Art. XXXIV.—*The Life of the Connecticut Trias*; by Richard Swann Lull.*

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One of the most interesting chapters in the earth's past history is that of the time when there were laid down the Triassic strata of the famed Connecticut valley, interesting in the profusion of its indicated life, and fascinating in the baffling obscurity which shrouds most of its former denizens, the only records of whose existence are "footprints on the sands of time."

It is not surprising, therefore, that geologists should have turned to the collecting and deciphering of such records with zeal; nor is it to be marveled at that, after the exhaustive researches of the late President Hitchcock, workers should have turned to more productive fields, leaving the footprints aside as relics of little moment compared with the wonderful discoveries of the great unknown West.

Except for small summary papers by Professor Charles H. Hitchcock containing descriptions of some new species, and occasional papers by other authors, nothing was done from the time of the publication of Edward Hitchcock's notable "Ichnology of New England" in 1858, and the Supplement to it in 1865, until 1904, when a new study of the tracks in the light of recent paleontology was published by the present author.

Skeletal remains which were brought to light from time to time were described mainly by Professor Marsh in this Journal, and by E. Hitchcock, Jr. (1865) and by Cope (1869); and later summarized by Marsh in his "Dinosaurs of North America" (1896).

A final, more exhaustive study of the skeletal remains was made by Professor Friedrich von Huene in his "Dinosaurier

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der Aussereuropæischen Trias." No serious attempt, however, has been made to reconstruct the physical conditions of the Trias and to repeople the Connecticut lands of that time with their living, breathing, strenuous inhabitants. The purpose of this essay, therefore, is to reconstruct the environment, both physiographic and climatic, to clothe it with its proper vegetative life, and to discuss as fully as may be the animate nature of that distant day.

One of the most remarkable features of the fossil remains of the Connecticut valley is the dearth of actual bones and the marvellous abundance of footprints—conditions exactly the reverse of those found in other fossil fields, for, outside the Triassic of New England and New Jersey, footprints are rarely met with, whereas the bones in some localities are nearly as numerous as in the Valley of Dry Bones, the vision of which was vouchsafed to Ezekiel. Somewhat similar conditions to those in the Connecticut valley seem to prevail in the Southwest and elsewhere, but in no other known locality is the profusion of footprints so great. In spite of this the discovery of bones preceded a scientific appreciation of the tracks by nearly a score of years, though doubtless the latter were often seen by observers like Pliny Moody in 1802, who failed to realize their great significance. The reference of one to the footprint of "Noah's raven" is probably only one of the many similar interpretations in the folk-lore of the Connecticut valley.

The profusion of species of animals represented by the tracks, which of course included the creatures the skeletons of which are known, is, so far as my present knowledge goes, as great if not greater than that of any other known vertebrate fauna of prehistoric times, and emphasizes once more the usual incompleteness of our geologic record and the countless multitudes of creatures which peopled our globe in the more remote ages.

The Connecticut Valley.

The tracks of the Newark system, which include the fossils under consideration, occupy a number of areas along the eastern coast of North America, of which the best known are that of the far-famed Connecticut valley, and the adjacent one stretching from New York through New Jersey, Pennsylvania, and Maryland into Virginia.

The Connecticut valley area, extending as it does across the states of Massachusetts and Connecticut, follows in general the depression now occupied by the Connecticut river, except in its lower course where the river forsakes the ancient valley at Middletown and cuts its way through the Eastern Highlands, reaching the Sound far to the eastward. The length of the

Triassic trough is about 110 miles, from the village of Northfield, Massachusetts, on the north, to New Haven bay on the south. Its width varies, but averages some 18 miles, the total area being not far from 2000 square miles.

This Triassic depression is bounded on either side by elevations of the more ancient crystalline rock, none younger than the Paleozoic, the weathering of which constituted the source of the Triassic sediments. The age of the latter, which has been referred to the Newark system, is usually correlated with the Rhætic of the Old World, though Eastman in his recent paper on the Triassic fishes of Connecticut (Bulletin 18, Conn. Geol. & Nat. Hist. Survey, p. 32), in speaking of the fish fauna, says: "The Triassic fish fauna of eastern North America is of a more or less manifold nature, and corresponds in a general way to the interval between the uppermost Muschelkalk and the basal division of the Keuper in the Mediterranean region." The English footprints found in the Lower Keuper Storeton quarry near Liverpool, however, do not resemble those of the Connecticut valley in a single instance, though a three-toed dinosaurian track described by Sollas as *Brontozoum thompsoni* which was found at Newton Nottage, Glamorganshire, and referred to the Lower Keuper (Magnesian Conglomerate), shows affinities with those in the Connecticut fauna.

