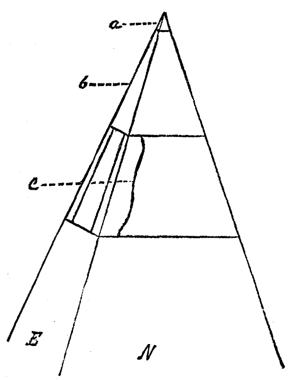
shows the crack in the stone in the next lower course.

Col. T. L. Casey, U.S.A., the engineer in charge of the construction of the monument, requested Professors Rowland of Baltimore, Newcomb of the U. S. navy, and Mendenhall of the signal-service, to examine the monument, and recommend such additions to the present arrangements for protection from lightning as would seem to them necessary and sufficient. It was ascertained on examination, that, with the exception of that shown in the sketch, the monument showed no evidence whatever of having received the stroke. A careful examination of the tip of the aluminum apex has not yet been made; but it seems likely that it will be found to be somewhat blunted by fusion, as is so often the case even where no other effect of the stroke is to be seen.



This aluminum pyramid is secured to the capstone by a heavy copper bolt one and a half inches in diameter. From the end of this, four copper rods, each three-quarters of an inch in diameter, are carried to the extremities of four heavy iron columns extending to the base of the monument, inside of which the elevator runs. As originally put in, these rods are bent out towards the four corners of the pyramid near which they run on their way to these iron columns. Just where one of these is nearest to the angle of the pyramid, and hence nearest to the outside of the structure, the rupture occurred; and to this must doubtless be attributed the localization of the stroke.

The damage done to the monument is in reality very small, and can easily be repaired; but the accident is exceedingly instructive to those interested in lightning protection. The conducting power of the interior seems to be ample for any discharge which could possibly occur, and no evidence appears of any weakness in this respect; but it is evident that the aluminum apex alone does not possess sufficient collective or distributing power, and the improvements suggested by the committee will doubtless be in the direction of increasing that power by the addition of more metal.

M.

Washington, D.C., June 15.

THE PERIODICAL CICADA.[1]

JUST at this time considerable interest is manifested in this curious insect, because of the concurrence of two extensive broods, the one belonging to the typical septendecim form, the other to the tredecim race. These two broods appeared simultaneously in 1664, and will not concur again till the year 2106. The following are the localities in which these two broods will respectively occur: —

TREDECIM (1872, 1885).

Illinois. — Jackson, Union, Macoupin counties.
Missouri. — St. Louis, Boone counties.
Georgia. — DeKalb, Gwinnett, Newton counties.
Tennessee. — Madison county, and northern portion of the state.
Mississippi. — Copiah county, Oxford, and eastern portion of the state.
Louisiana. — Carroll Parish.
Kansas. — Phillips county.
Arkansas. — Flat Bayou.

The existence of this brood has been verified in past years in the parts of Illinois, Missouri, Tennessee, Mississippi, and Arkansas, indicated; but the localities in Kansas, Georgia, and perhaps Louisiana, require further confirmation this year.

SEPTENDECIM (1868, 1885).

New York. — Kings, Monroe counties.
Massachusetts. — Fall River, south-east portion of the state.
Vermont. — Rutland.
Pennsylvania. — Lancaster.
Ohio. — Green, Franklin, Columbiana, Pike, Miami counties, and vicinity of Toledo.
Indiana. — Tippecanoe, Delaware, Vigo, Switzerland, Hendrick, Marion, Dearborn, Wayne, Floyd, Jefferson counties.
Michigan. — South-eastern portion.
Delaware. — Very generally.
Maryland. — Very generally.
District of Columbia. — Very generally.
Virginia. — Very generally.
Kentucky. — Around Louisville.
Georgia. — Habersham county.

