ART. XII.—*The Environment of the Amphibian Fauna at Linton, Ohio*;* by E. C. CASE.

THE group of vertebrates including amphibians, fishes, and the probable reptile *Eosaurus copei*, from the Lower Freeport Coal at the old station of Linton in eastern Ohio has been known since 1856, when the first description of *Pelion lyelli* was published by Wyman in this Journal. Since that time papers have been published by Newberry, Cope, Williston, and Moodie, all dealing with the morphology of the animals. A complete bibliography of the subject appears in Moodie's Monograph, *The Coal Measures Amphibia of North America*,† and need not be repeated here.

As our knowledge of the taxonomy and morphology of the fauna is now fairly complete, it is possible to turn to a consideration of the various factors which influenced their life and development. Fortunately the presence of workable coal in the region has led to a large amount of exploration and exploitation of the beds in which the animals occur and it is possible to gain a clear idea of the conditions in which they lived.

The key to an understanding of this fauna was grasped by Newberry as is shown by the following quotations:

"In the descriptive portion of this volume, quite a number of species of the fossil fishes from the Coal Measures of Ohio are figured and described. A large part of these are from a single locality, which has already become somewhat celebrated for the number and interest of the fossil forms it has furnished. I refer to Linton, on the Ohio river, at the mouth of Yellow Creek. The fossils are found there in a thin stratum of cannel which underlies a thick seam of bituminous coal, that we have called Number 6, because it is the sixth workable seam from the base of the productive Coal Measures. Already about twenty species of fishes have been obtained from this deposit, and at least as many Amphibians; and all found here for the first time, although two or three species have since been met with in other localities, in this or adjoining States. On tracing Coal-seam No. 6, in various directions from Linton, the cannel at its base is found to thin out and soon disappear. We learn, from a careful study of the deposit, that there was in this locality at the time when the coal was forming, an open lagoon, densely populated with fishes and salamanders; and that after a time this lagoon was choked up with growing vegetables; and peat (which afterward changed to cubical coal) succeeded to the carbonaceous mud (now cannel)

* This paleogeographic study is published by permission of the President of the Carnegie Institution of Washington.

† Moodie, R. L., Publication 238, Washington, 1916.

that had previously accumulated at the bottom of the water. The fishes of this pool were mostly small, tile-scaled Ganoids, belonging to the genus *Eurylepis*. Though here extremely abundant, they have not been found elsewhere. I have enumerated nine species of this genus, but possibly some of them should be considered as mere varieties. There were also in this lagoon two, or perhaps three, species of *Coelacanthus* (one of which is so closely allied to *C. lepturus* of the Coal Measures of Europe that they should not be separated, and yet this genus has been nowhere else recognized on the American continent). There are also found here the thin scales, from one to two inches in diameter, some ornamented and some plain, and also the lance-head teeth of *Rhizodus*, and the teeth and spines of *Diplodus*. On the whole, this must be looked upon as one of the most interesting localities of vertebrate fossils known on this continent; and it is even doubtful whether *any* other equals it in the number of new species or in their zoological and geological interest.”*

“The large number of species of fishes and amphibians (about fifty) found in one single coal mine at Linton indicates that the vertebrate fauna of the Coal Measures was much richer than has heretofore been supposed. The cannel coal of this locality was undoubtedly deposited in a lagoon of open water in the marsh where Coal No. 6 was formed. How extensive this lagoon was, we have not as yet learned; but all the fossils found there have been taken from an area of a few hundred feet in diameter. We have probably now obtained representatives of most of the fishes and salamanders that inhabited this body of water, but certainly not all, for every considerable collection made there has contained something new; and the fauna of the epoch in which this deposit was made must certainly have been very varied, since from this one spot have been taken the remains of fifty distinct species, less than a half dozen of which have been found elsewhere.

This coal mine at Linton may be regarded, therefore, as a kind of loophole through which we see, in all its details, the life of *one locality* in the great world of the Carboniferous age. Looking through that, we have before our eyes a little pool of water swarming with fishes of various kinds, some of them very large, clad in mail and provided with most formidable sets of trenchant teeth; others, small but exceedingly numerous, covered with enameled and highly ornamented scales and plates. These latter, as we learn by coprolitic masses, were the prey of the larger ones.