According to the usage of the United States Geological Survey, the non-committal name of Jura-Trias has often been applied to the strata in North America, and as I shall show, the very distinctive dinosaurian fossils are confined to the upper portion of the Newark system both in the Connecticut valley and in New Jersey, while in the lower beds creatures of very different rank predominated.

In a region of the classic interest which envelops the Connecticut valley, embracing as it does some of our most venerable seats of learning, and cradling some of America's greatest geologists, it is not surprising that the discussion as to the origin of the Newark rocks should have been animated. The theories of the method of deposition vary all the way from submarine, through estuarine to continental, and involve a considerable range of climatic conditions as well.

Emerson, in the Holyoke Folio (1898), p. 8, discussed the origin of the Newark deposits in the Connecticut valley as follows:

"The events of the Paleozoic age, constituting a prolonged history of geographic changes, had come to a close, and a land not greatly unlike the present in general configuration had been established, when a new sedimentary record was begun in a bay occupying the position of the Connecticut Valley in

Connecticut and Massachusetts. The shores of the bay were the west scarp of the Worcester County plateau on the east and the east scarp of the Green Mountain plateau on the west, and extending from near Brattleboro, Vermont, to New Haven, Connecticut. The sea waters rose to a considerable height above the present level of the bordering plateaus and spread sediments brought in from these elevated regions on either side of the bay. The shoreward sediments on the east are represented by the Mount Toby conglomerates, and the Sugarloaf arkose is the synchronous deposit formed along the western shore. The Longmeadow sandstone was deposited in the shallower and quieter off-shore area, and in the central zone of the latter area, where the basin was widest, the still finer Chicopee shale was laid down. All these deposits are partly contemporaneous sediments, differing as the strength of the current and the character of the shore rocks affected them. Strong tides, like those of the Bay of Fundy, seem to have swept up the west side of the bay, carrying the material of the granitic shore rocks far north, to rest against a shore made of dark schists, and the return currents ran along the east shore, carrying the eastern shorewash south, while quieter waters and shifting currents spread the sediments in the central area.

"The accumulation of sediments was interrupted by an eruption of lava through a fissure in the earth's crust, which opened along the bottom of the basin. The lava flowed east and west along the bay, as tar oozes and spreads from a crack, and solidified in a sheet which may have been 2 or 3 miles wide and about 400 feet thick in its central part. This is the main sheet or Holyoke diabase. This sheet was soon covered with sand layers, but its thickness was such that it shallowed the waters to near tide level, and thus occasioned extensive mud flats. This was an area suitable for the formation and preservation of unique records of the life of the time. The curiously shaped and often huge reptiles of that age wandered over the mud exposed at low tide, and their footprints, being covered by the deposit of the next flood tide, constitute the so-called 'bird tracks' which have been found in such great numbers and perfection.

"The sands had reached a considerable thickness over the first trap bed when a second outflow of the trap followed, represented by the posterior bed or Hampden diabase. Immediately after the outflow of this sheet an explosive eruption took place, and blocks of diabase and pulverized lava were spread by the waters over a broad area, forming the Granby tuff bed. A third period of volcanic activity followed, during which a line of small volcanoes broke out along the old fissure beneath the bay. The area was next the scene of dislocations or faults, by which the mass of sediment and volcanic rocks was divided into great blocks, often extending north and south. The blocks slipped one past another along nearly vertical planes. In these dislocations the strata were generally tilted eastward. . . . In these movements, associated perhaps with general uplift of the area, the bay became land and the rocks were exposed to erosion."

A view of the deposition of the Newark rocks more in keeping with the organic phenomena is that set forth by Davis in 1898 (pp. 32, 33) as follows:

"The pre-Triassic peneplain might have been warped so as to alter the action of the quiescent old rivers that had before flowed across it, yet not to drown or to pond them. Such a change would set the streams to eroding in their steepened courses, and to depositing where their load increased above their ability of transportation. As with marine or lacustrine deposits, the thickness of the strata thus produced would depend on the duration of the opportunity for their deposition. A progressive warping, always raising the eroded districts and depressing the area of deposition, would in any of these cases afford the condition for accumulating strata of great total thickness. The heavy accumulations of river-borne waste on the broad plains of California, of the Po, or of the Indo-Gangetic depression, all agree in testifying that rivers may form extensive stratified deposits, and that the deposits may be fine as well as coarse. They are characteristically cross bedded and variable, and they may frequently contain rain-pitted or sun-cracked layers. . . .