From chronological data, the fact that seventeen years or thirteen years are respectively required for the underground development of this insect, according to the race, is fully established, one of the first recorded septendecim broods having been observed every seventeen years since 1715. Such anomalous and excep-

[1] Extracts from a paper read to the Biological society of Washington, May 30.

tional facts in natural history always provoke scepticism, and the facts recorded regarding our cicada's hypogean life have shared in this tendency. Hence a few facts, especially such as bear on the development of the larva, will not prove uninteresting.

Of the tredecim brood which appeared in 1868, I have taken pains to follow the larval development as far as possible from year to year, my observations having been made in St. Louis county, Mo. Repeated efforts to rear the young larvae in confinement proved unsuccessful; and it was necessary to resort to careful and repeated digging out-doors in order to watch the growth from year to year. One of my employees at Cadet, Mo., has also been instructed to carefully pursue the same subject, and I have repeated the digging since residing in Washington. These observations have in all cases been made in special localities where the date of entering the ground was well known and observed. I have thus been able to follow the larvae for the first six years with great care, and for subsequent years with less care and continuity. As we might expect from the chronological history of the species, the development of the larva is extremely slow; and at six years old it has hardly attained one-fourth of its full size. Notwithstanding this slow development, moulting takes place frequently; i.e., the number of larval stages is more than one per annum, and probably twenty-five or thirty in all, whereas in the Homoptera generally — the suborder to which Cicada belongs — it ranges from two to four. In any hypogean insect which continually uses its claws in burrowing, the need of shedding and renewal of those organs is apparent, and may afford the chief explanation of this repeated exuviation, though the slow development is a factor; since my own experience has shown, in the larvae of other orders, that, in proportion as development is slow, exuviation is frequent. As the claws of the front tibiae are the chief instruments used in burrowing, the tarsi become useless or obstructive, and are gradually reduced, and finally lost. They are then regained suddenly during one of the later moults, but so articulated that they are thrown back on the inside of the tibiae, and form a good brace for strengthening these. They are thus out of the way for underground work, and come into use, with their well-preserved claws, only when the pupa issues from the ground, and ascends for the final change.

Much difference of opinion has been expressed by different writers as to the food of the larva; and this is not to be wondered at, from the fact that there is great difficulty in observing it feed. Dr. G. B. Smith insisted that it obtained its nourishment from the moisture of the earth, through capillary hairs at the tip of the proboscis; while many others have seen it with its beak inserted in the roots of trees, and pumping the sap therefrom. The former method is insisted on by Dr. Smith from his own observations; but while I think it not improbable, especially during its earlier larval life, that the cicada may feed on earth-exudation, — a belief which receives support from the well-known fact that this cicada will issue from ground that has been cleared of timber and cultivated for nearly seventeen years, and that other species are known to issue from the prairies, — the liquid is evidently pumped up in the ordinary way. The truth of the matter seems to be that the cicada larva can and does go for long periods without nourishment, where such fasting is necessitated; and that in the earlier years of its development, more particularly, it feeds on the rootlets or radicles, not only of trees, but of herbaceous plants. In my own observations I have rarely found it more than two feet below the surface during the first six or seven years of its life, and almost invariably in an oval cell, and more often away from roots than near them; yet I have also found it with beak inserted, and it will often hang fast by the beak after being unearthed. That the larva is capable of going to great depths is well attested by observers. Many of such reports may be based on the unobserved tumbling of the larva from higher levels; but, where the insect has been observed to issue from the bottoms of cellars ten feet deep, the information would certainly seem to be reliable.

The method of burrowing and making its cells is quite interesting. With the strong front tibial claws it scratches away the walls of its cell just as one would do with a pick; and if it is rising, so that the earth removed naturally falls to the posterior end of the burrow, it simply presses the detached portions on all sides, and especially on the end of the cavity, by means of its abdomen and middle and hind legs. If, however, it is burrowing downward, and the loose soil has to be pressed against the top of the cavity, it uses its broad front femora very dexterously in making a little pellet of the soil, and in placing it on the clypeal or front part of the head, when the load is carried up, and pressed against the top of the cavity. The motions made in cleaning its fore-arms remind one very forcibly of those made by a cat in cleaning its face. The femora and bent tibiae are rubbed over the clypeus, the numerous stiff hairs on which act like a comb or a brush in freeing the spine of dirt.

