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SEQUENTIAL DISTRIBUTION OF *FORMICA EXSECTOIDES* FOREL.

By E. A. Andrews.

Johns Hopkins University.

Observations here recorded, indicate that the mounds made by this ant arise and pass away in rhythms harmonious with phases of forestation.

The continued life of this species may indeed be dependent upon the migrations to new growths of trees. Trees that when young furnish food for the ant, when mature may cut off sunlight needed to make the mound a successful incubator for the young.

Thus in fifteen years there has been found a migration of mounds comparable to the moving on of some primitive peoples dependent upon newly cleared forests.

According to *the* book upon ants, and to other writings of that foremost student of these animals, Professor William Morton Wheeler; the most common mound building ant of North America belongs in the species of *Formica exsectoides* Forel, and its mounds have been observed in Nova Scotia, Ontario, Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, North Carolina, Georgia, Wisconsin, Illinois and Colorado, though there may be doubt as to all the extreme western forms being of the same species as the others.

In general these ants are spread along the Appalachian region and are to be looked for in hilly or mountainous regions where the land is wooded more or less. It is thus exceptional to find these mounds near sea level as Wheeler observed them in Staten Island and as I have seen a few in Massachusetts ten feet

above low tide and but few hundred feet from open salt water and again near Baltimore in the region of Cowenton on the neck between Bird River and the Gunpowder at an elevation of much less than one hundred feet.

One important factor in restricting these mounds to hilly country may well be not so much the elevation as the probable association of good cultivation with level and lower lying land while in the hills there are greater opportunities for partly wooded regions, especially abandoned fields and clearings growing up with new woods and left comparatively free from live stock and human interferences, so that the colonies of ants may find both food and freedom from disturbance for long periods of years.

The classical account of the mound building ants of America is that of the enthusiastic student of ants, the late Rev. Henry C. McCook, who camped out for a week in August 1876 amongst the ant communities one mile north-east of Hollidaysburg near Altoona, Pennsylvania, where there were some fifty acres of ant mounds on the southwest base of Bush mountain belonging to the Cambria Coal and Iron Co. This region of sandy, stoney soil grown up with open woods of oak and few pines was known to the people of the region as the "Ant City": and at the present date the trolley station there is labelled "Ant Hills." In this community or city were no less than 1700 dwellings; 25 to 33 to the acre. In other neighboring regions: Warriors Mark and Pine Hill: there were in the former 30 to the acre (but some were abandoned and moss grown) and in the latter 1800 dwellings at the rate of 30 to 59 per acre.

Not only were the mounds so numerous but some were of great size, 10-12 feet around the base and 2½-3 feet high. A photograph published by McCook shows a mound that was 25 feet around, 6 ft. 9 in. up the West front, 3 ft. 6 in. up the East, 4 ft. 4 in. on the South and 4 ft. 3 in. down the North face. Another photograph represents a mound 24 inches in vertical height and a third one 32 in height.

At Warriors Mark and Pine Hill he records even larger mounds. A fine cone was 12 feet across over the top and 30 feet around the base. While the largest of all three thousand or more seen was 42 inches in vertical height and 58 feet around the base

while a line across its top measured 24 feet. This was one of a pair and the other measured 15 feet across the top and 47 feet about the base. Both these great structures were built up upon an old level charcoal hearth; and hence their age was limited.

No such large accumulation of these vast works of mound-building ants seems to have been recorded elsewhere; but Wheeler figures a mound in New Jersey 1 m. x 3.25 meters and a mound of another species in Belgium as 2.15 x 9.8 meters.

In Maryland the mounds made by this ant are not uncommon in the wooded mountains of central and western countries where the summer visitor often evicts them with little regard for any claims that might be set up by these red and black original inhabitants so that in time not only the demands of agriculture but the thoughtless aspects of enjoyment of nature may combine to exterminate the present mound builders.

In eastern Maryland one may find the mounds here and there in Baltimore County, near Baltimore, as along the hills West of the limestone valley in which lies Cockyesville, up the Beaver Dam Run, and north of Green Spring valley where a fine grass-grown mound was measured and photographed in 1906 by Professor Philip H. Friese, along the North Run, a mile north of Stevenson. As described in a letter of that date this mound was about thirty inches in height and a perfect cone except for rounded top and evidently owed its steepness to being covered with grasses, some of which were not represented among the grasses of that neighborhood. And as above noted there are quite a number of small medium mounds near the shore below the Piedmont Plateau, in the region near Cowenton. While most of these mounds stand alone or a few in a group, an unusually populous settlement of ant's mounds was found near Lutherville and Timonium, some nine miles north of Baltimore, by the late Professor Basil Sollers who called attention of the Baltimore Naturalists Field Club to this favorable place for study of these mound builders.

However these ants were earlier known to the late Professor Philip Uhler, sometime Associate in Natural History in the Johns Hopkins University and Provost of the Peabody Institute, who told me that in his boyhood, when he lived at Lutherville,

these ant mounds were less numerous but individually larger. That period was probably about 1850. This is in harmony with the existence in 1905 of a few very large circular regions indicating old mounds long since washed away.