"In contrast to marine deposits, Penck has suggested the name 'continental' for deposits formed on land areas, whether in lakes, by rivers, by winds, under the creeping action of waste slopes, or under all these conditions combined. This term seems more applicable than any other to the Triassic deposits of Connecticut. It withdraws them from necessary association with a marine origin, for which there is no sufficient evidence, and at the same time it avoids what is to-day an impossible task—that of assigning a particular origin to one or another member of the formation. A continental origin of the formation would accord with Dana's conclusion that the Triassic beds 'are either fresh-water or brackish-water deposits.' There may possibly be included an occasional marine deposit along the axis of the depressed trough, for at one time or another a faster movement of depression than usual may have outstripped deposition and thus caused submergence; but, in the absence of marine fossils, the burden of proof must lie on those who directly maintain the occurrence of marine deposits."

In general geologists now regard the theory of the continental deposition of the Connecticut valley sediments as definitely proven.

The Physical Environment.

The weight of evidence seems to show that the physical environment within which the animals of the Triassic lived consisted of several broad depressions along what is now the northern Atlantic coast. It is, nevertheless, inconceivable that creatures of such ample locomotive powers as the majority of the Connecticut valley remains would imply were limited to the actual troughs, but they must have roamed far and wide across the uplands as well, though naturally their records of wanderings would only be made where sedimentation was in progress.

The climatic conditions of Triassic times may be judged by three criteria: the character of the sediment itself, the physical phenomena impressed upon the strata, and the evidence of the organic life.

Barrell (1908, p. 183), who has made extensive studies upon the relations between climate and sedimentation, comes to the conclusion that the "dominant red color of the whole of the Triassic formation, considered in connection with its feldspathic sandstones, indicative of the kind of erosion, mud-cracked shales, disseminated gypsum, and calcite, indicative of conditions of sedimentation, point . . . to a subarid climate," and furthermore that "the Triassic conglomerates . . . are associated with many features of climatic significance . . . which independently indicate a semiarid climate with hot summers and possibly cold winters" (p. 259).

Fenner (1908, p. 305), in describing the shales of the New Jersey Newark areas, summarized the physical phenomena thus:

"They are finely comminuted siliceous material, strongly impregnated with oxide of iron. Their laminations may be paper-like in thinness, but are generally coarser. On exposure to the weather they break up into a multitude of crumbly fragments. Mica scales are very plentiful. The surfaces of the laminæ frequently show a multitude of irregular markings —grooves, pits, curved lines, lumps, smooth patches of irregular shape, etc., not all of which can be deciphered with any certainty. Many, however, can be identified. Mud-cracks, rain-pits, and worm-grooves are frequent. Rill-marks are sometimes found. At times films of impalpable sediment are found in the depressions in the lumpy surfaces of certain sandstone layers, which, in their delicate markings, suggest irresistibly the frothy scum left in hollows after a rain."

One very characteristic physical phenomenon impressed upon the sandstones and shales of the Connecticut valley is that of mud-cracking as the fresh deposits dried under the ardent heat of the Triassic sun. These cracks are often found associated with the fossil footprints, and in many instances, notably from the Portland, Connecticut, sandstone quarries, they lie in the axes of the digital impressions, often radiating from the tips of the toes, thus showing conclusively that the drying was subsequent to the passage of the animal, the cracks following the already weakened lines of least resistance.

Yet another very characteristic Connecticut valley phenomenon is that to which the elder Hitchcock gave the poetic name of "Nature's Hieroglyphics." As he says, the most remarkable locality is at the Portland quarries, "where sometimes the surface looks like mosaic, or rather like a pavement of polygonal masses, with mortar between the pieces." Barrell describes this as "mud-cracks filled with æolian sands." He says (pp. 279–80):—

"Silt and sand will be blown over and fill up the cracks developed by the drying of argillaceous water-laid deposits. Consequently, the sand is filled in under the raised rims of the polygonal discs and becomes continuous with the mantle of sand above. In this way the concavity upward of the individual plates is preserved and the mud-cracks are not obliterated, even in a silty clay which would crack and crumble immediately upon being rewet by the advancing waters of the following inundation. Experiments by the writer [Barrell] go to show that the upturned edges of the clay plates would not usually hold their form while the broad sweep of sand-laden waters should deposit clean sand both under the edges and over the plates. The concavity of the plates thus testifies to æolian burial and such may be distinguished from mud-cracked flats buried by fluvial action."