With the fishes were a large number of aquatic, carnivorous salamanders, some of which must have been eight or ten feet in length, and as formidably armed as the larger fishes. Others were snake-like in form, yet several feet in length, bristling with spines, or protected by thick and bony scales. Others still were a few inches in length, very slender and delicate, and, as we

* Newberry, J. S., Geol. Survey, Ohio, vol. i, Paleontology, pp. 284-5, 1873.

know by their mutilated fragments, served as food for the more powerful.

A remarkable circumstance connected with the Linton deposit is this: that in working up some hundreds of tons of the cannel coal which contains the fishes and amphibians, we have obtained not a fragment of an insect, and only a few small and imperfect remains of crustaceans. Mollusks, too, are entirely absent, no shell of any kind being found there, except those of *Spirorbis*, which is thought to have been an annelid. These occur, however, in millions, and we may infer from the multitudes of these delicate organisms that the water they inhabited was quiet, warm, and almost stagnant. Whether salt or fresh, we do not know, but it seems to me most probable that it was fresh.

Very few remains of plants have been found in the Linton cannel, and these, if leaves, are skeletonized, showing their long maceration in water. In this, as in many other respects, the Linton deposit is strikingly different from that of Mazon Creek, Illinois, which has yielded a large number of insects, crustaceans, and plants, and very few fishes and amphibians.”*

The first step in the study of the Linton fauna was an attempt to determine whether Newberry was correct or not in his assumption that the Linton fauna was isolated in a pool of open water in the midst of a great swamp and that this pool was finally closed by the growth of vegetation causing the death of the animals. The attempt was made along two lines of evidence; first, the stratigraphy of the region around Linton and second, the method of formation of cannel coal.

1. *The evidence from the stratigraphy.*

The Linton fauna occurs in the Lower Freeport Coal of the Allegheny series of the Pennsylvanian. To test Newberry's idea an area of considerable size was selected surrounding the location of the fauna. This included Beaver, Allegheny, Washington, and Greene Counties in Pennsylvania; Hancock, Brooke, Ohio, and Marshall Counties in West Virginia; and Columbiana, Jefferson, Carroll, Harrison, and Belmont Counties in Ohio, as shown on the accompanying map, fig. 1. Many sections of the Allegheny series in this area were plotted and a few of the most detailed are shown in the columnar sections, fig. 2. The location of the sections is indicated by numerals on the map.

A study of sections 4, 3, 2, and 1, north and east of Linton, show a strong tendency for the Lower Freeport Coal and its accompanying beds to break up, indicating the edge of the local swamp. From Sprucevale, Columbiana County, Ohio (4 on the map), south of the mouth of the Little Beaver River,

* Newberry, J. S., Geol. Survey of Ohio, vol. ii, pp. 179-180, 1874.

in Beaver County, Pennsylvania (3), then east to near the mouth of the Beaver River in Beaver County (2) and southeast to Sewickley in Allegheny County, Pennsylvania (1), the Upper Freeport Coal maintains a nearly uniform thickness of 2 to 3 feet underlain by a varying thickness of fire clay with a thin limestone at

FIG. 1.

FIG. 1. Map showing the location of Linton, Ohio and the stations from which sections are quoted.

stations 4 and 2. Beneath this is a considerable thickness of sandy shales broken at station 1 by thin beds of sandstone and fireclay. The Lower Freeport Coal is very thin at these stations, represented by a carbonaceous slate only at station 1. Below the Lower Freeport Coal lie from 10 to 20 feet of sandy shales and then a heavy bed of massive sandstone, 50 to 75 feet, which at station 1 becomes a micaceous sandstone broken by the Upper Kittanning Coal.