The region in which these ant mounds of Timonium occur is a large tract of deserted land of some 600 acres, roughly a mile on each side, bounded on the West by the York turnpike, on the East by a road leading out of the old Dulaney Valley and Sweet Air Turnpike, on the North by the "cinder" road and on the South by the open farming country of Long Quarter. This region is largely given up to young woods and used as wood lots, not pastured nor fenced for the most part, having been formerly used as source of bog-iron ore for the Ashland Iron Ore Co. of Ashland, Md. which left various large and small excavations abandoned at different dates down to 1888 when the last work was done. It is represented by diagram one, which shows the positions of the ant mounds, but with the size exaggerated.

The land slopes gently from elevation of 400 feet in the northwest to elevations of 300 toward the southeast and two springs give rise to a little run which flows toward the Gunpowder.

The soil is poor with gravel and at the south a small outcrop of crystalline limestone with two large excavations. The geological formation is said to be Potomac or lower Cretaceous.

A reconnaissance of this area made in December 1905 showed that the ant mounds were located in two regions, a larger "town" near the York road [above in the diagram] and a smaller "village" to the south [to the right and below in the diagram] separated from the larger settlement by a third of a mile of woods in which however a few faint indications of the former existence of large mounds suggested that at one time the two settlements might have been connected. Ants carried in the following summer from the mounds of the larger to the mounds of the smaller settlement did not seem to excite hostile responses but were immediately allowed to run into the mounds without being fought by the inhabitants. Ants taken April 14, 1906 from the "village" and put in a mound in "town" did not start up a fight, but the queens were seized and dragged along into holes in the strange mound. This may be taken as some indication that the ants in

the two settlements were not of remotely different origin, but probably all of one general society.

In the larger town 157 mounds were enumerated of which 95 were occupied and 62 deserted while in the village only 27 mounds were found; of these 22 were occupied, and 5 deserted. The larger mounds were in the larger settlement, while the village had the appearance of being a more recent growth from immigration.

In size the mounds varied from 1 to 8 feet in diameter and 4 to 24 inches in vertical height.

Three general types of architectural effect were noted. Some mounds were free from vegetation and showed fine conical forms the resultant of the untiring efforts of the ants to carry up onto the mound mouthfulls of earth and bits of stick and dead leaf as well as large bits of stone and other objects to be found on the surface of the ground near the mound, counteracted more or less by the down rolling and washing of the materials in the usual process of denudation of hills of all sizes. When the subsoil is red the mounds are red, when white, white, and again the collections of small sticks may give grey effects.

A second type of mound common in grassy glades presents more abrupt sides and artificial, tower-like contours from the combination of the above factors complicated by the upgrowth of certain grasses and other plants, as peppergrass, which tend to holding the down-rolling materials in steep slopes. A third and rare aspect is that of the mound partly coated over with moss which makes the natural surface more resistant to denudation and tends to emphasize differences in slope between the faces of the mounds that do and do not support moss.

While the typical mound is nearly circular many are much elongated as if made up of the fusion of two formerly separate cones: while others elongate down steep slopes of the ground.

Changes in Distribution of Ant Mounds in the Timonium Ant Community in 15 Years.

The census of the mounds of the entire region made in 1905 showed 184 mounds of which 117 were occupied and 67 deserted.

A second census made by several students in 1920 recorded

193, of which 182 were occupied and 10 or more deserted. The impression, however, was that many mounds were smaller, that there were not as many great mounds as fifteen years before; and this is in harmony with the opinion of Professor Uhler that the mounds of 1850 or so had been larger and fewer than fifty years after that.

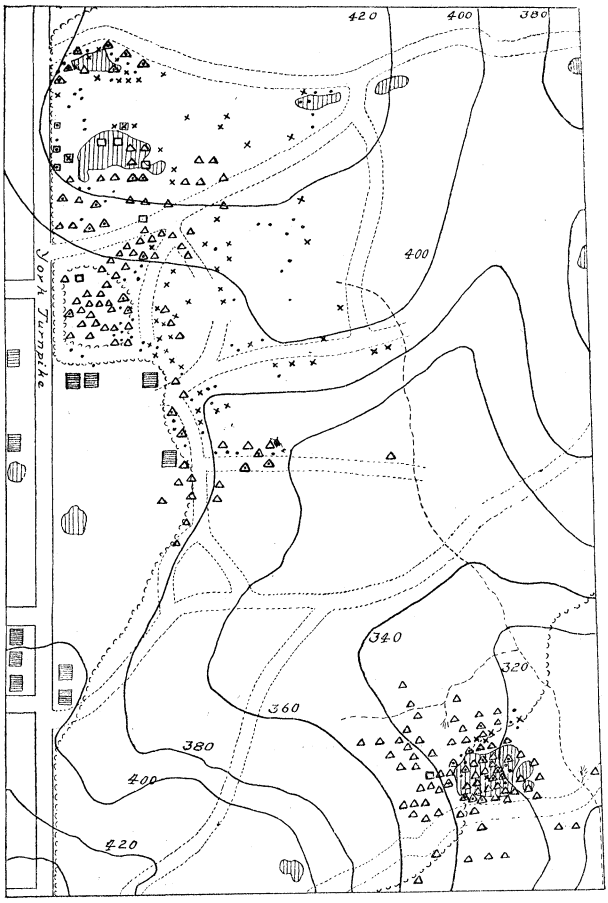


Diagram 1

Actual survey showed that the many mounds were distributed differently from the mounds of 1905. The following table shows the changes in distribution:

	North		Middle		South	
	Active	Deserted	Active	Deserted	Active	Deserted
1905	40	24	55	38	22	5
1920	33	9	65	1	84	1

Thus the deserted mounds of the north section had largely disappeared, and so had those of the middle region and of the southern region; however, the census of deserted mounds was not as accurate in 1920 as in 1905.

The increase in active mounds was most pronounced in the southern settlement or village where the number jumped up from 22 to 84, nearly a 400% increase.

There was also an increase from 55 to 65 in the middle region and a diminution in the north from 40 to 33. The increase was greatest in the south, great in the middle, and negative in the north.

The shift of population from the north and the occupation of new mounds in the middle and south is shown at a glance in the first diagram, which shows by dots the mounds that were active in 1905 and by x marks the mounds deserted in 1905, and by triangles the active mounds of 1920 and by squares the inactive mounds of 1920.

Many of the active and very many of the deserted mounds of 1905 were not extant at all in 1920. We see here that the more easterly mounds of the community had been abandoned, all the mounds of 1920 being to the west or to the south, with few exceptions. None of the deserted mounds became reinhabited as far as ascertained. After 15 years but two of the deserted mounds were still discernible as traces as indicated by a square enclosing an x. In 1920 three of the active mounds of 1905 had been deserted as indicated by squares enclosing dots. After 15 years, some 25 mounds still remained active as indicated by triangles around dots. But very many of the active mounds, shown by the plain triangles, were new developments not directly connected with the mounds of 1905.

The nearly pure constellations of these new mounds are,

near the York Road in the middle region, called the flats, and the larger one in the south, village, region.

The area embraced by the population in 1920 is no more extensive than in 1905 and the number of active mounds about the same, but there was a shift of relative location of many domiciles: the north losing, the middle and especially the south village gaining many new mounds.

There had been increase in density of housing: in the north and middle concentration had resulted from occupancy of about one fourth the former area. Concentration is accompanied by abandonment of some areas and migration into others but the entire area is not abandoned nor fundamentally altered in its interior, but rather one edge fades away as the opposite advances. After fifteen years the northwest part is reorganized; there is recession all along the east and great protrusion in the middle west portion; while the south village expanded in all directions.

In the town the centre of population moved to the west; destruction of some suburbs being compensated for by new growths elsewhere.

Yet the entire occupied area has shrunken while holding about the same number of domiciles.

Before considering possible causes of these shifts in population, some details of change in the northwest region may be considered. Of 61 nests mapped in 1905 only 18 were found, of these 8 were still active and 10 dead; but three of these had been dead in 1905, thus of the 18 found, 8 had continued 15 years and 7 had failed in that time. Of the 61, 21 were apparently deserted in 1905. Thus, of 40 active nests, fifteen years left 7 remaining as vestiges and 8 as still active. Also there were still remaining vestiges of three that were dead in 1905.

Table of amount of growth in 6 of the 8 that survived 15 years.

Mound No.	Gain in Height	In Diameter.
3	2 in.	34 in.
54	2	5
54 twin	8	18
58	12	50
59	3	12——36 N. S.
60	9	18——20 N. S.
	Average 6	Average 23-27

The mounds that continued active through 15 years had grown variably, from 2 to 12 inches in height and from 5 to 50 inches in width. Each of the above eight mounds was a foot or more in height in 1905 and doubtless of some years' standing.

Special attention should be called to the pair of mounds No. 54 on the edge of a gravel pit which were always conspicuous for dark color and coarse sandy surface due to the special environment; there being hereabouts little but subsoil and a growth of false indigo which in the fall yielded dark blackish leaves that were collected on the nests to such an extent as to make these appear very dark. The hills in 1905 were small but not apparently young; one 9 by 24, the other 4 by 18 inches. In the whole 15 years the former grew to be 11 by 29 and the latter 12 by 36. They had grown almost to touch at the base and one had advanced a little over the edge of the cliff. From that period up to the present, these two mounds remain but little changed, being of very slow growth, apparently resulting from poor conditions of soil and of vegetation.

In contrast, the mound No. 59 which was very large in 1905, being 2 feet by 5 feet, had in fifteen years grown to 32 inches by 96 inches, measuring 115 inches over its surface and with a circumference of 22 feet. This mound in the midst of Japanese honeysuckle has always been nearly clear of all but a little grass and the vine has stopped rather abruptly at the moat or clear area about the base, being restricted in growth by the ants of this very successful nest. This mound still continues, and though in the past few years it showed signs of weakness in lack of growth and poor upkeep it is greatly recovered in 1926.

