of travels to the equatorial regions of the new continent*, vol. iv, p. 191. London, 1819.

¹⁵ Gabriel Soares de Souza: *Tratado descriptivo do Brazil em 1587*. *Revista do Instituto Historico do Brazil*, vol. xv, p. 271. Rio de Janeiro, 1851.

What is said of that period is equally true today:

" . . . Wherever they go they destroy the fields of mandioca, the orchards, orange trees, pomegranates, and vines. If it were not for these ants there would be many Portuguese vines and grapes in Bahia. These ants come a long way at night to find a mandioca field, and where they march they wear a path as if people had walked along it for many days, and they never go out except by night. And in order to prevent their eating the trees which they injure, a ring of mud is put around their bases and filled with water, and if the water dries up during the day, or if a straw falls across it in the night they have spies who notify them at once, and immediately such a multitude of them crosses over on the straw that before morning they have all the leaves on the ground; . . . and while everything grows here that can be desired, this curse interferes to such an extent that it takes away men's desire to plant any more than that without which they can not live."

A late and thoroughly trustworthy writer says of the ants in the coffee regions:

"The enemy most dreaded in the fazendas is indubitably the *sauva*, or *tana-jura*, a dark-brown ant, two centimeters long, which undermines the ground by digging extensive passages and dens in all directions. It attacks all sorts of trees, the coffee-shrub among others, but has a decided preference for the orange and citron trees in the coffee gardens.

"In former times these ants seem to have worked frightful havoc in the *cafesaes* (coffee plantations) by causing landslips, because the means of destroying whole nests at once was not then discovered. Now they are less feared, although it still costs from 8 to 12 guineas a month per plantation to keep them down.

"On every fazenda two or three slaves are kept, whose exclusive business it is to find out the nests of the *sauvas*. Frequently they are even paid a certain sum to encourage and quicken their zeal. . . .

"The subterranean ant-labyrinth destroyed in my presence near the fazenda areas in Cantagallo seemed to be very extensive."¹⁶

The expense of fighting these ants is a really serious item in the cost of the production of Brazilian coffee. A distinguished Brazilian planter says, with perfect justice, that "among the obstacles with which the planters have to contend . . . there stands perhaps in the front rank the destructive force represented by the *sauúba*."¹⁷

One can get some idea of the economic importance of ants in Brazil from the fact that in the 70's and early 80's an enormous number of privileges or patents were asked of the Brazilian government for machines and devices of various kinds for killing ants, and especially the *sauúbas*.

¹⁶ C. F. Van Delden Laërne: Brazil and Java. Report on coffee culture in America, Asia, and Africa, pp. 297-298. London, 1885.

¹⁷ Henrique de Paula Mascarenhas: Revista Agricola do Imperial Instituto, vol. xiv, p. 215. Rio de Janeiro, December, 1883.

In 1857 the province of Rio de Janeiro voted a reward of \$25,000 for the discovery of a means of destroying *saúbas*.¹⁸

The growing of oranges, roses, and other flowering plants is similarly interfered with in many places because of the cutting and carrying away of the leaves by the *saúbas*.

It is impossible to keep things out of their reach on any large scale. Certain devices are used with more or less success for protecting things indoors when they are constantly watched, but standing crops or considerable stores require constant watchfulness and war.

Bates has the following in regard to the *saúbas* in the Amazon region:

"This ant (the *saúba*) is seen everywhere about the suburbs, marching to and fro in broad columns. From its habit of despoiling the most valuable cultivated trees of their foliage, it is a great scourge to the Brazilians. In some districts it is so abundant that agriculture is almost impossible, and everywhere complaints are heard of the terrible pest."¹⁹

At another place (page 11) he says:

"Besides injuring and destroying young trees by despoiling them of their foliage, the *saúba* ant is troublesome to the inhabitants from its habit of plundering the stores of provisions in houses at night, for it is even more active by night than in the daytime. At first I was inclined to discredit the stories of their entering habitations and carrying off grain by grain the farinha, or mandioca meal, the bread of the poorer classes of Brazil. At length, while residing at an Indian village on the Tapajos, I had ample proof of the fact. One night my servant woke me three or four hours before sunrise by calling out that the rats were robbing the farinha baskets, the article at that time being scarce and dear. I got up, listened, and found the noise very unlike that made by rats, so I took the light and went into the storeroom, which was close to my sleeping place. I there found a broad column of *saúba* ants, consisting of thousands of individuals, as busy as possible, passing to and fro between the door and my precious baskets" (p. 12). "My servant told me that they would carry off the whole contents of the two baskets (about two bushels) in the course of the night if they were not driven off."

ATTACKS ON MAN

The *formiga de fogo*, or fire ants, are so called on account of the painfulness of their sting. When they are met with in large numbers there is simply no withstanding them.

One of the reasons for calling ants the kings, rulers, and owners of the country is due to the vicious attacks they make upon all kinds of animals. Bates tells of one case in which a town on the Tapajos was actually

¹⁸ Auxiliador da Indústria Nacional, vol. xxxvii, p. 64. Rio de Janeiro, 1869.

¹⁹ H. W. Bates: The naturalist on the River Amazons, 4th ed., p. 9. London, 1875.

depopulated by ants of this kind. This statement seems so remarkable that it is quoted here at length:²⁰

"Aveyros was deserted a few years before my visit on account of this little tormentor (*formiga de fogo*), and the inhabitants had only recently returned to their houses, thinking its numbers had decreased. It is a small species, of a shining reddish colour, not greatly differing from the common red stinging ant of our own country (*Myrmica rubra*), except that the pain and irritation caused by its sting are much greater. The soil of the whole village is undermined by it; the ground is perforated with the entrances to their subterranean galleries, and a little sandy dome occurs here and there, where the insects bring their young to receive warmth near the surface. The houses are overrun with them; they dispute every fragment of food with the inhabitants, and destroy clothing for the sake of the starch. All eatables are obliged to be suspended in baskets from the rafters and the cords well soaked with copaiba balsam, which is the only means known of preventing them from climbing. They seem to attack persons out of sheer malice; if we stood for a few moments in the street, even at a distance from their nests, we were sure to be overrun and severely punished, for the moment an ant touched the flesh he secured himself with his jaws, doubled in his tail, and stung with all his might. When we were seated on chairs in the evenings in front of the house to enjoy a chat with our neighbors, we had stools to support our feet, the legs of which, as well as those of the chairs, were well anointed with the balsam. The cords of hammocks are obliged to be smeared with the balsam in the same way to prevent the ants from paying sleepers a visit."

In order to give a clear understanding of the seriousness of the bite of these ants, I quote the following from Dr. Richard Spruce's personal experience of them:

"Aug. 15, 1853.—Yesterday I had the pleasure for the first time of experiencing the sting of the large black ant called *tucandera* in Lingoa Geral. . . .

"I had gone after breakfast to herborise in the caapœra north of San Carlos, where there were a good many decayed trunks and stumps. I stooped down to cut off a patch of a moss on a stump, and remarked that by so doing I exposed a large hollow in the rotten wood; but when I turned me to put the moss into my vasculum I did not notice that a string of angry *tucanderas* poured out of the opening I had made. I was speedily made aware of it by a prick in the thigh, which I supposed to be caused by a snake until, springing up, I saw that my feet and legs were being covered by the dreaded *tucandera*. There was nothing but flight for it, and I accordingly ran off as quickly as I could among the entangling branches, and finally succeeded in beating off the ants, but not before I had been dreadfully stung about the feet, for I wore only slippers without heels, and these came off in the struggle. I was little more than five minutes' walk from my house, . . . and I wished to walk rapidly, but could not. I was in agonies, and had much to do to keep from throwing

²⁰ Naturalist on the Amazons, p. 205.

myself on the ground and rolling about, as I had seen the Indians do when suffering from the stings of this ant. I had in my way to cross a strip of burning sand, and then to wade through a lagoon, partly dried up, and not more than two feet deep. Both these increased the torture; I thought the contact with the water would have alleviated it, but it was not so.

"When I reached my house I immediately had recourse to hartshorn. No one was near but an Indian woman, . . . and she, without my telling her, . . . bound a ligature tightly above each ankle. After rubbing for some time with the hartshorn and experiencing no relief, I caused her to rub with oil, and then with oil and hartshorn mixed. None of these seemed to have any effect; when the oil was made hot it relieved me a little, but very little, indeed, and the wounds which were least rubbed ceased to pain me the soonest, one that had not been touched being the first cured.

It was about 2 p. m. when I was stung, and I experienced no alleviation of the pain till 5. During all this time my sufferings were indescribable. I can only liken the pain to that of a hundred thousand nettle-stings. My feet and sometimes my hands trembled as though I had the palsy, and for some time the perspiration ran down my face from the pain. With difficulty I repressed a strong inclination to vomit. I took a dose of laudanum at 4, and I think this did more than anything to lull the pain. I had been stung on the two big toes and on the soles of my feet, but the stings that caused me most suffering were four close together among the fine veins below the left ankle. When the pain of all the others had subsided this continued to torment me, and pains shot from it all over the forefoot and some way up the leg, notwithstanding the bandages.