As the time approaches for the issuing of the pupa, it gradually rises nearer and nearer to the surface; and, for a year or two before the appearance of any given brood, the pupa may be dug up within one or two feet of the surface.

In the year of their ascent, from the time the frost leaves the ground, they are found close to the surface, and also under logs and stones, seeming to await the opportune moment, and apparently without feeding. They begin to rise from about the 20th of May in more southern localities, and but little later farther north. In Washington, the present year, they began to rise in scanty numbers about the 23d, and were perhaps most numerously rising on the night of the 27th. Those in the city were somewhat earlier than those in the woods just over on the Virginia side. The unanimity with which all those which rise within a certain radius of a given tree crawl in a bee-line to the trunk of that tree, is most interesting. To witness these pupae in such vast numbers that one cannot step on the ground without crushing several, swarming out of their subterranean holes and scrambling over the ground, all converging to the one central point, and then in a steady stream clambering up the trunk, and diverging again on the branches, is an experience not readily forgotten, and affording good food for speculation on the nature of instinct. The phenomenon is most satisfactorily witnessed where there is a solitary or isolated tree.

The pupae begin to rise as soon as the sun is hidden behind the horizon, and they continue, until, by nine o'clock, the bulk of them have risen. A few stragglers continue until midnight. They instinctively crawl along the horizontal branches after they have ascended the trunk, and fasten themselves in any position, but preferably in a horizontal position on the leaves and twigs. In about an hour after rising and settling, the skin splits down the middle of the thorax from the base of the clypeus to the base of the metanotum, and the forming cicada issues. Ecdysis is always an interesting phenomenon, and, when closely watched in our cicada, cannot fail to entertain.

There are five marked positions or phases in this act of evolving from the pupa-shell; viz., the straight or extended, the hanging head downward, the clinging head upward, the flat-winged, and, finally, the roof-winged. In about three minutes after the shell splits, the forming imago extends from the rent, almost on the same plane with the pupa, with all its members straight, and still held by their tips within the exuvium. The imago then gradually bends backwards, and the members are all loosened and separated. With the tip of the abdomen held within the exuvium, the rest of the body hangs extended at right angles from it, and remains in this position from ten to thirty minutes or more, the wing-pads separating, and the front pair stretching at right angles from the body, and obliquely crossing the hind pair. They then gradually swell, crimp, and curl, until they form a more or less perfect loop; and during all this time the legs are becoming firmer, and assuming the natural positions. Suddenly the imago bends upward with a great deal of effort, and, clinging with its legs to the first object reached, — whether leaf, twig, or its own shell, — withdraws entirely from the exuvium, and hangs for the first time with its head up. Now the wings perceptibly swell and expand, until they are fully stretched, and hang flatly over the back, perfectly transparent with beautiful white veining. As they dry, they assume the roofed position, and during the night the natural colors of the species are gradually assumed.

The time required in the transformation varies; and though from the splitting of the skin, and the full stretching of the wings in the flat position, the time is usually about twenty minutes, it may be, under precisely similar conditions, five or six times as long. But there are few more beautiful sights than to see this fresh-forming cicada in all the different positions, clinging and clustering in great numbers to the outside lower leaves and branches of a large tree. In the moonlight, such a tree looks for all the world as though it were full of beautiful white blossoms in various stages of expansion.