Many other cases were recorded showing marked individuality in the mounds, not only in architecture and location but in longevity, rate and character of growth and decay.

The individuality of each mound is a result of interaction of the environment and the special internal states of each community, as failure or success depends upon both external and internal factors.

The mound is not only the abode of the adults but preeminently the incubator for the young and thus the means of securing the perpetuation of the race. The mound is not a tem-

porary seasonal affair like the nest of a wasp but may be of very considerable permanence, one of the most enduring architectural results of insect communism. In considering possible reasons for differential success and failure as between mounds near together, it must be born in mind that these ants are long-lived amongst insects. Ants were kept in captivity by Lubbock for five or six years as workers and up to fifteen years of age in the case of a female ant.

In nature ants of this species lie dormant about four months of the year and it may be that thus they live longer than in captivity; nevertheless it is probable that the mound may outlast the lives of the original builders and be possessed throughout the generations.

Some of the mounds mapped in 1905 were already large and remained active in 1920 and even in 1926. To attain that large size probably requires several or many years judging from the measurements elsewhere recorded (Andrews, Growth of Ant Mounds, Psyche, 32, 1925); so that a mound already large in 1905 may at this present writing be over thirty years old which is in harmony with the estimates of McCook as to the time that one mound may endure and in agreement with the fact that Forel had a prosperous mound of a related European ant under observation for forty years. The final end of the existence of a mound may be like that of a human city, variable, complex and to be known only by detailed history—which has not as yet been written up to the last day of any ant mound.

That the mound may persist longer than the original founders of the mound is probable also from a described habit of this ant to seize upon young female ants after swarming and to get them into the old mound in some cases so that many mothers of different ages are actually found in a well advanced mound. Hence the deficit of population from old age may be compensated for and the tribe or family be able to live on in the same old mound, if all goes well.

As to empty mounds: beside desertion by migration any one mound may lose its inhabitants either from internal or external causes, (sufficient disease or epidemics are not yet known) but old age of the inhabitants would lead to an empty mound if

the above process of substitution of younger for older did not succeed in any one mound. Of external inimical factors there are many, such as man's culture of the field, his domesticated animals tramping on ants and the mounds, his direct hostile acts and the attacks from animals that feed on ants, as the skunk and the woodpecker, also adverse influences of mosses and other vegetation. In this Timonium region, the direct causes of the extinction of life in mounds are not at all known.

On the other hand the differential dying off of many mounds in one part of the area and the coincident appearance of new mounds in another section of the area is a phenomenon that may be correlated with environmental factors. As far as known important enemies of the ants are largely absent from the whole area and as impotent in one as in another section of the region and the success or the failure of groups of mounds would seem more likely due to some factors that have changed slowly through the many years.

As in general *Formica exsectoides* is found where there are trees but not dense old forests, it may be regarded as a dependent upon certain stages of forestation.

In the north region of the diagram during the slow disappearance of so many mounds there was greater growth of the trees and increase in their age. In the middle region the inrush of new mounds in fifteen years has been accompanied by the upspringing of a new growth of young trees.

This correlation of many new mounds with new trees and many empty mounds with old trees may well be significant. It is supported by such facts as: the vestiges of old mounds in the region between the ant "town and village" where the woods are dense and old; the failure of a mound transplanted to the large woods of "Homewood" and its better success when the ants migrated spontaneously to the open edge of the wood in Wyman Park; the great success of colonies in the Holidaysburg region where mining operations kept the forest cut down in part; the present flourishing of a large colony in the cut-over forests of the neighboring Warriors Mark. (Andrews, Ent. News, 1925), and the observation that this ant in early spring is more active in regions of sunny exposure than in older woods.

If the trees and ants are interconnected possibly one or the other of the two basal factors of animal success may be involved; the gaining of food for energy of the individual ant or else the proper conditions for reproduction and the continuance of the species. One mound may not obtain food enough to keep up the depletion in population, while another mound may obtain a surplus of food and be able not only to maintain itself but actively to colonize the surrounding neighborhood with new and rapidly growing mounds.

Unfortunately little is known about the food of this particular mound building ant. In this region it is observed that the ants climb the trees near their mounds and go out on the branches and leaves; it is observed that they get honey dew from some kinds of aphids or plant lice and from the black leaf hopper *Vanduzea arcuata* Say. They are seen to drag various dead insects into their mounds.

It may be assumed that these ants depend greatly upon trees for their food supply which is partly at least carbohydrate in nature. In artificial formicaries many kinds of ants can be kept very long periods when fed chiefly sugar and water or honey.

If it be granted that ants derive their energies from food supplied by trees, there may be an inverse ratio between the food got and the work done in getting it, according to the height and food-supplying character of the trees. If small young trees give as much food per unit of leaf or photosynthetic element as do the old trees, then the labor of going up the old tree to get the food will be greater than going the short distance up the young tree; and on an exceedingly tall tree, the ants might use up all the energy acquired before they ever got down to the ground again. Also, it may well be that the tender young shoots of young trees feed more aphids and yield more sap than is available from like area of the twigs of an old tree, so that it would advantage the ant to visit the young rather than the old tree.