"After the pain had become more bearable, it returned with great force on two occasions, at 9 o'clock and at midnight, when I stepped out of my hammock on my left foot, and each time caused me an hour of acute suffering. Towards morning I slept, and when I woke up I felt no inconvenience beyond a slight numbness in the feet, but the inflammation continued unabated for thirty hours. It is curious that nothing was visible externally more than would be caused by the stinging of an ordinary nettle. Possibly swelling was prevented by the application of the hartshorn and oil, for I have heard of cases where the swelling was considerable. Rubbing in the ingredients served to increase the pain both at the time and afterwards."²¹

BENEFICIAL ANTS

Not all the ants are to be looked upon as pests. Certain carnivorous ants are rather to be regarded as beneficial to agriculture, and to mankind generally, on account of their destruction of caterpillars and other noxious insects. In districts where cotton is grown the larvæ of the cotton moths are kept in check by the ants destroying the young ones, especially during the early part of the season. The invasion of houses by ant colonies is a common occurrence in every part of Brazil. Ordinarily these invasions are only temporary. During the hour or two when these

²¹ Richard Spruce: Notes of a botanist on the Amazon and Andes, vol. 1, pp. 362-364. London, 1908.

ants swarm through one's house or rooms they are certainly annoying, but they soon disappear, and one feels that he has been relieved to a considerable extent from the cockroaches and other more offensive and serious plagues.

Many writers have described the operations of these ants, but the following, quoted from Dr. Richard Spruce, will give a clear idea of these operations:²²

"Ecitons, or foraging ants (called *Cazadoras* in Peru), seem to be true wandering hordes, without a settled habitation, for a certain number of them may always be seen carrying pupæ, apparently of their own species; but they sojourn sometimes for several days whenever they come upon suitable food and lodging.

"The first time I saw a house invaded by *Cazadoras* was in November, 1855, on the forest slope of Mount Campana, in the eastern Peruvian Andes. I had taken up my abode in a solitary Indian hut, at a height of 3,000 feet, for the sake of devoting a month to the exploration of that interesting mountain. The walls of the hut were merely a single row of strips of palm trees, with spaces between them wide enough to admit larger animals than ants. One morning soon after sunrise the hut was suddenly filled with large blackish ants, which ran nimbly about and tried their teeth on everything. My charqui proved too tough for them; but they made short work of a bunch of ripe plantains, and rooted out cockroaches, spiders, and other such like denizens of a forest hut. So long as they were left unmolested they avoided the human inhabitants; but when I attempted to brush them away they fell on me by hundreds and bit and stung fiercely. I asked the Indian's wife if we had not better turn out a while and leave them to their diversions. 'Do they annoy you?' said she. 'Why, you see it is impossible for one to work with the ants running over everything,' replied I. Whereupon she filled a calabash with cold water, and, going to the corner of the hut where the ants still continued to stream in, she devoutly crossed herself, muttered some invocation or exorcism, and sprinkled the water gently over them. Then walking quietly round and round the hut, she continued her aspersion on the marauders, and thereby literally so damped their ardour that they began to beat a retreat, and in ten minutes not an ant was to be seen.

"Some years afterwards I was residing in a farm-house on the River Daule, near Guayaquil, when I witnessed a similar invasion. The house was large, of two stories, and built chiefly of bamboo-cane, the walls being merely an outer and an inner layer of cane, without plaster inside or out, so that they harboured vast numbers of cockroaches, scorpions, rats, mice, bats, and even snakes, although the latter abode chiefly in the roof. Notwithstanding the size of the house, every room was speedily filled with the ants. The good lady hastened to fasten up her fresh meat, fish, sugar, etc., in safes inaccessible even to the ants, and I was prompt to impart my experience of the efficacy of baptism by water in ridding a house of such pests. 'Oh!' said she, laughingly, 'we know all that; but let them first have time to clear the house of vermin,

²² Richard Spruce: Notes of a botanist on the Amazon and Andes, vol. II, pp. 371-373. London, 1908.

for if even a rat or snake be caught napping they will soon pick his bones.' They had been in the house but a very little while when we heard a great commotion inside the walls, chiefly of mice careering madly about and uttering terrified squeals; and the ants were allowed to remain thus and hunt over the house at will for three days and nights, when, having exhausted their legitimate game, they began to be troublesome in the kitchen and on the dinner table. 'Now,' said Dona Juanita, 'is the time for the water cure,' and she set her maids to sprinkle water over the visitors, who at once took the hint, gathered up their scattered squadrons, reformed in column, and resumed their march. Whenever their inquisitions became troublesome to myself during the three days, I took the liberty to scatter a few suggestive drops among them, and it always sufficed to make them turn aside; but any attempt at a forcible ejection they were sure to resent with tooth and nail, and their bite and sting were rather formidable, for they were large and lusty ants. For weeks afterwards the squeaking of a mouse and the whirring of a cockroach were sounds unheard in that house." (Footnote.)

"The ants called Carniceras, or butchers, in Maynais are probably of a tribe distinct from the foragers, for they are burrowing ants, and are said to prefer the flesh of human carcasses to any other food. Padre Velasco, in his *History of Quito*, assures us that they will make a perfect skeleton of a corpse the very day it is buried, and that they devour any disabled animal, however large. they find in the forest."

Thomas Belt has a good deal on the swarms of ants in Central America. The following extract is from his "Naturalist in Nicaragua," page 17 :

"One of the smaller species (*Eciton predator*) used occasionally to visit our house and swarm over the floors and walls, searching every cranny and driving out the cockroaches and spiders, many of which were caught, pulled, bitten to pieces, and carried off. The individuals of this species were of various sizes, the smallest measuring one and a quarter lines and the largest three lines, or a quarter of an inch.

"I saw many armies of this, or a closely allied species, in the forest. My attention was generally first called to them by the twittering of some small birds, belonging to several different species, that follow the ants in the woods. On approaching, a dense body of the ants, three or four yards wide, and so numerous as to blacken the ground, would be seen moving rapidly in one direction, examining every cranny and underneath every fallen leaf. On the flanks and in advance of the main body smaller columns would be pushed out. These smaller columns would generally first flush the cockroaches, grasshoppers, and spiders. The pursued insects would rapidly make off, but many in their confusion and terror would bound right into the midst of the main body of ants."

Bates has the following regarding the *Ecitons* (page 354) :

"One or other of them is sure to be met with in a woodland ramble, and it is to them, probably, that the stories we read in books on South America apply of ants clearing houses of vermin, although I heard of no instance of

their entering houses, their ravages being confined to the thickest parts of the forest.

"When the pedestrian falls in with a train of these ants, the first signal given him is a twittering and restless movement of small flocks of plain-colored birds (ant thrushes) in the jungle. If this be disregarded until he advances a few steps farther, he is sure to fall into trouble, and find himself suddenly attacked by numbers of the ferocious little creatures. They swarm up his legs with incredible rapidity, each one driving its pincer-like jaws into his skin, and with the purchase thus obtained, doubling in its tail, and stinging with all its might. There is no course left but to run for it; if he is accompanied by natives, they will be sure to give the alarm, crying, 'Tauóca!' and scampering at full speed to the other end of the column of ants. The tenacious insects who have secured themselves to his legs then have to be plucked off one by one, a task which is generally not accomplished without pulling them in twain, and leaving heads and jaws sticking in the wounds.

"The errand of the vast ant armies is plunder, as in the case of Eciton legions; but from their moving always amongst dense thickets, their proceedings are not so easy to observe as in that species. Wherever they move, the whole animal world is set in commotion, and every creature tries to get out of their way. But it is especially the various tribes of wingless insects that have cause for fear, such as heavy-bodied spiders, ants of other species, maggots, caterpillars, larvæ of cockroaches, and so forth, all of which live under fallen leaves or in decaying wood. The Ecitons do not mount very high on trees, and therefore the nestlings of birds are not much incommoded by them.

"The armies never march far on a beaten path, but seem to prefer the entangled thickets, where it is seldom possible to follow them. I have traced an army sometimes for half a mile or more, but was never able to find one that had finished its day's course and returned to its hive. Indeed, I never met with a hive; whenever the Ecitons were seen they were always on the march" (p. 355).

ANTS AS FOOD

In the Amazon region some of the ants are even used by the Indians for food.

"I have many times seen Indians eat the *saúba* ant (called *bacháco* in Venezuela). The large kinds only are eaten, and at those times when the bachacos pour from their holes in great numbers (probably sending forth colonies after the manner of bees), if it be near any pueblo, all the unoccupied Indians in the place turn out to collect them. The head and thorax are the parts eaten, the abdomen being nipped off (at San Carlos I constantly see them eaten entire), and it is eaten uncooked. The taste to me is strong, fiery, and disagreeable, but those who have eaten the bacháco fried in turtle oil tell me it is quite palatable."²²

In the more thickly settled parts of Brazil the custom of eating these ants is either not practiced nowadays, or, if it is, it is not generally known.

²² Richard Spruce: Notes of a botanist on the Amazon and Andes, vol. I, p. 484. London, 1908.

In the early history of the country, however, when the native Indians were much more abundant than they are now, the custom appears to have been common. Gabriel Soares de Souza, after living 16 years in Bahia, wrote as follows in 1587:²⁴

"There are in this same country other ants which the Indians call *içans*, and which have bodies the size and color of an Alicante raisin . . . which live on the leaves of trees and worms and other small animals they find on the ground; these ants the Indians eat roasted over the fire, and they are greatly enjoyed; and some white men who live amongst them and the half-breeds regard them as good food, and boast of it as being very savory; . . . and when roasted they are white on the inside."

Orton²⁵ says the *saúbas* "are eaten by the Rio Negro Indians, and esteemed a luxury, while the Tapajos tribes use them to season their mandioca sauce."