South from Sprucevale (4) the Upper Freeport Coal is 3 feet thick at Linton (5), underlain by fire clay but the limestone is

absent, then follows 10 feet of shale and 5 feet of limestone, obviously not the upper bed at (4), and then 50 feet of shale and sandstone. The Lower Freeport is 7 feet thick, the lower part cannel coal, with 5 feet of fire clay and below this 7 feet of shale and sandstone with possibly thin layers of coal. At Wellsburg, Brooke County, West Virginia (6), the Upper Freeport Coal has been removed by erosion, but there are 40 feet reported as fire clay, 5 feet of Lower Freeport Coal, no

FIG. 2.

FIG. 2. Sections taken from the stations indicated on the map, fig. 1. Black, coal, Upper and Lower Freeport, Upper and Middle Kittanning. White, fire clay and unknown. Dotted, sandstone. Lined, shale and shaly sandstone. Obliquely lined, "slate." Vertically lined, limestone.

cannel, and one foot of fire clay underlain by 60 feet of shale and slate. At Wheeling, Ohio County, West Virginia, the Upper Freeport is removed by erosion, but there are 50 feet of blue shale, then 7 feet of Lower Freeport Coal, without cannel or fire clay, lying above 96 feet of shale and sandstone. West of Linton the Lower Freeport Coal shows, in the adjacent counties at least, a decided thinning, with a corresponding increase in the accompanying layers. "The Lower Freeport Coal becomes locally important as the Whan Coal bed within

a small area in central Columbiana, but for the most part it is worthless.”*

“The Freeport coals both thin. . . . Eastward the Upper Freeport is important, it can be followed from Yellow Creek in Columbiana County somewhat decreased in thickness, but in the southern part of the county is often 4 feet 6 inches and yields good coal. The chief drawback is the frequency with which it is cut out by the overlying sandstone. . . . The Lower Freeport is persistent, usually too thin to be utilized. It is rarely more than thirty feet below the upper.”†

In Carroll County, Ohio, the following section has been given:‡

	Ft.
Upper Freeport Coal	2
Shale, sandstone, and conglomerate	40
Lower Freeport sandstone, massive	30
Concealed	50
Coal, Middle Kittanning	3
Fire clay	3
Slate	15
Coal	1
Slate	22

Near Sherodsville in Carroll County.

	Ft.
Upper Freeport Coal	4
Fire clay	6
Limestone	1
Concealed	40
Black shale	2
Lower Freeport Coal	3
Fire clay and modular iron ore	12

Newberry's generalized section for Stark County.

	Ft.
Coal, 7 (Upper Freeport)	1 to 3
Fire clay	1
Shale and sandstone with thin coal near the middle§	75 to 110
Coal, 6 (Middle Kittanning)	2 to 6

*Stevenson, J. J., Bull. Geol. Soc. Amer., vol. xvii, p. 111, 1907.

†Ibid., p. 113.

‡Geol. Survey, Ohio, vol. v, p. 74.

§Includes Lower Freeport “a mere blossom.”

Generalized section for Tuscarawas County.

	In North Ft.	In South Ft.
Coal (Upper Freeport)	3	4
Interval	70	35
Coal, 6a (Lower Freeport)	thin	2
Conglomerate, sandstone, and shale (Free- port)	50	52
Coal, 6 (Middle Kittanning)	4	4

Orton's section of northwest Guernsey County.

Upper Freeport Coal bed, Cambridge	thin
Clay, Upper Freeport limestone	10
Interval	50
Lower Freeport Coal bed	thin
Middle Kittanning	3

Stevenson remarks in the article quoted above, page 71, that the "Lower Freeport shows abrupt and extreme variations in thickness (in eastern Ohio) as well as in quality and occasionally carries on top a thick deposit of impure cannel."

A study of these sections taken in all directions from Linton shows that the Freeport Coal either becomes thinner, loses its fire clay (the leached ground soil of the marsh in which it was formed) or the accompanying layers become disturbed by intercalated beds. While it is admitted that the Lower Freeport Coal is variable in thickness and quantity, in almost every place where it is known, the peculiarity of the thickening at Linton, the presence of underlying cannel coal, and the undisturbed deposition of the accompanying shales and sandstones is at least strong confirmatory evidence of the presence of an open pool in the center of a great swamp.