From the data given in "Bau und Leben unserer Waldbäume," M. Buesgen, Jena, 1917, we infer that the total photosynthetic area of a young tree five or six years old may be some 4 square meters; but of an older tree 13 to 14 meters in height, from 8 to 24 square meters according as to whether it grows under

shade or jutting up into the sunshine. In a crowded stand of such trees each may have 12 square meters area of leaf. Each of these crowded trees may then expand three times as much leaf area as when young but it will be perhaps six times as high as when young: thus the ant to get all over its green leaves will have to run up twice as much trunk as when the tree was young. We conclude that as long as the trees are young and have not crowded one another and have plenty of sunshine their combined leaf surface within the ant's walking distance to its mound will be greater than when these trees have grown crowded and tall, since the stems of the trees increase more rapidly in height than the entire leaf area expands.

In endeavoring to apply the above considerations to the observed changes in distribution of the ant mounds we observe that in the fifteen years the trees of the old wood in the northwest area had grown older and the ground more densely shaded, and the ants had not increased.

In the middle region where in 1905 the earth was quite bare and very poor dump, spread out in a plain of several acres, there had grown up more and more young trees, especially black locust, gradually encroaching from the edges over more and more of the bare area along with coarse grass and brambles and Japanese honeysuckle. In this region the new ant mounds became very abundant.

Again in the region of the "village", where in 1905 trees were few and far from the two old mine holes that were grass-grown, there sprang up more and more young trees and here again the number of ant hills greatly increased.

On the other hand, in the region where the large "stone house" group of mounds had been in 1905 there was no increase and no new trees, and besides the fields were cultivated and there was some passing of vehicles along the wood edge. Also the diminution along the older roads to the east may have been due to the fact that trees had grown larger so that there may not have been as good feeding conditions here, in 1920, as formerly.

There seems to be some correlation between the success of new mounds and the presence of young vigorous trees, and some

correlation between the dying away of colonies of old mounds, and the maturity of trees which brings shading and presumably difficulties of food getting. The subject of shading as a cause of decay is very important and may be the decisive factor in the effect of old trees upon ant mounds.

Although in the Alps the natives may find their way by the elongation of the E. W. axis of mounds of *Formica exsecta* (as confirmed by Huber, 100 yrs. ago);—in Timonium, many nests seem elongated N. S. with longer south slope, but that this is not universal is indicated by the following measurements made for me in April 1920 by Mr. Spielman.

Twenty vigorous nests in the region on the flats, were measured as to diameters N. S. and E. W. and as to angles at the top of the nest along those directions of compass as follows

	E. W. angle	N. S. angle	Diameter E. W.	Diameter N. S.
	Degrees		Inches	
	130	145	63	63
	130	125	57	44
	120	155	60	60
	120	120	46	57
	125	140	67	86
	125	135	28	26
	115	140	36	40
	130	135	66	74
	130	125	63	62
	130	145	82	89
	125	100	50	48
	120	130	56	65
	125	100	50	48
	120	115	42	40
	130	125	44	60
	125	130	55	52
	110	115	45	40
	120	120	52	56
	125	150	80	73
	120	120	40	42
Sum	2475	2570	1082	1125
Average	123.75	128.5	54.1	56.25

While these measurements show that some nests do not have any extension toward the South, which would lower the angle and increase the diameter N. S. as compared with the E. W., yet on the average there is a slightly greater angle and greater diameter in the N. S. direction.

Moreover the angles, running from 100 to 155 degrees, are much more uniform in the E. W. than in the N. S. directions; thus there are no very flat nor steep angles E. W. while the extremes are all found in the N. S. direction.

When the above angles are plotted on curves of frequency it is seen that the E. W. angles cluster close to the 120-130 degree norm, in a steep curve, while the N. S. angles spread widely right and left from an irregular flat curve having the same norm.

Apparently there is some factor in the N. S. direction acting to disturb the conical symmetry the materials of the nest would exhibit if deposited without preference, like the sand in an hour glass.

A second set of measurements of vigorous growing mounds taken at random in the same general region rather newly occupied, was made in October 1920 by students, Spielman and Lord, with the results given in the following table:

Height in inches.	Angle at top.		Angle of slope to horizon.					Distance over top. in inches
	E. W.	N. S.	W.	E.	N.	S.	E.W.	N. S.
22	104	110	34	42	27	43	80	92.5
11	121	102	28	31	55	23	42	39.5
21	121	123	30	29	31	26	91	90
7	131	130	26	23	22	28	31	28
12.5	126	124	30	24	37	19	46	53
11	112	115	34	34	33	32	40	43
11.75	108	126	30	42	24	30	43.5	50
15	114	126	30	42	24	30	43.5	50
24	120	125	30	30	30	25	84	87
32	100	110	50	30	50	20	77	80
16	110	125	30	40	25	30	54	55
24	120	125	30	30	30	30	90	89
20	130	125	30	20	25	30	89	85
16	110	105	30	40	45	40	54	54
14	120	125	30	30	25	30	58	55
Sum 258	1747	1796	482	487	483	436	923	951
Aver. 17	116.5	119.7	32	32.5	32	29	61.5	63.5