STRUCTURES ABOVE GROUND

Origin of the structures.—The word "nests" frequently applied to the superficial structures of ants should not be understood to mean nests in the ordinary signification of the word. These structures sometimes contain the queens, eggs, and larvæ, but at other times these are kept in excavations below the surface.

The mounds made by the true ants all begin as small funnel-shaped ridges around the excavations started by individual females. The large mounds are the results of the work of many generations and of a vast number of individuals.

Without going into any detailed description of the habits of the ants, it is worth while to give, for those unfamiliar with their habits, a general idea of the methods followed by these ants in establishing new colonies and in increasing them. When the swarming or mating season of the *saúba* ants comes, the young females leave their homes and fly away. They seem to fly about very much at random—at least, I have rarely seen them going in any particular direction—and when they have been seen going together it was apparently due to the direction of the wind or the position of the sun at the time, rather than to any definite purpose on their part.

When the female alights after a flight of only a few minutes, she breaks off her wings and at once falls to work at excavating a burrow. All kinds of places are selected for these burrows. It does not appear that the selection is deliberate, but it seems to be determined by the acci-

²⁴ Gabriel Soares de Souza : *Tratado descritivo do Brazil em 1587*. *Revist. Inst. Hist. do Brazil*, vol. xiv, pp. 273-274. Rio de Janeiro, 1851.

²⁵ James Orton : *The Andes and the Amazon*, 3d ed., p. 301. New York, 1876.

dent of alighting from an aimless flight. Judging from the large number of individual females I have frequently seen in the air and on the ground at one time, the great majority of these young colonies must fail to survive. Often I have seen the young females so abundant that there must have been an individual to every square meter of land surface over areas of many hundreds of acres.

In some places where the new arrivals alight the mounds are already so thick that there is little or no room for new colonies, and it is probable that some of these young females must either be adopted into the old colonies or they are killed or die.²⁶

It is evident from the nature of the case that where such a large number of new colonies is started most of them must perish from mere overcrowding, if for no other reason.

The excavation first made by a young female is small and simple, and the earth taken from it is heaped about the opening without any apparent order. Doctor Huber, in the paper just cited, states that at Para, in a colony started by a single female, the first workers appear at the end of 40 days. Shortly thereafter the queen, or founder of the colony, ceases to be an active worker, and all subsequent excavating is done by the constantly increasing number of workers. As the colonies increase in numbers more underground room is required, and the amount of earth excavated and carried to the surface increases proportionately. This earth is brought to the surface in the form of small pellets in the jaws of the workers, and are thrown down apparently without any other object than to be rid of them. Sometimes they are heaped up in funnel-shaped pits; sometimes they are thrown out on the downhill side of the opening. At first these bits of earth form heaps of loose, incoherent material, but in time, and with rain and sunshine, it packs down until it is often as hard as an unbaked brick. As long as the colony is active and growing, additions are constantly being made to these accumulations, and these additions may be at any point over the sides or at the top. Passageways are either kept open through these heaps of earth or they are reexcavated. This is demonstrated by digging into the mounds; but it is evident without opening them, from the fact that the fresh material is brought out and spread over any and all parts of the surface.

Size of the mounds.—It might be inferred that there would be practically no limit to the size of the mounds built in this fashion, and I am not sure that there are any limits save those which may be imposed by

²⁶ Just how new colonies of saubas can be established by a single female is described by Dr. J. Huber, in *Biologisches Centralblatt*, vol. xxv, pp. 606-618, 624-635, and in the *Boletim do Museu Goeldi*, vol. v, pp. 223-241. Para, 1907-8. Also in the *Annual Report of the Smithsonian Institution for 1906*, pp. 355-367.

certain physical conditions, such as the amount and distribution of the rains, the character of the soil, the area over which the necessary plants or food can be obtained, etcetera. Of course, the mounds are of different sizes according to their ages; but considering only the largest and oldest ones made by a single species, and found in various different localities, it is noteworthy that there is a great difference in the sizes of the largest of them. Just what determines this variation I can not say positively, but the influences referred to above—that is, rainfall, character of soil, and vegetation—naturally suggest themselves as possible influences.

Bates has the following in regard to the mounds made by the *saúbas* in the vicinity of Para:²⁷

“In our first walks we were puzzled to account for large mounds of earth, of a different colour from the surrounding soil, which were thrown up in the plantations and woods. Some of them were very extensive, being forty yards in circumference, but not more than two feet in height. We soon ascertained that these were the work of the *saúbas*, being the outworks, or domes, which overlie and protect the entrances to their vast subterranean galleries. On close examination, I found the earth of which they are composed to consist of very minute granules, agglomerated without cement, and forming many rows of little ridges and turrets. The difference in colour from the superficial soil of the vicinity is owing to their being formed of the undersoil, brought up from a considerable depth. It is very rarely that the ants are seen at work on these mounds; the entrances seem to be generally closed; only now and then, when some particular work is going on, are the galleries opened.”

Nowhere do I remember to have seen more or larger ant-hills than along Rio Utinga, in the diamond regions of the interior of the State of Bahia. From the town Riachão, down the river to the village of Pegas, the examples are big and abundant. In a few places they are so close together that, big and little, they appear to cover half of the ground. My notes, written on the spot, say “more than half of the ground.” Such places, however, are exceptional. The distribution is always more or less irregular—bunched apparently on account of characteristics of soil or drainage, or for some other reason that does not appear. In some areas of from 10 to 20 acres the ant-hills occupy from a fifth to a third of the ground, while over larger tracts they take up from one-eighth to a seventh of the ground. In height the mounds are often as much as 5 meters high, with bases 15 or 16 meters in diameter. In the forests these mounds are generally overgrown with young trees. On many of the big mounds I have seen trees more than 30 centimeters in diameter. At the village of Antonio José the people have planted pineapples upon the mounds.

²⁷ Naturalist on the River Amazons, 4th ed., p. 10. London, 1875.

FIGURE 1.—Ant-hills on Rio Utinga, near the Village of Pegas, State of Bahia

From a photograph by R. Crandall, 1907

At fazenda Bello Horizonte, about 18 kilometers north of the village of Pegas, the ant-hills are so large and stand so thickly upon the ground that they form one of the most striking illustrations I have ever seen of the work of these insects. An area of some 30 acres or more is there covered with mounds resembling haystacks. They probably average 2 meters in height and a diameter of 4 or 5 meters at the base.

At a place called Ponte Nova, on Rio Utinga, 8 kilometers north of the village of Pegas, the ant-hills are a remarkable feature of the landscape. To the east and northeast of the Protestant college the mounds

FIGURE 2.—Ant-hill (*Formiga de mandioca*) near Mundo Novo, State of Bahia, Brazil
From a photograph by R. Crandall, 1907

cover the old fields. One of the accompanying photographs (figure 2, plate 35) and figure 1 were made in this region.

In the region south of Morro do Chapeo, in the State of Bahia, they are equally large on the clayey soils derived from the Caboclo shales.

The accompanying illustrations were made from photographs taken near Mundo Novo and Ventura, in that area.

Farther east in the State of Bahia, in the vicinity of Serrinha, a station on the São Francisco Railway, the ant-hills are large and abundant.

Six kilometers north of the station one was found by measurement to be 1.8 meters high and $4.5 \pm$ meters wide at the base. This mound was not regarded by the people of the locality as anything unusual.

To the east of Serrinha several mounds were observed with a height of 3 meters and a diameter at the base of 10 meters. These mounds, therefore, contain each 78.5 cubic meters of earth.

At and about Catuny, a station on the São Francisco Railway, the ant mounds are notably abundant, and many of them have a height of 1.5 meters.

FIGURE 3.—Ant-hills made by the "*Formiga de mandioca*," near Ventura, State of Bahia, Brazil

From a photograph by R. Crandall, 1907

Along the western half of the Bahia and Minas Railway, that starts from the coast near Caravellas, in the southern part of the State of Bahia, and runs west 376 kilometers into the State of Minas Geraes, ant-hills are big and abundant. The newer ones are steeply conical, but with age they become more or less rounded and flattened. In the vicinity of Urucú Station (kil. 226) the mounds are so thick and so close together that the country looks like a field of gigantic potato hills.

In some places they stand so close that their bases touch each other, though such cases appear to be rather exceptional. The mounds in this

part of Minas and Bahia that appear to have reached their full development range from 1 to $4\frac{1}{2}$ meters in height and from 3 to 10 meters in diameter at the base. The biggest of these mounds—that is, one 4.5 meters high and 10 meters in diameter—contains approximately 117 cubic meters of earth.

Mention has already been made of the abundance and size of the mounds in some parts of the Rio Utinga region, in the interior of Bahia. At one place in this region, where the forests had been cleared away so that the mounds were clearly visible, I selected a spot where they were strikingly abundant, and measuring a space 100 by 100 meters, as nearly as it could be done by pacing, counted the mounds within the area and estimated their heights and diameters at the base.

The slopes of these mounds vary from less than 30 degrees up to 47 degrees, and on some parts of them there are even perpendicular places. It was thought that 38 degrees was a fair average for the ones in this particular area.

The figures obtained are given in the table below:

Table of Areas and cubical Contents of Mounds of different Sizes within an Area of 10,000 square Meters.

(All measurements are in meters.)