Of the Lower Freeport sandstone, I. C. White says,* "It is one of the most persistent sandstone horizons in the Allegheny series. . . . The rock is usually quite hard, micaceous, and often pebbly, but does not split evenly." In the western part it is very uniform in character, running from 75 to 100 feet thick, but toward the east (station 1 on the map), it is broken by shale and a thin bed of coal (Upper Kittanning).

In the time before the deposition of the Lower Freeport Coal, the Linton area was evidently for a considerable time a region of deposit from moving water bearing the debris from a region undergoing rapid denudation, as is shown by the presence of undecomposed mica and the pebbles included in the matrix. This was one of the longer periods of depression in the region and the depression was extended over a wide area.

* White, I. C., *Geol. Surv. West Va.*, vol. xi, page 473, 1913.

2. *The evidence from the presence of cannel coal.*

Without going into the history of the discussion of the origin of the various kinds of coal, it is sufficient to state that it is now the generally accepted opinion that boghead, boghead-cannel, and cannel coals have been formed by the accumulation of algæ, spore exines, bits of resin, and other light, wind-blown materials which have grown in place in open water or have accumulated on the surface of open pools. Details of the discussion and the general conclusions may easily be found by following the references given by David White in his treatment of the origin of coal.* It is also of interest to note that the theory of the origin of cannel coal recognizes the necessity, or at least the advantage, of the presence of decomposing animal matter in its formation.

Accepting as a working basis that the stratigraphy and the presence of the cannel coal demonstrate the presence of an open pool in the vicinity of Linton, we may turn to the history of this pool and the other factors which influenced the development of the fauna.

East of Linton the Lower Freeport Coal lies directly upon the sandstone, but at Linton the section of the old Diamond Coal Mine shows several feet of fire clay beneath it. Fire clay is the result of the action of peaty waters, containing much CO_2 in solution upon an underlying soil. It is apparent that succeeding the long period of submergence during which the Lower Freeport Sandstone was formed there was a slight elevation, but a local depression in the vicinity of Linton retained a considerable body of fresh water in which accumulated the sediments of the adjacent land. The water at the edges of this pool was not deep enough to prevent the rapid development of an abundant flora. The roots penetrated the soil and the decomposition of the vegetal material furnished an abundance of CO_2 which deprived the soil of its alkalis, alkaline earths, and iron, reducing it to a fire clay. The bordering vegetation did not for a long time spread out over the surface of the pool in the middle of the swamp and during this interval there accumulated the material of the cannel coal and the amphibian and fish fauna developed large numbers both of individuals and species. The presence of a single form which must be placed with the reptilia indicates either a land at no great distance, from which the body of the animal was transported after death, or an aquatic habit for the reptile.

The physiographic environment of the fauna.

I. C. White has insisted upon the fact that though the beds of the Allegheny series are subject to frequent changes in the

* White, David, The Origin of Coal, Bull. 38, Department of the Interior, Bureau of Mines, page 198, 1913.

material, due to minor changes induced by slight but repeated and rapid fluctuations of level, they maintain on the whole a homogeneity which speaks of widespread and long continued uniformity in the general aspect of the land and water. Perhaps the best picture that has been presented of the region is that given us by David White in Bulletin 38 of the Bureau of Mines, page 63:

“SUMMARY OF TERRESTRIAL CONDITIONS.

Coal formed on subsiding areas.