Other phenomena indicative of climatic conditions are the impressions of frequent hard showers, such as are often observed in semi-arid regions, and pieces of recent sun-cracked mud deeply pitted with rain impressions secured by Professor Marsh on the Laramie plains in 1868 might well be of Triassic origin.

Still other phenomena, namely the impressions found in Portland and attributed to a fucoid to which was given the name of *Dendrophycus triassicus* by Newberry (1888, p. 82), have been seen in actual formation upon the clay banks of streams, and are nothing less than the wonderfully wrought-out series of branching rill marks made by tiny streams of trickling water.

The animals of the Connecticut Trias, in so far as they throw light upon past climatic conditions, include the remains of at least two species of shells, both belonging to the fresh-water Unionidæ, which preclude the possibility of saline tidal waters, at least in the neighborhood of Wilbraham, Massachusetts, a locality which, unfortunately for the estuarine theory of origin, is far to the south of places where the sediment would seem to demand the strongest tides. On the other hand, the presence of shells implies more or less permanent waters, either in slow moving or impounded condition. The one insect reported from the valley is found in great abundance at Turners Falls, Massachusetts, and has been described as the aquatic larva of a neuropterous insect, hence again implying the presence of waters of some duration. If the period of larval life was equivalent to that of the ephemerids of to-day, the water must have continued not one season but three; this may, however, have been an annual insect the larval life of which would require but a transitory stream. The invertebrate trails show no characters which would debar them from such a climatic environment as Barrell has assumed for the Connecticut Triassic.

Fishes are, with the exception of one crossopterygian, all ganoids. And, while confined stratigraphically to two or three black shale bands, their geographical range is from Turners Falls to New Haven. They are, however, all of fresh-water affinities, and may well represent the recurrence of climatic cycles of greater than average humidity and consequent expansion of the aquatic habitat, or a disturbance of the drainage, due to volcanic damming or deformation, the climatic conditions remaining constant.

Over the terrestrial vertebrates, aside from a few of the forms unquestionably dinosaurian, so deep a shadow of obscurity rests that safe conclusions may hardly be drawn. There is no reason to suppose that all are reptilian; and, if the Amphibia of that day were of similar constitution to the present-day descendants, to whom a one per cent solution of salt is fatal, the proof of their presence would preclude the possibility of marine waters, and add their evidence in favor of continental deposition to that of the lower forms. There are, however, stegocephalians known from brackish water deposits.

On the Laramie plains in 1899, when conditions were dry even for a semi-arid climate, I found in the dust of the ground within the tent a large and lively salamander of brilliant coloring whose advent and departure were alike mysterious. Van Dyke in his description of the desert remarks that all desert trails run in straight lines, showing the animal to be not prowling but intent in getting across to the mountain. The same is true of the fossil trails of the Connecticut valley; and from the compact type of foot, long stride, sometimes suddenly lengthening marvellously, and the narrow trackway of many species, it can easily be seen that the character imposed by the desert of speed and great travelling powers was here at a high premium. As I have shown elsewhere (1910, p. 37), a climate of semi-aridity, compelling cursorial adaptation as a means of getting food but more especially water, may well have been an impelling cause in dinosaurian evolution. Bipedality among lizards of to-day is, so far as I am aware, confined to denizens of semi-desert environment, certain instances being the large frilled lizard, *Chlamydosaurus* (Sayville Kent), of Australia, and several lacertilian species of our own Southwest.

That water was rare and at a premium when the rains did come is evidenced by the frequency of the association of rain-prints with dinosaurian tracks and the above-mentioned mud-cracks which *followed* the passage of the animal. Again, the depth of the impression of the tracks of two species of animals upon the same strata is sometimes entirely out of proportion to the apparent difference in the makers' size, for the presumption is that then as now the supporting area of an animal's feet must have borne a certain ratio to the weight in accordance with the type of environment to which the creature was adapted. The inference is, therefore, that the passage of the two animals was on their way to or from a water hole during a period of desiccation, and that the deeper impression was made some time before the shallower one and nearer the time of the preceding rains.

The Vegetal Environment.

Chamberlin and Salisbury (Vol. iii, pp. 38–40) speak thus of the plant life of the Triassic:

"The record of the vegetation is very imperfect. The vegetation was probably scanty in reality, for . . . arid tracts imply conditions inhospitable to plant life. An environment that could give rise so generally to coarse red sandstones and conglomerates—even limestone conglomerates—could not well be congenial to luxuriant vegetation.