That this insect, in its distribution and in its numbers, has been and is being seriously affected by our civilization, must be apparent to every observer. The records show that the numbers have decreased in the successive appearances of certain broods, owing largely to the presence of our domestic animals in the woods. Then, again, the clearing of land and the building of towns and cities have all had their effect upon the decrease of this cicada. There are doubtless many places in Brooklyn, N.Y., where the insect appeared seventeen years ago, in which there will be none the present year. And similarly, I believe that whereas around every tree that has been planted more than seventeen years, or upon land that grew trees seventeen years ago, the insect is now abundant in Washington, it will scarcely be noticed in any part of the District seventeen years hence. I base this opinion upon a new phase in the cicada history; viz., the presence of the English sparrow. It is the first time, perhaps, in the history of the world, that Passer domesticus has had an opportunity of feeding upon this particular brood of Cicada septendecim: and so ravenously and persistently does this bird pursue its food, that the ground is strewn with the wings of the unfortunate cicada wherever these have been at all numerous; so that, considering the numbers of the sparrow and their voracity, very few of the cicada will be left long enough to procreate and perpetuate the species in this District.

* * * * *

THE GEOLOGY OF NATURAL GAS.

THE recent introduction of natural gas into general use as a source of heat for industrial and domestic purposes has raised it from the rank of a mere curiosity to one of the earth's most valuable treasures.

To the reader unacquainted with the great change natural gas has effected in all industries where it can be obtained, the following quotation from an article in *Macmillan's magazine* for January, written by Mr. Andrew Carnegie, the chief iron master of Pittsburgh, will be a revelation: "In the manufacture of glass, of which there is an immense quantity made in Pittsburgh, I am informed that gas is worth much more than the cost of coal and its handling, because it improves the quality of the product. One firm in Pittsburgh is already making plate glass of the largest sizes, equal to the best imported French glass, and is enabled to do so by this fuel. In the manufacture of iron, and especially in that of steel, the quality is also improved by the pure new fuel. In our steel-rail mills we have not used a pound of coal for more than a year, nor in our iron mills for nearly the same period. The change is a startling one. Where we formerly had ninety firemen at work in one boiler-house, and were using four hundred tons of coal per day, a visitor now walks along the long row of boilers, and sees but one man in attendance. The house being whitewashed, not a sign of the dirty fuel of former days is to be seen; nor do the stacks emit smoke. In the Union iron-mills our puddlers have whitewashed the coal-bunkers belonging to their furnaces. Most of the principal iron and glass establishments in the city are to-day either using this gas as fuel, or making preparations to do so. The cost of coal is not only saved, but the great cost of firing and handling it; while the repairs to boilers and grate-bars are much less."

This new fuel, which bids fair to replace coal almost entirely in many of our chief industrial centres, has not received that attention from the geologist which its importance demands. So far as the writer is aware, nothing has been published on the subject which would prove of any value to those engaged in prospecting for natural gas, and it is the existence of this blank in geological literature that has suggested the present article.

Practically all the large gas-wells struck before 1882 were accidentally discovered in boring for oil; but, when the great value of natural gas as fuel became generally recognized, an eager search began for it at Pittsburgh, Wheeling, and many other manufacturing centres.

The first explorers assumed that gas could be obtained at one point as well as another, provided the earth be penetrated to a depth sufficiently great; and it has required the expenditure of several hundred thousand dollars in useless drilling to convince capitalists of this fallacy which even yet obtains general credence among those not interested in successful gas companies.

The writer's study of this subject began in June, 1883, when he was employed by Pittsburgh parties to make a general investigation of the natural-gas question, with the special object of determining whether or not it was possible to predict the presence or absence of gas from geological structure. In the prosecution of this work, I was aided by a suggestion from Mr. William A. Earsenian of Allegheny, Penn., an oil-operator of many years' experience, who had noticed that the principal gas-wells then known in western Pennsylvania were situated close to where anticlinal axes were drawn on the geological maps. From this he inferred there must be some connection between the gas-wells and the anticlines. After visiting all the great gas-wells that had been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated either directly on, or near, the crown of an anticlinal axis, while wells that had been bored in the synclines on either side furnished little or no gas, but in many cases large quantities of salt water. Further observation showed that the gas-wells were confined to a narrow belt, only one-fourth to one mile wide, along the crests of the anticlinal folds. These facts seemed to connect gas territory