Number of mounds.	Diameter of base.	Area of each in square meters.	Total area in square meters.	Height.	Cubical contents.	Total contents in cubic meters.
1	15	176.71	176.71	4.5	265	265
2	11	95.03	190.06	4.2	133	266
6	10	78.54	471.24	3.9	102	612
8	8	50.26	402.08	3.1	51	408
12	7	38.48	460.76	2.9	37	444
5	6	28.27	141.35	2.3	21	105
4	5	19.63	78.52	2.0	13	52
7	4	12.56	87.92	1.7	7	49
8	3	7.06	56.48	1.2	3	24
Totals, 53			2,064.82			2,225

This estimate makes the area actually covered by the mounds close to one-fifth of the total area under consideration. My notes show that within areas of a few acres the ground covered by the mounds is sometimes as high as one-half of the total area. The cubical contents of the mounds, if evenly distributed over the entire 10,000 square meters, would have a thickness of 22.25 centimeters.

Although the mounds within the area here considered were large, they were not the biggest I have seen, nor do they average as large as can be

found. The largest ones measured were on the upper drainage of Rio Utinga; several of these were found to be 5 meters high and 16 and 17 meters in diameter at the base, and each contained, therefore, about 340 cubic meters of earth. There were no other mounds closer to these than 10 or 15 meters.

M. Gounelle, a French entomologist, has calculated from a photograph the size of some of the Bahia mounds. Following is a translation of a part of his article. The mounds mentioned by him are near Condeuba, which is in the southern part of the State:²⁸

"A photograph shown to the Society makes it possible for one to appreciate the enormous amount of work done by certain ants, and to measure fairly well the volume of the materials moved by them in digging their galleries. This photograph, taken in the vicinity of the little city of Condeuba, in the southern part of the State of Bahia, shows a clearing in which appear five conical nests of an ant, probably *Oecodoma cephalotes* Latreille.²⁹ The five cones have about the same dimensions. One notes in the foreground that the scale is one centimetre to the metre, as is readily seen by comparison with the man standing on top of the mound. Its diameter is 16 metres and its height is 4.5 metres, which by a simple calculation gives 301 cubic metres for its volume and 1,500 cubic metres for the total volume of the five mounds. The clearing has a surface of about one hectare, so that the earth of the five mounds, if spread evenly all over it, would have a thickness of 15 centimetres. . . . It should be added that the building of ant-hills of this size within a limited area is not an isolated case. The traveller in these regions meets with them everywhere, and that, too, over an enormous extent of country."

The reader should be reminded just here that this sort of thing is not to be seen in all parts of the country, by any manner of means. So far as my own observations go, ant mounds are unusually large and unusually abundant in this particular part of Brazil.

Age of the mounds.—The amount of work done by these ants in a region where they seem to be favorably located is fairly well shown in the preceding table. Trustworthy data for calculating the time required to build a mound of a given size or to do any given amount of work is lacking. Necessarily the time must vary with the size of the colonies, other things being equal. The colonies, however, appear to have their ups and downs, for while some of them increase in numbers and continue to add to the mounds for long periods, others appear to be less active, while still others disappear, whether by migrating or through the death or captivity of the members is not certainly known at present. It is interesting to note that the Brazilians generally regard the size of the ant-hill as

²⁸ E. Gounelle: Transport de terres effectué par des fourmis au Brésil. *Annales de la Société Entomologique de France*, 7me sér., no. 6, pp. 332-333. Paris, 1896.

²⁹ This is the name of the so-called *sauba*. J. C. B.

directly related to the age of the colony. At Serrinha, on the São Francisco Railway, I was told that mounds about 2 meters high and having a base of about 5 meters were probably as much as a hundred years old. This was an expression of views based simply upon a general impression and not upon records.

M. Gounelle³⁰ says in regard to the age of ant-hills:

"The age of these ant-hills is rather difficult to determine; however, the curate of the city mentioned above (Condenba, Bahia) has assured me that three nests like those in the photograph, located at the entrance to the cemetery, were not more than one metre high when he went to that country, about sixty years ago. Taking a hundred years as an average for the building of these gigantic ant-hills, it does not seem rash to suppose that in these regions the soil must have been worked over by the ants to a certain depth several times in the course of geologic periods."

UNDERGROUND WORK

So far as I can learn, there has never been any careful examination or study of the character, extent, and uses of the underground excavations made by ants in the tropics. What is known about them has been learned accidentally, and our knowledge of the passages is, therefore, fragmentary. I have frequently dug into the mounds, but always without the time necessary for satisfactory results. The most I have been able to make out in these hasty explorations is that the superficial mounds are penetrated in every direction with passageways. The large mounds were in no case opened down to the original surface of the ground; but when small mounds were opened they were found to connect through small tunnels with the underground excavations.

A pit started by the removal of a large ant-hill east of Timbo, in the interior of Bahia, and continued to a depth of about 4 meters, showed the arrangement of the underground tunnels better than I have seen it elsewhere. The section did not pass through the main shaft or tunnel that connected the ant-hill with the subterranean excavations, but a little to one side of it. The upper layer of the earth, to a depth of half a meter, was undisturbed; then there was one tunnel with a flat floor, about 20 to 25 centimeters across, and having a low arched roof; below this, at a distance of about 25 centimeters, were two tunnels at the same level and of about the same size and shape; below these, at a further depth of about 25 centimeters, were three similar openings. This arrangement continued to a depth of nearly two meters, the tunnels being more numerous always at the lower levels. The tunnels at the lowest

³⁰ E. Gounelle: Transport de terres effectué par des fourmis au Brésil. Bull. Soc. Entomologique de France. 7me sér., no. 6, p. 332. Paris, 1896.

level did not form a complete row, but the work seemed to have been commenced at the outside.

This same arrangement of the tunnels has been seen frequently in railway cuts and ditches, but nowhere else have I seen so many levels or such a clearly defined plan in the placing of the excavations.

In some other cases noted the number of tunnels connecting the above-ground mounds with the underground galleries seemed to vary with the size of the mounds—that is, the more ground the mound covered, the more passageways there seemed to be to connect with the galleries beneath.

FIGURE 4.—Nest of leaf-cutting Ant

After Belt. "The Naturalist in Nicaragua," p. 80

Bates gives the following regarding the *saúbas*:³¹

"The entrances are small and numerous; in the large hillocks it would require a great amount of excavation to get at the main galleries; but I succeeded in removing portions of the dome in smaller hillocks, and then I found that the minor entrances converged, at the depth of about two feet, to one broad, elaborately worked gallery, or mine, which was four or five inches in diameter."

The section through the burrows given by Belt is reproduced in figure 4. This section, however, is diagrammatic, and does not claim to show the great extent of the galleries. Belt tells, however, of galleries 1.5 meters in depth (page 76). The best evidence I have been able to gather in regard to the depth to which the ants penetrate has been obtained in cuts along railways and canals, and in deep ditches often dug to serve as fences. On Rio do Peixe, near Serro, in the State of Minas Geraes, I found the galleries as deep as 2.5 meters at several places along a canal under construction. Most of them, however, were only about 1.5 meters below the surface at the deepest points exposed. At Bomfim, on the

³¹ H. W. Bates: The Naturalist on the Amazons.

Bahia and São Francisco Railway, I found the burrows exposed in a deep ditch at a depth of 2.1 meters.

Sampaio, a Brazilian entomologist who has given much attention to the *saúba* ants, shows one burrow as much as 3.5 meters below the surface.³²

In the State of São Paulo, Brazil, the coffee planters have among their employees men whose business it is to fight the *saúbas*. These ant-killers, in the course of their operations against the ants, are said to open out sometimes their underground excavations to a depth of 3.6 meters.

Dr. Joaquim Lustosa, a Brazilian mining engineer of Lafayette, State of Minas Geraes, Brazil, writes me (June 16, 1909) as follows in regard to the depth to which ants burrow in Minas: "Competent persons assure me that the true ants burrow to a depth of 10 metres or more, and that they exhibit a strange and remarkable intelligence, and that they even cross wide and deep streams by means of tunnels so deep as to avoid the infiltration of the water."

The length of the tunnels has often been demonstrated by forcing smoke through them. I have myself seen fumes blown into one opening and issuing from others as much as 300 meters away. Mr. Charles J. Dulley, a civil engineer of São Paulo, informs me that he has seen fumes driven into the chief nucleus of a colony of *saúbas*, and issuing 183 meters away.

The following statement is given in Mrs. Agassiz's book:³³

The *saúbas*

"make houses by excavating, and sometimes undermine a hill so extensively with their long galleries that when a fire is lighted at one of the entrances to exterminate them, the smoke issues at numerous openings, distant perhaps a quarter of a mile from each other, showing in how many directions they have tunneled out the hill, and that their winding passages communicate with each other throughout."

On the authority of Rev. H. Clark, Bates says³⁴ that ants

"excavated a tunnel under the bed of the River Parahyba, at a place where it is as broad as the Thames at London Bridge. At the Magoary rice mills, near Pará, these ants once pierced the embankment of a large reservoir; the great body of water which it contained escaped before the damage could be repaired. In the Botanic Gardens at Pará, an enterprising French gardener tried all he could think of to extirpate the *saúba*. With this object he made fires over

³² A. G. de Azevedo Sampaio: *Sauva ou Manhu-uára*, pp. 22, 52, 64. Sao Paulo, 1894.

³³ Prof. and Mrs. Louis Agassiz: *A journey in Brazil*, p. 105. Boston, 1868.

³⁴ H. W. Bates: *Naturalist on the Amazons*, 4th ed., pp. 9-15. London, 1875.

some of the main entrances to their colonies, and blew the fumes of sulphur down the galleries by means of bellows. I saw the smoke issue from a great number of outlets, one of which was 70 yards distant from the place where the bellows were used. This shows how extensively the underground galleries are ramified.”