"The Triassic was distinctly an age of gymnosperms the world over; the supremacy of the pteridophytes had ceased, though ferns, true to their persistent nature, still held an important place, and the equisetales were a more vital factor than now. . . . conifers of the types that had come in during the Permian, and kindred new ones, were prominent, while the cycadean group was still in a stage of deployment and occupied the central place of interest. . . . The Triassic conifers bore the scrawny aspect of the walchias and voltzias of the Permian. . . . It does not appear from the record that any of these gymnosperms were especially large, but on the contrary rather dwarfish, the conifers bearing the aspects now found on sandy barrens and arid tracts. The calamites had given place to true equiseta, which were represented by forms that were gigantic in comparison with modern types. . . .

"In the closing stages of the period, the Rhætic epoch and its equivalents, there seems to have been much amelioration of the previous hostile conditions and a much ampler development of the flora. The larger part of the known American fossils belong to this stage. In favored portions of the Newark series from Connecticut to North Carolina, plant remains occur, and in the coal-beds of the latter state and of Virginia, the flora is more amply represented."

The Fauna.

In both vertebrate and invertebrate relics the proportion of known fossils to footprints is much the same, the former being of such extreme rarity as to warrant special mention of practically every find.

Invertebrates.

Of the actual fossils the species represented are but four,—two known species of molluscs, a small phyllopod crustacean, *Estheria* sp., and a single insect species of which fortunately there are numerous examples, all, however, from three or four localities in the neighborhood of Turners Falls, Mass., and near Middletown, Conn., though whether the latter locality yields the same form as that at Turners Falls is unknown.

A brief summary of the invertebrate species follows:

Of the phylum Arthropoda the Class Hexapoda is represented by the one known species *Mormolucoides articulatus* Hitchcock. This creature was first described by Hitchcock in 1858 as a crustacean and its true relationships were discovered by J. D. Dana, to whom Hitchcock sent specimens for examination. Dana, in a postscript to his letter reporting on the insect, says: "The larve was probably the larve of a neuropterous insect, which often has false legs along the abdomen; but, if so, it is surprising that there are no legs to the corselet, neuropterous larves having three pairs." This insect was afterwards studied by Scudder, who published an elaborate monograph amplifying the previous descriptions. It remained, however, for the present writer to have the good fortune to find upon a single individual among many impressed upon the shale, well-preserved remains of the antennæ and limbs which served still further to verify the taxonomic conclusions of Dana. These are described in detail in the memoir from which this extract is made. The further placing of this insect in the classificatory scheme brings it into the order Neuroptera, family Sialidæ.

A second arthropod has just been announced (Jan. 1912) by Miss Mignon Talbot, professor of geology in Mount Holyoke College, and represents in all probability a new species of the phyllopod genus *Estheria*, heretofore reported from the New Jersey–Pennsylvania area but not from the Connecticut valley. The locality is West Holyoke, Massachusetts, which would place it geologically in the "Lower Series of granitic, coarse sandstones," exactly what one would be led to expect from the distribution of the genus in the New Jersey–Pennsylvania area.

Mollusca have been reported several times from the Connecticut valley, but the only authentic find seems to be that recorded by Emerson (1900, p. 58). This slab, which has been sent to me for study, is from near Wilbraham, Massachusetts, and contains at least 14 imperfect impressions representing at least 2 species of undoubted *Unio*, the type of Emerson's species being similar to *U. alatus*. It should hereafter be known as *Unio wilbrahamensis*. The second species is quite distinct from the first but is too imperfect to characterize. It is also unquestionably *Unio*, and may hereafter be known as *U. emersoni* in honor of Professor Emerson. *Anoplophora*, the genus to which Emerson referred the first species, Schuchert says is probably always marine, and the shells in question are doubtless in fresh-water deposits. The slab, which is a portion of an ice-transported bowlder, the parent ledge of which is probably unknown and therefore not necessarily as far south in the valley as Wilbraham, gives evidence of having been deposited in permanent waters, a habitat in keeping with that of present-day Unios. Wilbraham being toward the eastern side of the valley, is, therefore, near the summit of the Newark series stratigraphically.

Invertebrate Trails.

A summary of the invertebrate trails given by Professor C. H. Hitchcock in 1889 is as follows:

Hexapod Arthropoda, 8 genera and 24 species.

Inferior Arthropoda, including larval forms and worms, 10 genera, 16 species.

Mollusca, 4 genera and 6 species.