From this table may be gathered that the average angle at the top was slightly larger in the N. S. than in the E. W. direction and that the distances over the top were somewhat greater, in

average, in the N. S. than in the E. W. directions; moreover the four different angles made by the slopes N. S. E. and W. were least in the S. and greater and almost equal in the other three, on the average. This indicates a tendency for the south slope to be spread out, increasing the angle at the top and the distance over the top and diminishing the angle of slope on the south face.

These fifteen hills were steep cones, the angles at the top being small, from 100 to 131 degrees and graphs indicate a norm about 120-125. The angles on the W. and E. were similar in variation from 26-34 and from 23-42 respectively while the angles N. and S. show a wider range, 22-55 and 19-43 respectively. Thus the most gentle slope was found on the south face and the most abrupt slope, 55 degrees, on a north face.

The measurements over the top show the mounds to range from 31 to 91 inches E. W. and 28 to 92.5 N. S. And curves of these measurements show the norm of the N. S. distances to be greater than that of the E. W., indicating again that the mounds are prevailingly drawn out in the N. S. direction.

This slight average overgrowth of the southerly exposure of many mounds in this Timonium region is due to more work being put on that part of the mound and this is very patent in some mounds whose northerly sides show but few ants over them and even become abandoned to such an extent as to be no longer thatched over with a compact layer of earth and organic fragments, as are the perfect mounds, but are eaten out by the rain so that some internal cavities are bared, as in an abandoned roofless part of a human dwelling.

Irrespective of North and South, extra work upon only one aspect of a mound is often very patent when the mound is reared upon a slope, as often happens in this region of many old open mine holes. Here the running of the soil down hill is ever counteracted by the ants placing more particles upon the steep slope till the form of the mound departs very greatly from a cone of circular base and becomes drawn out like a glacier. Investigation would be needed to determine why the ants put more material on the side from which it tends most to roll away but this may be connected with the observed ability of the ants to repair breaches in the mound, filling up cavities, and finally reconstructing perfect

cones, when as much as half the mound has been taken away completely.

Presumably the greater work on the south side is connected with temperature or some other result of insolation. In general the ants are very sluggish in cool weather and very increasingly swift and active with high temperatures and we know from horticultural experience that any mound of earth in these latitudes tends to be noticeably warmer on the southerly expanse and this difference in temperature might be the reason for greater work put on that more sunny side just as Forel has assumed that the early morning sun on some European mounds enables ants to get to work earlier and so succeed in rearing more young on the easterly slope of a mountain than on the westerly slope.

On the other hand the connection between sunshine and mound building may be much more complex as is suggested by the remarkable facts brought out by the investigations of this ant, *Formica exsectoides*, by foresters in New England. It was observed from 1912 onward that plantations of forest trees were found to show dead regions about ant-mounds and after some false clues it became evident that the ants took active part in killing the trees.

H. B. Pierson (Jour. of Forestry, XX, 1922) described the actual actions of the ants in biting and stinging the small trees not far above the ground, resulting in death of the whole tree. In other trees the ants killed the leaves. Mapping the dead trees indicated that the ants killed the trees with reference to the sun, the trees being damaged most greatly on the east, west and south of the mounds. "As soon as the shadow of a tree was cast on the nest for any length of time, that tree was attacked."

Some attacks of these ants upon vegetation near the mounds were seen in the Timonium colonies as follows. About each mound there is a well cleared area or moat on which most all vegetation is checked and surface material carried off till the underlying pebble or gravel is often exposed very markedly. When the strongly encroaching Japanese honeysuckle is rampant all over the adjacent area, its leaves and shoot tips are nibbled by the ants as soon as they encroach onto the mound or even grow within a foot of it. External to this circumferential band of de-

nudation there are also attacks upon vegetation. In one case catbriars growing to overhang the mound on the north were attacked and the ants seen to nibble the bases of the leaves that overhung the mound. In other cases small shoots of poplar about a foot in height were attacked, the twig nibbled near the base and farther up irregularly and the bases of the leaves bitten till the leaves shrivelled. Also rank upgrowing shoots of blackberry arising after a wood fire that killed most all vegetation down to the ground were seen to be attacked by these ants which opened their jaws as wide as possible to bite the bark of the upper parts of the bramble and at the bases of the leaves, which wilted and drooped down. Some other smaller plants were also attacked. The attack involves not only biting, but curving of body and apparently ejection of acid and resulting brown dead areas on the plant. Now these attacks were two to four feet from the mounds and on all sides without any discerned reference to the shading effects that might be assumed, in fact some of the objects attacked could scarcely intercept any appreciable light and one might compare the attack to that of an ant upon a new object as upon the legs of a person standing near a nest, when the ant runs up till something soft enough to be bitten is encountered and then bites persistently in one spot. Also in founding a new mound the ants did kill all the small plants in and close to the mound when its foundation is first begun.