Another writer, Rev. J. C. Wood, tells of the *saúbas* having “ruined a gold mine for a time, breaking into it with a tunnel some 80 yards in length and letting in a torrent of water, which broke down the machinery and washed away all the supports, so that the mine had to be dug afresh.”³⁵

The diameter of an underground passage varies from 1 or 2 centimeters up to 5 centimeters or more. They widen out and narrow down without any apparent reason, and those made by the *saúbas* that have been examined have here and there local enlargements that are commonly from 1 to 2 decimeters in height and from 1 to 3 decimeters in length. These chambers, when freshly opened, I have generally found filled, or partly filled, with loose, mouldy masses of dead leaves.

Belt describes the underground passages in Nicaragua as follows:³⁶

“In our mining operations we also, on two occasions, carried our excavations from below up through very large formicariums, so that all their underground workings were exposed to observation. I found their nests below to consist of numerous rounded chambers, about as large as a man’s head, connected together by tunneled passages leading from one chamber to another.”

RELATIONS TO THE SOIL

The distribution of ant colonies as shown by their mounds suggests, if it does not prove beyond question, that the character of the soil has an important influence on the distribution of the ants themselves. In view of the habits of ants, it seems highly probable that at the time of leaving their nests the young females scatter over the surrounding region pretty much at random. When they alight, some of them find themselves in locations where ant colonies, on account of the character of the ground, can not possibly survive, and as these young females break off their wings as soon as they alight, they can not renew their flight and seek more favorable ground, but they must perish without having founded a new colony. And this must happen over and over again, with the final result that localities unfavorable for ants do not have ant colonies, while the favorable localities may have a superabundance of them. Favorable and

³⁵ Charles Waterton: *Wanderings in South America*. Explanatory Index, Rev. J. G. Wood, p. 47. London, 1882.

³⁶ *The Naturalist in Nicaragua*, p. 80.

unfavorable conditions are not always sharply defined, but merge into each other.

In some cases it is quite evident what constitute unfavorable conditions. Ground that is constantly wet or liable to inundation can not be occupied; hard, rocky surfaces, or even very thin soils, are not available; soils so sandy or friable that underground tunnels dug in them will not stand are evidently not available for the establishment of colonies.

Between soils most favorable and unfavorable ones there are all sorts of gradations, so that one is prepared, for this reason alone, to find the ant-hills bigger and more abundant in some places than in others. It is evident that it is all a question of adaptability, however, rather than a matter of choice on the part of the ants.

Just what kind of soil is most favorable for the ants I can not state positively. My general impression is that the mounds are most abundant on clayey soils, whether the clay comes directly from the decomposition of feldspathic rocks or from the disintegration of shales and slates.

This preference for the clayey soils is well shown at many places through the diamond-bearing highlands of the interior of Bahia, where the diamond-bearing quartzites, known as the Lavras series, are underlain by a thick series of shales called the Caboclo (or Paraguassú ?) series. The Lavras beds being quartzites, or sandstones, break down into a very sandy soil, while the Caboclo shales form a stiff, clayey soil, and as they are adjacent to each other the line of demarcation between the two soils is usually well defined. While traveling through that district in 1907, I was frequently able to locate myself geologically by the abundance or absence of the ant-hills. Not infrequently the line of parting between the two series was concealed by a thick soil and overgrown with forests, but the distribution of the mounds would often show the line of parting within 20 or 25 meters.

My former assistant, Mr. Roderic Crandall, who has traveled extensively in Bahia, Pernambuco, Piahy, Minas, and Goyaz, writes, in reply to my inquiries, as follows regarding the preference of the ants for certain soils: "In Bahia the ants of all kinds show a preference for the Estancia and Caboclo shales; next to these the granites seem to have the biggest nests." (Private letter; Rio, June 23, 1909.)

I infer that the smaller number of the mounds on the sandy soil is due to the fact that during the rainy season water soaks through into the burrows, and the excavations do not stand up where the soil is wet.

Thinking it possible that the exposure of the mounds or of the ground on which they stand to the sun might influence location and distribution, an outlook has been kept with these questions in mind. It does not

appear thus far that such exposure influences the location or size of the mounds, even in the southern part of Brazil, where the sun is on the north most or all of the year.

THE WHITE ANTS, OR TERMITES

GENERAL CHARACTERISTICS

The so-called white ants, or termites, belong to the *Isoptera*, and are therefore not ants at all. They are included in this paper solely on account of the geologic work done by them in the tropics, which bears a certain similarity to the geologic work of the true ants.

In Brazil the white ants are commonly known by the name of *cupim*. In their habits the white ants both resemble and differ from the true ants. They generally avoid the light, carrying on their work, even when it is above ground, in galleries which they construct as they go. Their nests are sometimes attached to tree trunks or rocks, but they are often built directly upon the ground. Not infrequently these nests are as large, or even larger, than the nests of the true ants, but they are very different in shape and character.

ABUNDANCE

Here, again, I am unable to give anything regarding the biology of the white ants.³⁷

Dr. Fritz Muller, who lived for many years in southern Brazil, reports 15 or 16 species of termites in that part of the country, but not all of these live on or in the ground.

M. Jules Desneux, in his monograph on the Termitidæ, reports 45 species from Brazil and some 15 or more from other tropical parts of America.

White ants, like other animals, are not evenly distributed in the tropical parts of South America. They are so much less obtrusive and pugnacious, however, that they do not attract the attention as promptly as do the true ants.

Azara says he has seen these insects during the mating season filling the air for more than a mile.³⁸

³⁷ For the benefit of those who are interested in the biology of white ants I cite the following:

K. Escherich: Die Termiten oder weissen Ameisen. Eine Biologische Studie, vol. xii, p. 198. Leipzig, 1909.

Genera Insectorum publiées par P. Wytsman. Fasc. 25, Isoptera, fam. Termitidæ par Jules Desneux. Bruxelles, 1904.

³⁸ Don Felix de Azara: Voyages dans l'Amérique Méridionale, t. i, p. 192. Paris, 1809.

The fact that the white ants live and work entirely under cover might naturally lead one to infer that they were much less abundant than the true ants. But nowhere have I found the ground as thickly covered with the termites' nests as with those of the true ants, a fact probably due to some extent to the methods by which the two kinds of insects procure their food supplies.

I have never been able to estimate the number of individuals in the old colonies, nor have I found such an estimate made by any one else. In the matter of numbers we are obliged to depend on general impressions gained from the abundance of the above-ground structures of the separate colonies and from certain of their habits. For example, it is stated that the queen of an allied species whose habits have been studied has "an egg-laying rate of 60 per minute, or something like 80,000 per day."³⁹

Prince Maximilien, who traveled through the region between Rio and Bahia, says of their abundance: "One can get some idea of their prodigious numbers when he remembers the vast extent of the interior of Brazil, and of the number of the little animals that occupy these nests, when he reflects that one can not go 20 paces without meeting their mounds."⁴⁰

This statement must be taken with certain allowances, for, as pointed out elsewhere, the nests are not everywhere equally abundant.

ANIMALS FEEDING ON TERMITES

As the white ants have no means of defense against their natural enemies, they are easily destroyed and are preyed on by many other insectivorous animals. Indeed, one of the impressive evidences of the great numbers of the white ants in South America is the existence there of certain large vertebrate burrowing animals that are said to feed almost exclusively upon the white ants.⁴¹

The great ant-eater, known in Brazil as the *tamanduá bandeira*, is said to live entirely on ants. Brazilians acquainted with the habits of the *tamanduá* tell me, however, that the ant-eater does not eat the *saúbas* or other biting or stinging ants, but that it lives chiefly and almost exclusively on the *cupim*, or so-called white ant. To give an idea of the size of the animal, I quote the following measurements of an ant-eater as given by Wells: Head, 16 inches; back, 4 feet; tail, 4 feet; total length, 9 feet 4 inches. He says it has no teeth.⁴²

³⁹ C. L. Marlatt: Circular 50, p. 3, 2d ser., Bureau of Entomology, U. S. Department of Agriculture. Washington, 1908.

⁴⁰ Maximilien, Prince de Wied-Neuwied: Voyage au Brésil, t. iii, p. 129. Paris, 1822.

⁴¹ Holes often found in the mounds of the true ants show that some of these large ant-eating animals feed on the true ants also.

⁴² J. W. Wells: Three thousand miles through Brazil, vol. II, p. 141. London, 1886.

The existence of an animal as big as an ordinary dog, over 2 feet high at the shoulder, with its long, slender muzzle, its powerful forelegs and claws adapted to the excavation and exploration of ant-mounds, and its tongue nearly a yard in length, and living chiefly, if not entirely, upon white ants, is an important witness on the side of the abundance of termites in the region in which it lives. Bates reports four species of ant-eaters in the Amazonas region, two of which are large and two small ones (op. cit., 2d ed., p. 110), while Wallace says there are five species in tropical America, besides one extinct form.⁴³

The armadillos, known in Brazil as *tatus*, are also ant-eaters. As Mr. Wallace points out,⁴⁴ the armadillos are highly characteristic of tropical South and Central America, and at the time of the publication of his famous work on the geographical distribution of animals they embraced 6 genera and 17 species, to say nothing of many extinct species found by Lund in the caves of Minas Geraes. Some of these armadillos are so large that a single individual will weigh as much as 75 pounds, or even more.