Incertæ sedis, 5 genera, 6 species.

This places the total number of invertebrate and questionable trails at 52. In view of the number of undoubted vertebrate species known from the Newark system and the teeming number of living invertebrates, especially arthropods, compared with vertebrates, even under adverse climatic conditions, this number does not seem excessive. In fact, I imagine it may fall far short of the number of continental invertebrates of Newark time. My own grouping modified from that of Hitchcock (1889) is as follows:

Phylum Arthropoda

Class Insecta

Genera *Acanthichnus* with 9 species; *Bifurculapes* with 5 species; *Lithographus* with 3 species; *Copeza* with one species; *Hexapodichnus* with 2 species; *Conopsoides* with 2 species; *Harpepus* with one species; *Sagittarius* with one species.

Class Incertæ sedis

Genera *Lunula*, one species; *Pterichnus*, 2 species; *Hamipes*, one species; *Sphærapus*, 2 species; *Grammepus*, 2 species; *Stratipes*, one species; *Saltator*, 2 species.

Phylum Vermes

The old term Vermes is used as being more non-committal than Annelida, as one cannot be sure that in every case the following track-makers were oligochete annelids, though doubtless some were.

Genera *Herpystezoum* with 4 species; *Halysichnus*, 2 species; *Cunicularius*, one species; *Cochlea*, one species; *Cochlichnus*, one species.

Phylum Mollusca ?

Under this head are placed some peculiar multiple trails, the duplication of which seems to debar them from the worms.

Genera *Bisulcus*, one species; *Trisulcus*, one species.

Genera of doubtful origin and character.

Genera *Harpagopus*, one species; *Grammichnus*, one species; *Climacodichnus*, one species; *Ænigmichnus*, one species.

The Aquatic Vertebrates.

Among the vertebrate fossils found in the Newark rocks of the Connecticut valley, two classes, fishes and reptiles, are represented by actual osseous remains; the latter surely, and probably the Amphibia, are recorded by their footprints. Whether or not the two higher classes, the birds and mammals, are represented is not yet proven, though mammalian remains are known from the Newark system in North Carolina and the first authentic avian relics, those of *Archæopteryx*, already a long way along the road to avian perfection, coming as it does from the Middle Jurassic, would surely imply birds in some stage of their evolution during Newark time.

Professor C. R. Eastman, in a characteristically excellent paper (1911, p. 28), gives the following summary:

"List of Fossil Fishes occurring in the 'Newark' or Upper Triassic Rocks of Eastern North America. [In this list the names of those species occurring in the Connecticut valley are denoted by an asterisk.]

Crossopterygii

Family Cœlacanthidæ

1. **Diplurus longicaudatus* Newberry

Actinopterygii

Family Catopteridæ

2. **Catopterus gracilis* J. H. Redfield
3. **Catopterus redfieldi* Egerton
4. *Dictyopyge macrura* (W. C. Redfield)

Family Semionotidæ

5. **Acentrophorus chicopensis* Newberry
6. **Semionotus agassizi* (W. C. Redfield)
7. *Semionotus brauni* (Newberry)
8. *Semionotus elegans* (Newberry)
9. **Semionotus fultus* (Agassiz)
10. *Semionotus gigas* (Newberry)
11. *Semionotus lineatus* (Newberry)
12. **Semionotus micropterus* (Newberry)
13. **Semionotus ovatus* (W. C. Redfield)
14. *Semionotus robustus* (Newberry)
15. **Semionotus tenuiceps* (Agassiz)

Family Eugnathidæ

16. **Ptycholepis marshi* Newberry."

This fauna, except for one crossopterygian, is made up exclusively of ganoids and, judging by comparisons made with fish faunas of the Old World, is considered to be "of more or less manifold nature, and corresponds in a general way to the interval between the uppermost Muschelkalk and the basal division of the Keuper in the Mediterranean region."

The fish remains are nearly all from the two general levels of black bituminous shale, which also contain the plant relics, in varying profusion. Rarely are footprints found in juxtaposition to the fishes and never, so far as I am aware, upon the fish-bearing shales themselves. Geologically, the shale bands are associated with the trap outflows, an anterior bed following immediately upon the anterior trap sheet to a thickness of from 50 to 100 feet and a posterior zone of about 100 feet immediately preceding the posterior trap, the relationship of the shale and trap being in one case the reverse of the other. Geographically, the fish localities are distributed from Turners Falls, Massachusetts, to Lake Saltonstall, New Haven, Connecticut.