It may well be that the responses of the ants to sun and shade are very complex and deeply ingrained and that the mere warming of their bodies may not be the decisive factor in making them work more on the sides of the mound exposed more to the sunlight.

As the mound is largely useful as an incubator for the young, the slight differences in temperature between various internal parts of the mound may be potent, as in sprouting seeds or growing bulbs, and be the basis for the ants actions. In one mound thermometers showed differences varying from 25.5° to 32°C. when the natural soil near by was 24°C., June 1926.

Whether investigation shall prove that the internal temperature of the mound is a factor or not, the facts seem to be that these ants do work more on the sun side and that the

mounds are most permanent and successful in places exposed to the sun and less successful in deep shade. Thus the upgrowth of trees would eventually introduce an adverse element in the permanence of the mound as being hostile to the optimum temperature needed.

Attempts to establish transplanted mounds both in city back-yard and in the old forest at Homewood, in 1906, 1916 and again in 1926 proved futile; some communities of this ant, *Formica exsectoides* planted at Homewood at various seasons of the year were decimated by birds, especially robins and flickers.

Thus one influence of forestation upon this ant will be through the bird fauna of the forest; for where the robin is favored by the vegetation there can not be good stands of these ant dwellings and when the trees have grown so large as to furnish not only food but nesting sites for flickers, this ant cannot be expected to flourish; hence again the older forest will be inimical to *Formica exsectoides.*

Some of the facts as to association of trees and ant mounds are represented more in detail in the second diagram-map which embraces only the middle western part of the whole area indicated in the first diagram-map.

The area mapped in the second diagram is about four acres of sterile sandy iron soil from former iron ore pits, spread out in a flat with steep bank running down to the York Road on the west and roughly outlined to the east by abandoned wood roads.

In 1905 this was largely a bare barren expanse with little vegetation, few trees and about fifteen ant mounds; but by 1920 trees had come in over its eastern half and ant mounds had scattered all over it as roughly suggested in the first diagram. Both trees and mounds extended into the area from the east.

The first map shows that in 1905 these four acres had many deserted mounds in the easterly part and some occupied mounds in the middle part, but that in 1920 the population was chiefly in the western part and made up of active mounds while many mounds in the middle region had disappeared.

Along with this advance to the west and dying off to the east there was a fifteen year growth of trees which is indicated

in the second diagram, the trees to the east becoming older and new trees gradually growing up in the empty west.

That this same procession of forest and mounds is going on still is indicated in the second diagram which is based upon a detailed survey made in April 1920 by students, Hoffmeister, Swartz and Kellum combined with a re-survey in June 1926. The mounds present in 1920 are indicated by dots, except two which were then deserted and are indicated by crosses. The mounds grown up in the past four years are indicated by triangles except those now deserted which are represented by squares.

The last survey being made after a severe woods fire in the winter had destroyed underbrush and many trees; mounds were more conspicuous than formerly.

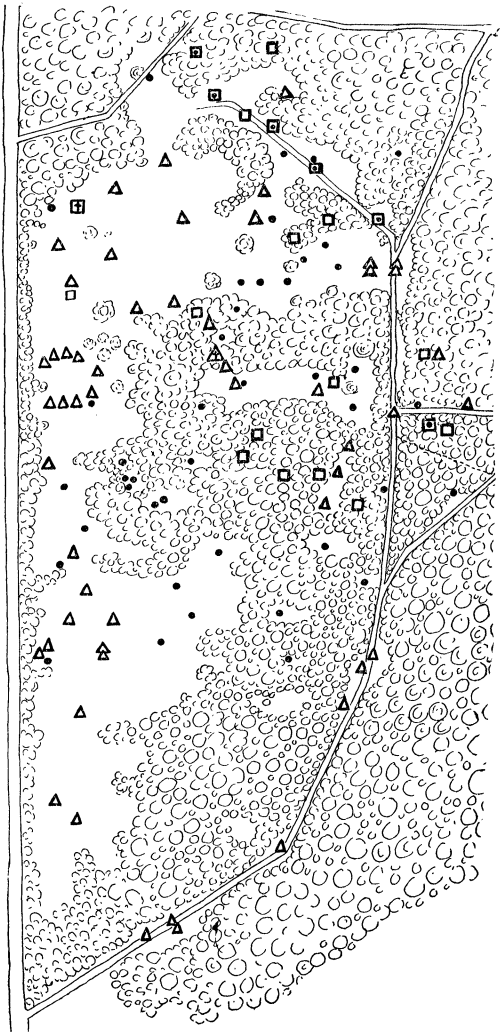
In the diagram the regions of little shade are left clear while the extensions of the wooded area are outlined. It is noteworthy that the woods to the east have spread largely over the area leaving but a strip of clear ground separated from the York Road by narrow band of trees.