They live upon insects chiefly, and the white ants seem to be their favorite food. They enter the nests by digging openings at the base of the cones with their powerful fore feet.⁴⁵

Gardner states that the white ants also form the principal food of the South American ostrich (*Rhea americana*), which is the largest bird in tropical America.⁴⁶

In addition, there are large numbers of birds and reptiles, such as toads, frogs, lizards, and snakes, that habitually feed upon these insects.

Azara says that almost all kinds of birds except the "milano" feed on them.⁴⁷

The true ants are enemies of the white ants worthy of especial mention. The abundance of the ants and their pugnacious dispositions make them serious obstacles to the development of the termites' colonies, and they are probably their worst natural enemies. The termites have in their colonies forms that are known among biologists as soldiers, but so far as I have been able to determine from personal observations these soldiers do not attack the true ants, though they do take the place of sol-

⁴³ A. R. Wallace: The geographical distribution of animals, vol. ii, p. 247. New York, 1876.

⁴⁴ Alfred R. Wallace: The geographical distribution of animals, vol. i, pp. 245-246. New York, 1876.

⁴⁵ The flesh of the *tatus* is very much prized for food, and this naturally leads to the hunting and killing of these animals, which should be protected.

⁴⁶ George Gardner: Travels in the interior of Brazil, p. 280. London, 1846.

⁴⁷ Don Felix de Azara: Voyages dans l'Amérique Meridionale, vol. i, p. 192. Paris, 1809.

diers in obstructing the passage of the ants into the termites' nests and galleries.

The result of the relations existing between the true ants and the termites is that the two kinds do not thrive together; at least I have never found the termites' nests where the *sauíbas* or other true ants were notably abundant. Preyed on by the true ants and by animals of so many different kinds, and even by insects themselves, it occurs to one that their chances of survival in the midst of so many enemies must be very small. That survival appears to be due largely to their habit of living and working under the protection of their covered roadways, and to the fact that their roads are constructed of materials that are remarkably inconspicuous. Nothing could look more thoroughly abandoned and lifeless than the common run of white ants' nests and their covered passages; yet if one breaks through these coverings he will usually find them fairly swarming with life.

My general impression is that those white ants which build mounds of earth are especially abundant in the highlands of Minas Geraes and through the semi-arid portions of Sergipe, Bahia, Goyaz, Matto Grosso, and the interior of Ceará, Maranhão, and Piahy. Mr. Crandall tells me that he finds them most common on the Diamantina plateau. (Letter of June 23, 1909.)

STRUCTURES ABOVE GROUND

General characteristics.—The nests of the white ants, or *cupim*, have no visible external openings. When a mound is new or is being added to, the outside of the new portion is so soft that it can be readily broken off with a stick; but with time the outside usually becomes as hard as a brick. This hard outside covers the entire mound, and is usually about 6 inches thick, but in the very big nests it is sometimes nearly or quite a foot thick. Inside of this hard, thick covering the materials are quite soft and brittle, and the partitions are sometimes almost as thin as paper, though thicker in the larger nests. Where the mound stands on the ground, the cavities of the upper portion connect through the perforated base with subterranean excavations.

Parts of the nests are made of the excrement of the inhabitants. I have often broken the nests or the covered roads of these insects in order to observe the workers repair them. In every case observed the repairs were made by building up a wall or covering of excrement or something of the kind. At least it is voided from the posterior part of the body in a plastic condition, and is smoothed down on the sides so that the later layers always override the earlier ones on both sides of the wall. An ex-

amination of their construction, however, shows that they are made partly of clay or the earth about the nest and partly of woody fiber. These two substances are variously mixed in structure, sometimes one being more abundant, sometimes the other. An examination of the

FIGURE 5.—Above-ground Structure of White Ants

Seven kilometers west of Queluz, between Piquiry and S. Gonçalves, State of Minas Geraes. From a photograph by the author, August 4, 1907

materials of the outside part of the large and old nests, however, shows that this part of the nest at least contains fragments of quartz, sand grains, and such like rock fragments that could not possibly have passed

through the bodies of the insects. The structure of some of the nest walls suggests that these walls are constructed partly of earth and rock fragments brought up from beneath the ground and built into the nests

FIGURE 6.—Mound of Termites or White Ants, State of Minas Geraes, Brazil

From a photograph by R. Crandall, July, 1909

by cementing them together with excrement or some other adhesive substance.

The outer parts of the nests, when they stand on the ground, are, so far as my observations go, always made of earth cemented in a thick, hard wall. In the inner portions of the nest the partitions are thinner, and though they are made largely of an easy-spreading clay, they are often made partly, or at least overspread, with a dark, friable substance that has the appearance of being masticated wood, leaves, or other organic matter.

The openings through the mass of the nests are pretty uniform in size, being from 3 to 10 millimeters in diameter and averaging close to 5 or 6 millimeters. The openings within the nests sometimes have the appearance of being arranged in rude tiers; sometimes they are apparently haphazard labyrinths.

The external forms of the nests vary considerably, but unfortunately I do not know whether this variation is due to difference in the species of termites, to difference in the nature of the ground, or to other causes.

As a rule the mounds are rudely domed, rounded or conical, and the method of adding to the outside gives them a bumpy, lumpy appearance, so that, as Burmeister suggests, they resemble gigantic Irish potatoes. In some localities they are mostly tall and slender. Most of the tall, slender forms observed have been in wet ground or on ground that is sometimes overflowed. For this reason it is inferred that these forms are due to the presence of water rather than to a different species of termites. In size they also vary greatly. I have seen them as much as 6 meters high and 8 meters in circumference, but these very large ones are exceptional.

In southern Minas, south of Barbacena, Dr. R. Walsh notes mounds of the white ants 10 or 12 feet high: "I rode close by several which were considerably higher than my head on horseback and 9 or 10 feet in circumference."⁴⁸

Charles J. Dulley tells me that in the vicinity of Caximbu, in southern Minas, he has seen white ants' nests 4 meters high and nearly 2 meters in diameter at the base. Mr. H. E. Williams, assistant on the Geological Survey of Brazil, says that in the vicinity of Taubaté, in São Paulo, they are often 2.4 meters high, while about the city of São Paulo they usually are 1 meter and less in height.

Gardner says that many of the level tablelands of the interior of Piauí, where the soil is red clay, the mounds of white ants are abundant and often 6 or 8 feet high.⁴⁹

⁴⁸ Rev. R. Walsh: *Notices of Brazil in 1828 and 1829*, vol. II, p. 50. Boston, 1831.

⁴⁹ George Gardner: *Travels in the interior of Brazil*, p. 280. London, 1846.

In the valley of Rio Sapão, in northwest Bahia, Wells notes great numbers of white ants' nests from 4 to 6 feet high.⁵⁰

At and about Asuncion, in Paraguay, I found the nests very abundant on the clayey soils, and many of them as much as 3 meters high.

The outer portion of the nest being thick, hard, and compact, and the inside being friable and easily removed, it is a custom in the interior of Brazil and Paraguay to scoop out the inside of white ants' nests and to use them for ovens. The door is cut near the base of the cone, and the inside parts removed through it.

The accompanying illustrations will probably give a better idea of the sizes and shapes of the nests than verbal descriptions.

FIGURE 7.—White Ants' Nest, built of Earth, in the State of Minas Geraes

From a photograph by R. Crandall, July, 1909

I add short extracts concerning these nests taken from other writers. The following is translated from Auguste de Saint-Hilaire:⁵¹

"In the vicinity of Parahyba we saw along the side of the road the nests of the termites, or white ants; further on we saw nothing of them, but near Pinho Velho, and especially near the Mantiqueira, we found large numbers of them. . . . The nests of the species common to the vicinity of Mantiqueira are made of a much masticated clayey earth. They are nearly cylindrical,

⁵⁰ J. W. Wells: He says that in that part of Brazil the mounds are often occupied by bees. Three thousand miles through Brazil, vol. ii, p. 127. London, 1886.

⁵¹ Voyage dans les provinces de Rio de Janeiro et de Minas Geraes, vol. i, p. 108. Paris, 1830.

rounded at the top, and look like mile stones. Most of them are two or three feet high, but some of them are as much as five or six feet high, and I saw one that must have been twenty feet high and about as big round the middle where it was enlarged. The outside is covered with a crust as thick as a finger length, and no openings appear in it. The insides of some of these nests that have been overturned showed a series of black horizontal floors (planchers), one above another, close together, and pierced by round holes.

"The termites do not build their nests all at once. They enlarge them in proportion as the population of a colony increases, and the new parts are readily distinguished by the earth freshly laid on."

Sir Woodbine Parish speaks of "Corrientes and Paraguay, where whole plains are covered with their dome-like and conical edifices, rising 5 and 6 feet and more in height."⁵²

FIGURE 8.—White Ants' Nest of Earth in Matto Grosso, on the Plains of the Upper Paraguay

Sketch by J. C. Branner

In the region about the headwaters of the Paraguay the nests of the white ants are extremely abundant in favorable localities, and the forms of the nests are different from those noted in other parts of tropical America. The tall and very slender forms are especially noticeable in the low, flat prairie lands south of Cuiaba. (See figure 8.) These slender forms are known in that part of Brazil by the Indian name of *tacurú*.

Dr. João Severiano da Fonseca has the following in regard to ants in the vicinity of the city of Matto Grosso:⁵³

⁵² Sir Woodbine Parish: Buenos Ayres and the provinces of the Rio de la Plata, 2d ed., p. 252. London, 1852.

⁵³ Viagem ao redor do Brazil, vol. i, p. 352. Rio, 1881.