On the whole the criteria relating to the terrestrial conditions of deposition show that the formation of widely extended coals in series were regions of subsiding base-level coastal plains or filled basins. That the rate of subsidence was variable is shown by the varying character of the rocks of the coal measures; the presence of marine faunas in places immediately above the coal; the occurrence of shallow water limestones, of ripple-marked, rain-marked, or sun-cracked layers or of conglomerates or local unconformities: and in particular the occurrence of great thicknesses of coal covering large areas. The deposition of the great thicknesses of peat necessary for the production of a thick bed of coal, probably 10 to 20 feet of peat being required to produce a single foot of high-grade bituminous or semi-bituminous coal, could hardly have taken place except under such close adjustment of the rate of subsidence to rate of peat accumulation as to maintain a depth of water cover within limits that would permit the growth of peat-forming vegetation for an exceedingly long time. Too rapid a subsidence would have flooded the swamps so deeply as to kill the principal peat-forming vegetation, produce open water conditions, and allow the invasion of sediment-bearing water with its oversweep of mineral matter, or of oxygenated water which would have permitted the advance of decay (biochemical process), to the complete destruction of the superficial organic matter, unless the deposition of sand or mud were sufficiently rapid quickly to arrest the decay by exclusion of the sources of oxygen supply. The roofs of many coal beds bear evidence of the latter conditions. In most cases, however, the oversweep of clays and sands appears to have been so abrupt as to seal the underlying more or less aseptic organic mass from access of oxygen and to prevent its continued decomposition. On the other hand, if the subsidence of the region was too slow or there was warping of the region, the surface of the peat may have reached the upper limit of its formation and entered the zone of increasing exposure (insufficient water), in which the organic matter was reduced to

'humus' soil, and even destroyed, so that the formation of a thick bed of coal was impossible, unless the rise of the water level, usually by accelerated submergence, was brought about. The formation of a thick bed of coal is therefore seen to indicate in general the maintenance for a long period of an approximate balance between the rate of peat accumulation and the rise of the water, so as to maintain a depth of water favorable for the growth of the vegetation and its preservation as peat.

In confirmation of the views of many geologists the writer's observations of the horizontally extensive coal beds in the American fields lead him to conclude that the peat-forming vegetation, which was probably largely vascular, grew in place over nearly all of the areas of these coal beds and that it occupied these areas almost continuously during the deposition of the peat except at times marked by the inundation inwashes represented by the clay or shale partings in the coal. In other words, most of our commercial coal has been formed from plants that grew above the surface of the peat, and is of autochthonous origin. Coal that may be attributed to the mere accumulation of drift vegetation is, according to the author's observations, very restricted in area and variable in thickness, and much of it is too high in ash to be of value.

In certain regions in which the water was quiescent, but of too great depth for occupation by vegetal growth, bituminous shales and black carbonaceous muds, many containing marine or brackish water shells, seem to have been deposited in many places, the state of the organic material—that is, its stage of decay—being dependent largely upon the rate of accumulation of the vegetal debris and the supply of oxygen. At many points small areas of open water, temporary in duration, occurring in the midst of the swamps were marked by the concentration of spores, resins, waxes, etc., forming cannel layers or lenses, the more destructible matter being lost by decomposition, which here again is dependent on the oxygen supply and rate of delivery of the plant debris. In other cases very restricted areas of open water (not occupied by vascular plant growth) whose stagnant depths were more toxic seem to have favored the accumulation, without decay to the point of destruction, of plankton of various types, as well as of wind-borne spore materials forming boghead, and boghead-cannel coal. In none of the important and widely extended coal beds examined by the writer has he observed any lenses or intercalated bodies of coal that may be interpreted as masses, floating islands, or rafts of vegetation somewhat abruptly submerged, in accordance with the hypothesis proposed by numerous writers."

Elsewhere David White speaks of the region as "one vast peneplain."

The climatic environment of the fauna.

The flora of the region around Linton has been reported upon by David White. His list* of the plants of the Freeport group contains no forms differing especially from those of the whole Allegheny series, and all indicate the existence of a "singularly equable and humid but not tropical or even semi-tropical climate." There is no evidence either in the woody growth foliage, florescence, or fruition of any seasonal changes, either of temperature or of humidity. In other words, the animals lived in a period characterized by the extreme monotony of the climatic environment.

The organic environment.

The organic environment of any animal or group of animals may be defined as the group of contacts of that animal with other forms of life. Normally, the organic environment comprises both the flora and fauna, but in this instance the animals were not, so far as we can see, influenced by the vegetation more than that they profited by the shade of the umbrageous growths, sought refuge in the interstices of submerged roots, or possibly fed upon some forms of the algæ in the pool. None of these factors would have left any readable record in the morphology of the animals. The list of the flora occurring in the shales accompanying the coals of the Freeport group has been cited above.