The Terrestrial Vertebrates.

Reference has already been made to the great disparity in numbers of actual bone remains as compared with the footprints, and while the number of the latter contained in our museums is so great as to be unrecorded, and many more have been destroyed, the skeletal remains are by no means as rare as is generally supposed, for as a matter of fact no fewer than three genera and five species of dinosaurs, one of a belodon, and two species of aëtosaurs have been described from the Connecticut valley area alone, while the actual number of specimens naturally exceeds this record of forms. Geographically, osseous remains are reported from Greenfield, Belchertown, South Hadley, and Springfield, Massachusetts; and from East Windsor, Ellington, Manchester, New Haven and Simsbury in Connecticut. The footprints occur scatteringly the entire length of the valley from above Turners Falls to New Haven, but the greatest abundance both of separate localities and profusion of species and specimens is in the more northern portion of the area, specifically around Turners Falls and near South Hadley, Massachusetts. Hitchcock, in the "Ichnology of Massachusetts," enumerates no fewer than 38 quarries for fossil footprints, and a very few localities have been discovered since that time. The geological sequence of the various fossil and footprint localities is shown in the appended table.

The creatures known from the bones are as follows:—

Class Reptilia

Order Parasuchia Huxley

Suborder Aëtosauria Nicholson and Lydekker (=Pseudosuchia Zittel)

Family Aëtosauridæ

Stegomus arcuatus Marsh

From the lower series of granitic, coarse sandstones (Fair Haven arkose), New Haven, Conn.

Stegomus longipes Emerson and Loomis

From the upper series of sandstones (Longmeadow sandstone), Longmeadow, Mass.

Suborder Phytosauria Baur

Family Phytosauridæ McGregor

Rhytidodon (Belodon) validus Marsh

From the lower series of granitic, coarse sandstones, of Simsbury, Conn.

Order Dinosauria Owen

Suborder Theropoda Marsh (Carnivorous Dinosaurs)

Superfamily Megalosauria Baur

Family Anchisauridæ Marsh

Anchisaurus (Megadactylus) polyzelus (E. Hitchcock, Jr.)

From the upper series of sandstones and shales (Longmeadow sandstone), Springfield, Mass.

Anchisaurus colurus Marsh

From the upper series, Manchester and East Windsor, Conn.

Anchisaurus solus Marsh

From the upper series of Manchester.

Ammosaurus major Marsh

From the upper series of Manchester.

Superfamily Compsognatha Huxley

Podokesaurus holyokensis Talbot

From the upper series (Longmeadow sandstone), South Hadley, Mass.

These forms may be briefly described as follows :—

The Parasuchia were reptiles, more or less lizard-like in form with an outer armor consisting of bony plates which are in part segmentally arranged. They were distinguished from the later crocodiles mainly by the position of the internal nares (nostrils), which were normal and not shifted to the rear by the growth of a secondary bony palate. In the modern crocodiles this is a device to prevent strangling while devouring prey under water by bringing the nasal chamber in direct communication with the glottis. The Parasuchia were both aquatic, fish-eating forms and, in the aëtosaurs, truly terrestrial reptiles though still doubtless of carnivorous habits.

Stegomus arcuatus Marsh is represented by the impression of the dorsal armor only, showing it to have consisted of narrow transverse plates extending from the mid-line well across

FIG. 1.

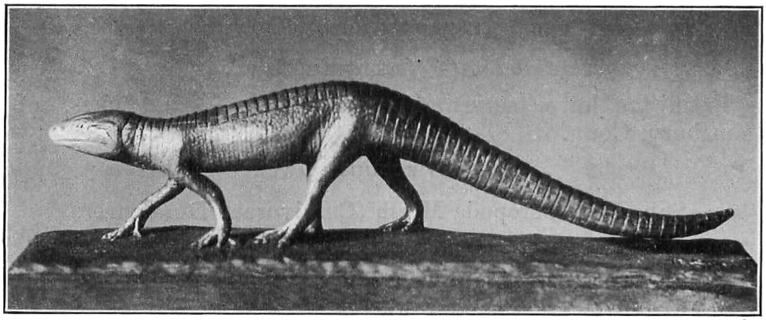

FIG. 1. Restoration of *Stegomus longipes* Emerson and Loomis. About two-sevenths natural size. Modeled by R. S. Lull.

the back, flanked by smaller plates along the sides, each series overlapping its successor behind. The animal was estimated

FIG. 2.