"The ants and the various kinds of *cupim* own the country. It is noteworthy that while their hives, or houses, vary in form according to the locality, they retain a certain uniformity of construction, having one shape here, another one there, and a different one somewhere else. I am unable to determine whether these differences depend on the soil and the materials of which they are constructed or upon the difference in the species of the constructors. It is certain, though, that in the vicinity of Cambara the country is covered with cylindrical columns called *tacurús* by the Indians. These are sometimes two metres high, and resemble the marks or columns known as stone friars. In some places, as below Corixa, on the Lixal and Burgres plateaus, they look like miniature castles half a metre high, with loopholes, gates, towers, and terraces. In other localities, such as Palma Real and Petas, they are lower, but thicker, sometimes isolated, and sometimes built against trees, but always very hard and made with a kind of bituminous cement that is impermeable to water."

Dr. Henry Drummond has the following on the white ants in tropical Africa:⁵⁴

"The material excavated from these underground galleries and from the succession of domed chambers—used as nurseries or granaries—to which they lead, has to be thrown out upon the surface. And it is from these materials that the huge ant-hills are reared which form so distinctive a feature of the African landscape. These heaps and mounds are so conspicuous that they may be seen for miles, and so numerous are they and so useful as cover to the sportsman that without them in certain districts hunting would be impossible. The first things, indeed, to strike the traveller in entering the interior are the mounds of the white ant, now dotting the plain in groups like a small cemetery, now rising into mounds, singly or in clusters, each thirty or forty feet in diameter and ten or fifteen in height; or, again, standing out against the sky like obelisks, their bare sides carved and fluted into all sorts of fantastic shapes (see figure 9). In India these ant-heaps seldom attain a height of more than a couple of feet, but in Central Africa they form veritable hills, and contain many tons of earth. The brick houses of the Scotch mission station at Lake Nyassa have all been built out of a single ants' nest, and the quarry from which the material has been derived forms a pit beside the settlement some dozen feet in depth. A supply of bricks as large again could probably still be taken from this convenient depot, and the missionaries on Lake Tanganyika and onwards to Victoria Nyanza have been similarly indebted to the labors of the termites. In South Africa the Zulus and Kaffirs pave all their huts with white-ant earth, and during the Boer war our troops in Pretoria, by scooping out the interior from the smaller beehive-shaped ant-heaps and covering the top with clay, constantly used them as ovens. These ant-heaps may be said to abound over the whole interior of Africa, and there are several distinct species. The most peculiar as well as the most ornate is a small variety from one to two feet in height, which occurs in myriads along the shores of Lake Tanganyika. It is built in symmetrical tiers, and resembles a pile of small rounded hats, one above another, the rims depending like

⁵⁴ Henry Drummond: Tropical Africa, pp. 89-90. New York, 1891.

eaves, and sheltering the body of the hill from rain. To estimate the amount of earth per acre raised from the water-line of the subsoil by white ants

FIGURE 9.—Mound of White Ants in the laterite Region of Africa

Redrawn from "Il Ruwenzori," parte scientifica, volume ii. Prof. Alessandro Roccati. Petrografia e mineralogia. Milano, 1909, plate I. figure 1

would not in some districts be an impossible task, and it would be found, probably, that the quantity at least equalled that manipulated annually in temperate regions by the earth-worm.

"These mounds, however, are more than mere waste-heaps. Like the corre-

sponding region underground, they are built into a meshwork of tunnels, galleries, and chambers, where the social interests of the community are attended to."

Age of the mounds.—The method of building the mounds and the habits of the termites, so far as I am acquainted with them, lead to the conclusion that the size of a mound is determined by its age and by the size of the colony building it. Just how long it requires to build the large mounds I have but little means of judging. One frequently sees nests built on houses and fences, and in these cases it has been possible to determine the maximum ages of these particular nests. These cases, however, afford only a suggestion. The oldest nests I have seen, and of which I could get an idea of their ages, were not more than 50 years old, and the biggest of them contained a little less than 1 cubic meter of earth, the estimate being made without reference to the cavities within the mass.

It is evident that the size and age in one of these cases may or may not help one to determine the time occupied in the construction of one of the very large nests figured in this paper, for the rates of building may have been very different.

UNDERGROUND STRUCTURES

The above-ground structures of the white ants connect with underground passageways, but wherever I have seen these passageways opened they appear to have been excavated and then to have been filled with smaller chambers made of materials like that used to make the chambers of the mounds above ground. An examination of the thin chamber walls found in some of the underground excavations shows that they have been constructed of soft, plastic materials so piled up that each later addition overlaps the preceding one on both sides of the wall. The materials are partly of reddish clay like that of the ground in which the nest is made, and partly of a dark brown substance that I take to be organic matter—probably masticated plants.

I have never seen the excavations made by the white ants more than a meter and a half below the surface, but I have heard of them being found considerably deeper. My friend, Dr. Joaquim Lustosa, of Lafayette, State of Minas Geraes, writes me on this subject: "As for the depth to which they penetrate the ground, it is my impression that it is but little more than 3 metres."

RELATION OF NESTS TO THE SOIL

The white ants do not seem to be so dependent on the character of the soil as do the true ants. This is probably due to the fact that when the

true ants excavate their tunnels in the earth they depend on the character of the ground and the form of the excavations to support the structures. The white ants, on the other hand, depend partly on the nature of the soil, but partly on their method of cementing the materials of which their nests are made.

The preference, however, of the termites for certain soils and certain localities is very evident in some districts. On the upper Paraguay places have been seen where the nests are quite thick over certain areas, while there were none, or but few, on an adjoining area. Wherever these marked contrasts have been observed, however, they have apparently been due to a difference in the amount of moisture in the ground. I have thought that the white ants are sometimes found in rather wet ground, because they are there comparatively free from the attacks of their enemies, the true ants.

Opinions of Brazilians in regard to the distribution of the termites' nests vary considerably; some think they are more abundant in the open campo regions than in the forests; others think they prefer fields; still others think they are favored by a dry climate. All of these views appear to have more or less support. I have much doubt, however, about the theory of their preferences for campos. It is true that they do appear very abundant in the campo regions, but I am of the opinion that the apparent abundance is deceptive and due to the fact that all the nests are visible at once over a wide area (see plate 35, figure 2), while in a forest-covered area no nests, or but few nests, can be seen on account of their being concealed by the dense vegetation. This impression has been deepened by the fact that in several instances where the forests have been cleared away the mounds of the white ants appear to be quite as abundant as they are in the old clearings or on the open campos.

Further support is given this theory by Maximilien, Prince de Wied-Neuwied, who, in speaking of the white ants' nests near Conquista, in the southwestern part of the State of Bahia, says that they are extremely abundant in covered and wooded places.⁵⁵

RELATIONS TO VEGETATION

Compared with the true ants, the white ants are harmless. At least they do not attack crops and animals or render certain localities uninhabitable. The harm they do to agriculture is confined to the mere encumbrance of the ground by their big, hard, rock-like nests. They do, however, destroy wood used in the construction of fences, houses, bridges,

⁵⁵ Voyage au Brésil, vol. iii, p. 129. Paris, 1822.

and furniture, and they sometimes burrow into books and papers that are left to stand for a long time undisturbed.

I quote below some remarks of other writers in regard to the destruction of timbers by termites, but I must add that I am disposed to question the rate at which these insects are said to destroy wood. My own observations lead me to conclude that the idea expressed by Drummond and others that a piece of furniture may be destroyed in a night is simply a picturesque way of putting it. In the first place, there are certain kinds of wood (in Brazil at least) that the termites do not attack at all. I am unable to say just now what kinds they are, but it is a matter of common information among Brazilian carpenters and cabinet-makers.

In the second place, the method of discovery of their destructive work frequently leaves an erroneous impression. In accordance with their general habit of keeping away from the light, termites attack a piece of wood that forms a part of a building from within. Their work does not appear at the surface at all, and it may be carried on for months, or even for years, without its being discovered. But some day a window-sill crushes in, a door-post is shattered by a trifling blow, or a rafter gives way without its ever having been suspected that they were being attacked by the cupim. The suddenness of the discovery not unnaturally leads to the unwarranted inference that all this work was done during the preceding night.

The following quotation is taken from pages 78-83 of Dr. Henry Drummond's little book called "Tropical Africa," which has an interesting chapter on white ants (pages 77-94) :

"The termite lives almost exclusively upon wood, and the moment a tree is cut or a log sawn for any economical purpose this insect is upon its track. One may never see the insect, possibly, in the flesh, for it lives underground, but its ravages confront one at every turn. You build your house, perhaps, and for a few months fancy you have pitched upon the one solitary site in the country where there are no white ants. But one day suddenly the door-post totters and lintel and rafters come down together with a crash. You look at a section of the wrecked timbers, and discover that the whole inside is eaten clean away. The apparently solid logs of which the rest of the house is built are now mere cylinders of bark, and through the thickest of them you could push your little finger. Furniture, tables, chairs, chests of drawers, everything made of wood, is inevitably attacked, and in a single night a strong trunk is often riddled through and through and turned into matchwood. There is no limit, in fact, to the depredation by these insects, and they will eat books, or leather, or cloth, or anything, and in many parts of Africa, I believe, if a man lay down to sleep with a wooden leg it would be a heap of sawdust in the morning. So much feared is this insect now that no one in certain parts of India and Africa ever attempts to travel with such a thing as a

FIGURE 10.—*Nests of White Ants in Africa*
From "Tropical Africa," by Henry Drummond, opposite page 88

wooden trunk. On the Tanganyika plateau I have camped on ground which was as hard as adamant, and as innocent of white ants, apparently, as the pavement of St. Paul's, and awakened next morning to find a stout wooden box almost gnawed to pieces. Leather portmanteaus share the same fate, and the only substances which seem to defy the marauders are iron and tin."