The character of the contacts within the fauna.

The list of known amphibians from Linton as given by Moodie† includes 51 species. The genera are as follows :

Brachydectes
Cercariomorphus
Cocytinus
Utnerpeton
Diceratosaurus
Eoserpeton
Erpetosaurus
Eurythorax
Hyphasma
Ichthyacanthus
Leptophractus
Macrerpeton
Molgophis

* White, David, Bull. Geol. Soc. Am., vol. i, page 154, 1900.

† Moodie, Roy L., Publication 238, Carnegie Institution of Washington page 18, 1916.

Odontopteron
Æstocephalus
Pelion
Phlegethontia
Pleuroptyx
Ptycnus
Saurorpeton
Sauropleuron
Stegops
Thyrasidium
Tuditanus

If we examine the animals as described and illustrated in Moodie's excellent monograph, we find that they were, one and all, provided with sharp, conical teeth, suitable only for a carnivorous or an insectivorous diet. This eliminates the vegetation of the period from consideration as a possible source, at least as an immediate source, of food, but introduces a most effective element of stress in the competition between the animals themselves, on the one hand to capture prey and on the other to escape the attack of predatory forms.

The possible sources of food were the fishes, the amphibia, and very probably the abundant arthropods, molluscs, and insects, though practically no traces of invertebrates have been found with the remains of the amphibians, except the casts of spirorbis-like forms. While there can be little doubt that some of the amphibians were carrion eaters and scavengers, the ultimate food supply must have been the invertebrate fauna of the waters and banks, and the very meagerness of the remains of such a fauna speaks eloquently of the crowded habitat and the eager search for every edible particle. Beyond this the diet was of flesh and the fauna was self-devouring.

From the description given it seems fairly certain that the amphibian fauna was isolated in a pool of clear water surrounded by a great stretch of swamp. The ordinary factors of environment which influence the development of a fauna were absent or ineffective, the physiography and the climate were monotonous in the extreme; the vegetation had only an indirect effect. The main stress upon the life was competition within the fauna. This stress became very high with the crowding of the pool, but as the monotonous environment afforded but limited possibilities for the formation of new habits, adoption of new habitats or the assumption of a new group of contacts in any form, it was not relieved by any over-specialization either in structure or habit. A study of the amphibia reveals only a very normal group of animals. They varied in size from ten feet to six inches in length, some were squat and sluggish, others lithe and serpentine, some even so snake-like that

they had lost their limbs. Some hid for safety in dark holes and corners, others lurked in the slime, feeding on carrion or the less active and well protected forms; still others flashed through the water in active pursuit of prey and dared give battle in their conscious strength. It was a fauna whose elements occupied all the possibilities of the pool to preserve their lives and propagate their kind, but there is an almost total lack of bizarre and overspecialized forms, none heavily armored and none with an excessive development of tusk or talon or spine, and none that could be called giants of their kind. There was a full occupation of all the reasonable possibilities of life but nothing that would indicate an extreme adaptation, either for offense or defense, to limited paths of life such as occur in other places and in other geological formations where the members of the faunas were very perfectly adjusted to each other. There was only the healthy growth induced by competition in a fauna which still retained all the resilience of its juvenile stage.

Such an assemblage existing under very powerful stress, if even from a single source, was full of the possibilities of development; ripe for the rapid and wide radiation in habits and structures long denied them by the monotony of their environment. For the animals in such a pool there were but two possible endings. Either the pool would become choked by the growing vegetation of the surrounding swamp, or in the many fluctuations of the land, channels would open whereby the animals could escape into other habitats and encounter a new environment. It was apparently the first of these fates which came to the Linton fauna. It was overcome in its full vigor before the ultimate adjustments of life to life had produced the extreme development of armor and weapons of attack seen in more mature or in senile faunas. Elsewhere in the same region similar faunas were released to expend in morphological advances and various adaptations to new conditions the stored up stresses of similar periods of isolation.

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