The trees are chiefly young seedling oaks, black gum, maple, tulip, dog-wood etc. of small size; with much black locust running rapidly from roots in the loose surface soil. The dense undergrowth of Japanese honeysuckle, catbriar, blackberry and "weeds" extends out into the sunny areas.

Of the 118 mounds found in June 1926, 42 are in the main open sunny region to the west, 11 in its chief extension toward the east, about 28 in various small clear areas amidst the woods, 21 along the grass grown roads to the east; leaving only 15 mounds in the denser shade of the woods as contrasted with the above 103 in the sun.

The old mounds of 1922 are largely in middle and eastern not in the western part; about 37 central and east to 14 west.

On the other hand the new mounds of the past four years are some 30 in the west, 22 in the mid region, and fifteen to the east and of these 11 are along the grassy roads. Thus in four years the advance of mounds has been into the sunny west, and along the grass roads which were not previously occupied



Diagran 2.

The considerable number of mounds in open spaces in the woods is noteworthy: though not all open spaces contain mounds most of them do and in the woods very few mounds are found that are not surrounded by clear spaces of some extent.

In the region immediately to the north of this second map, dense thickets of new growth are interrupted by a few rounded clear spaces each with a large ant mound within it, surrounded by catbriars but not overshadowed by the trees that seem to have grown densely up to a line about ten fee from the mound, and stopped as if the presence of the ant community had prevented other trees from growing up near to the mound.

The distribution of the 118 mounds shown in the second map with reference to more or less shading, may be shown in the following tabulation:

Entire number				Occupied	Deserted
	Those in shade	15	12%	4	11
118	Those in sun	103	88%	94	9
Part found in 1922	Those in shade	3	5%	1	2
51 in number	Those in sun	48	95%	43	5
Those added in 4 years	Those in shade	12	18%	3	9
67 in number	Those in sun	55	80%	51	4

Thus whether we consider the entire number of mounds shown on the map or the part there in 1922 or those added in the past four years, the small percentage is in the shade, much the largest in the sun.

Moreover almost all the mounds in the sun are occupied while the mounds in the shade are for the greater part deserted.

While a deserted mound may be found in the sun this is not common and it is also rare that ân active community is found in the shade.

The larger number of deserted mounds recorded in 1926 is due to the wood fire having revealed old mounds long deserted and concealed under thick growth of honeysuckle so as to be invisible. Many of these were doubtless deserted at the date of the first survey.

Strangely enough the mounds that have become abandoned in the past four years are chiefly along the old wood road to the north, but no special reason for this is discovered and shading

does not seem to account for these exceptional cases. House rubbish has been dumped in adjacent regions.

The interrelation of tree and ant is thus a sequential one, the young tree supplying food, the older tree deterrent to breeding by shading the mound. On the other hand, the result for the trees of the ant's activities is partly the furnishing of some protection by the removal of injurious insects but also conversely, defense of some enemies of the tree and in part, the destruction of some trees that may too soon shade the mound. Yet in the long run this association allows the trees to become mature, thus driving the ants to new regions of less shade; mounds dying off and new ones being made near by till some of them eventually become established in regions adjacent to trees but not overshaded by trees.

In the natural succession of forests it may be that the position occupied by *Formica exsectoides* is that of a dependent upon conditions in which the forest is temporarily interrupted or destroyed as by fire or wind or small areas of defective soil and that with eventual maturity of forest the ants must move gradually in the course of very many years from place to place.

Human intervention while tending eventually to eliminate *Formica exsectoides* may in some cases supply favorable conditions, as in mining and deforestation operations and in abandonment of old fields to new growths as well as in actual plantation of trees.

There is a general parallelism between the periods of time required for many trees to reach maturity, and the presumed length of existence of mounds of *Formica exsectoides,* thirty years and more. The ultimate extinction of the community living in any one mound may be brought about naturally by the failure of that community to perpetuate individuals, to replace those dying from accident and from old age; and this may be due partly to lack of ability of the ants to obtain food sufficiently from the crowns of old trees and partly from the lack of adequate temperature for successful rearing of many young when the optimum temperature is reduced by the shading of the mound by old trees.

Summary.

The ant *Formica exsectoides* constructs mounds in wooded regions. Observations made near Baltimore Md. show that the distribution of mounds occupied by a large community of colonies varied through the years 1905-1926, older mounds being replaced by newer ones in adjacent territory.

Individual mounds may persist many years or may be abandoned from unknown causes; but in general there seems a correlation between mounds and forest growth; new mounds arise in new forested regions and old mounds become vacant in older forests.

The history of a colony is coordinate with tree life, and in general will be briefer. It is inferred that the organic relation between tree and ant colony is sequential; the new ant family or colony obtaining food from younger trees (the growth of some of which they may prevent); the older colony having to contend against the greater shade and lesser food supply from the older trees, may be unable to continue existence except by migration into younger stages of forestation.

The "tree-ant-association" is complicated by such birds as frequent certain stages of forest growth and do destroy such ants.