The following extracts give an idea of how the work of the white ants looks from the point of view of the civil engineer:⁵⁶

"The forests contain some varieties of hardwoods which would be suitable for permanent structures were it not for the ravages of insects. A species of white ant, called locally 'cupim,' appears to be the most destructive. These insects seem to attack timber bridges more than they do the timber ties, which are partially buried in the ground. They work in armies, building nests and artificial tunnels on the outside of bridge timbers and, working into the heart of the timber from the ends. Although the largest of the 'cupims' yet observed is no longer than $\frac{1}{4}$ inch, so rapid and destructive is their action that the life of a timber bridge can hardly be considered more than two years. Frequently stringers and timbers whose ends butt together, appearing perfectly sound on the outside, are found in an incredibly short time to be so thoroughly honey-combed by this energetic little creature as to become unsafe members in a bridge or other important structure. No satisfactory method of preventing the action of the 'cupims' has yet been found here. Kerosene poured over a nest or into a tunnel will kill the insects within. The timber can then be scraped clean, but another army is soon at work again.

"Timber bridges have been built at various places to expedite the work and get the rail head to the front, but for permanency steel and masonry are the only materials suitable. A considerable quantity of pine lumber from the Southern States is being used for building purposes in Porto Velho. The experience up to date indicates that the insects do not attack this resinous wood, but not sufficient time has yet elapsed to prove conclusively that pine lumber will withstand their ravages. Ties of native lumber used in the track, either on account of the vibrations of passing trains or the partial covering of earth, resist the 'cupim' more successfully."

It should be noted that although the white ants are abundant in forests, I am not aware that they ever attack the living trees. They appear to eat only the dead trunks or dead limbs or bark. Many of them build their nests on the trees. Nests found high up on tree trunks are always, so far as I have observed, made of woody matter and not of earth. Those on trunks, only a meter or two above the ground, are often made partly of woody matter and partly of earth.

PHOSPHORESCENCE

It has been stated that some of the termites are luminous. On this subject see notes by Frederick Knab, *Science*, vol. xxx, October 22, 1909,

⁵⁶ John Y. Bayliss: The Madeira-Mamoré Railway. *Engineering News*, vol. lxi, p. 454. New York, October 28, 1909.

pages 574-575, and by J. C. Branner, *Science*, January 7, 1910, pages 24-25.

Herbert H. Smith, a thoroughly trustworthy entomologist, mentions phosphorescent termites near Santarem, on the lower Tapajos:

"There are white ant-hills along the sides (of the road)—pale glows of phosphorescent light, like coals in the ashes. . . . The phosphorescence is in the hills themselves, not, so far as I know, in the insects, and I believe that it is peculiar to the mounds of one or two forest species."⁵⁷

FIGURE 11.—White Ants' Nest in a Tree, Salitre Valley, State of Bahia

J. C. Branner, 1907

Prof. Harold Heath, who has studied the termites of California, has given me the following statement:⁵⁸

"Regarding the luminosity of termites, I can confidently assert that the three species (*Termopsis angusticollis*, *Calotermes castaneus*, and *Termes lucifugus*) living in the vicinity of San Francisco do not exhibit this peculiarity. The logs inhabited by these animals are occasionally infected by a species of phosphorescent slime mould (myxomycete), and when such colonies are disturbed at night, in the building of camp fires, for example, particles of brightly shining wood, or of the mould itself, may be seen attached to some of the individuals, but there is no true phosphorescence of the body. Furthermore, I have kept, during a period of several years, hundreds of colonies in glass jars placed in a cellar room, and these never showed any signs of the phenomenon in question."

⁵⁷ Herbert H. Smith: Brazil, the Amazon, and the Coast, p. 139. New York, 1879.

⁵⁸ Stanford University, California, February 7, 1910.

GEOLOGIC WORK

EARTH MOVED

The amount of earth brought to the surface by ants in a few instances has been given. The calculations at page 469 show that in one case the earth brought up would cover the ground to a depth of 22.25 centimeters. The estimate of Gounelle, mentioned at page 470, makes the earth brought up 15 centimeters thick. In neither of these cases is it known how long the building of the mounds occupied.

Mr. Darwin's study showed that the earthworms in many parts of England bring to the surface annually 10,516 kilograms of earth to the acre.⁵⁹ In order to compare the work of ants with that of earthworms, it would be necessary to know how long the ant-hills were in process of formation. Unfortunately I have no trustworthy means of determining the ages of the mounds. If we assume an average of 100 years for the age of the mounds over the area measured (an average which seems to me quite conservative in this case), the total work of worms and ants would compare as follows:

Total weight of earth brought to the surface in 100 years over 1 hectare (10,000 square meters):

By worms in England.....	2,598,500 kilograms
By ants in Brazil.....	3,226,250 kilograms

It is to be noted that the amount of work done in both instances is rather exceptional—that is, localities were selected favorable for exhibiting the activities of worms in one case and of ants in the other.

I have no trustworthy data showing the amount of earth brought to the surface by termites over a definite area. The places seen where the nests were most abundant were in low, inaccessible grounds on the upper Paraguay. My impression is that in those particular localities there was less earth brought up than in the case of the true ants cited above.

The sizes of individual white ants' nests were frequently measured. One of the largest I ever saw in Minas Geraes was 6 meters high and 8 meters in circumference 2 meters above the ground, and contained 30.55 cubic meters of earth, no account being taken of the porous nature of the structure, which would probably reduce this total by 3 or 4 cubic meters.

Another unusually large mound in the State of Minas was 4 meters high and 7 meters in circumference 2 meters above the base, and contained 15.59 cubic meters of earth. These are individual cases, however,

⁵⁹ Charles Darwin: *The formation of vegetable mould through the action of worms*, p. 305. New York, 1882.

and I am unable to say how large an area the contents can properly be distributed over, how long the termites were in doing the work, or how large the colonies were that made them.

In the case of the white ants, the earth undergoes some process of digestion and passes through the bodies of these insects, so that the chemical effect is probably more important than the mere upturning it gets from the true ants.

ORGANIC MATTER

The true ants carry into their burrows enormous quantities of leaves and other organic matter. These leaves must yield either directly or indirectly organic acids, which help attack the soil, the minerals, and the rocks with which they come in contact.

The organic matter carried into their burrows by the termites consists chiefly of the decayed wood and other vegetation eaten by them. These materials, however, can not fail to contribute organic acids that help attack the minerals of the soil and adjacent rocks.

OPENINGS IN THE SOIL

The extensive subterranean excavations, especially those of the true ants, permit the freer circulation of atmospheric air and of carbon dioxide. These channels must also serve from time to time for the passage of meteoric waters, and their great extent and ramification must hasten very considerably all the processes of atmospheric disintegration and alteration of soils, minerals, and rocks.

Unfortunately we have no observations at present that enable us to give quantitative values to these underground agencies and activities. We only know that the openings beneath the surface are rudely equal to the amount of soil in the above-ground structures.

RÉSUMÉ

Ants and termites are vastly more numerous in tropical America than they are in the temperate regions.

They show a marked preference for, or rather their structures stand up better on, clayey than on sandy soil.

They affect the geology, especially the soil and subsoil, both directly and indirectly.

Directly:

1. By their habits of making underground excavations that radiate from a central nucleus and often aggregate several miles in length.

2. By opening the soil to atmospheric air and gases.
3. By bringing to the surface large quantities of soil and sub-soil.
4. By introducing into their subterranean excavations large quantities of organic matter which must yield acids that affect the soil and the subjacent rocks.
5. By using these excavations for habitations and the production of gases that attack the soil and its contained minerals.

Indirectly:

6. By the periodic passage and circulation of meteoric waters through their extensive tunnels.
7. By affecting the availability of the soil for agricultural purposes.
8. By affecting the habitability of the land by man.
9. By the destruction of crops.
10. By the consumption (by termites) of dead plants and of timbers and lumber used in houses and for the manufacture of furniture, machinery, etcetera.

Although the data available are defective, we seem to be warranted in concluding that ants and termites are quite as important geologic agents in tropical America as are the earthworms of temperate zones.

They are also factors of great importance from an agricultural, economic, and social point of view.

POSTSCRIPT

Since this article was in type I have received the following letter from my Brazilian friend, Dr. Joaquim Lustosa, in regard to the subject of the luminosity of termites mentioned on pages 491-492. The letter is dated Lafayette, State of Minas Geraes, Brazil, July 8, 1910:

"I have just received authentic information to the effect that in the State of Matto Grosso, in the low, swampy lands along streams, and especially in the rainy months beginning with October, myriads of fireflies are seen covering the ground. My informant, who has lately come from the upper part of Matto

Grosso where it joins Bolivia, tells me that he has seen at night many of the nests of white ants that have been abandoned by the ants themselves entirely covered by fireflies that come from the small openings over the whole surface of the ant-hill. Is it possible that the fireflies select these abandoned ant-hills as places in which to grow their larvæ? . . . Unfortunately I have never observed anything of the kind hereabout, though I have been interested in the subject in order to furnish you information."

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Geologic work of ants in tropical America

J. C. BRANNER

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Notes