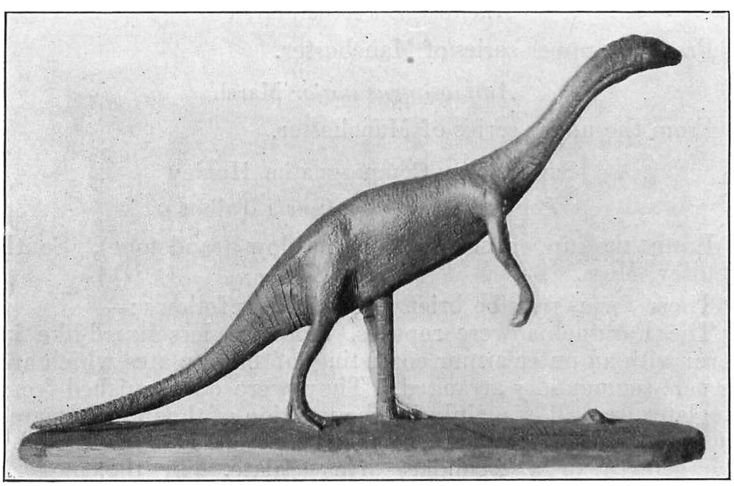

FIG. 2. *Anchisaurus colurus* Marsh. Right side of the statuette showing the flesh. One-twenty-first natural size. Modeled by R. S. Lull.

by Professor Marsh to have been of "moderate size, probably eight or ten feet long." It is preserved in the Yale University Museum.

Stegomus longipes Emerson and Loomis is much more completely known, as nearly the entire armor from neck to rump is preserved as well as the skull, sacrum, and remains of the limb-bones. The latter give indication of long slender legs, the whole organism indicating an animal of small size with limbs of such character as to indicate most strongly a correlation with certain abundant footprints of the genus *Batrachopus* in which the long step and narrow trackway indicate a mammal-like gait though the feet themselves were still typically reptilian. A restoration of *Stegomus longipes* is here shown

FIG. 3.

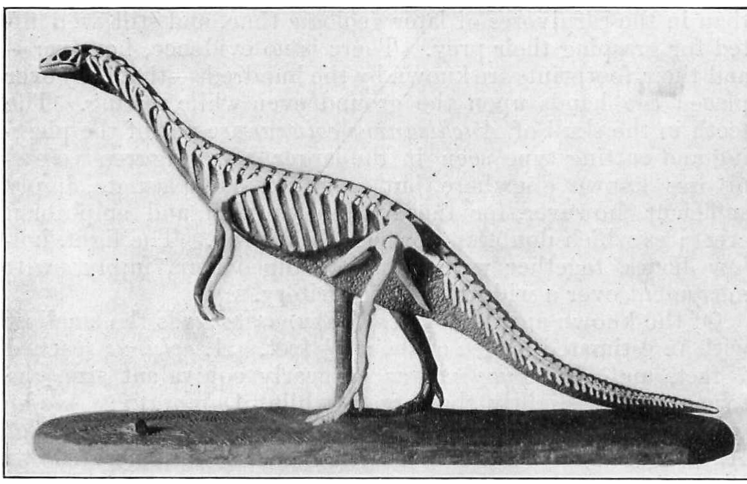

FIG. 3. *Anchisaurus colurus* Marsh. Left side of the statuette showing the skeleton. One-twenty-first natural size. Modeled by R. S. Lull.

(fig. 1), the original specimen being preserved in the museum of Amherst College.

The specimen of *Rhytidodon validus* described by Marsh as *Belodon* is much more meagre, consisting as it does of a single incomplete scapula. It pertains, however, to a very well-known genus, abundant remains of which have been found elsewhere than within the valley limitations, so that the entire character of the animal is approximately known. This creature was of decidedly more crocodile-like aspect, being comparable to the modern gavials which inhabit the large rivers of India, with their long attenuated snout and slender conical teeth. *Rhytidodon* also doubtless resembled the gavial in its fish-eating habits, and the finding of such remains at Simsbury, Connecticut, implies the presence during early Newark time of a large river or fresh-water lake containing sufficient fish for the maintenance of animals which may have attained the length of a dozen feet. The original specimen of *Rhytidodon validus* is preserved in the Yale Museum.

The Connecticut valley dinosaurs, known from their osseous remains, are all carnivores, but within that group, the Theropoda, two sorts are represented, the heavier, more powerfully aggressive anchisaurs and the slender, swift-running podokesaur, representing the two main phyla of the suborder. The anchisaurs, represented by two genera and four species, were animals of fairly robust proportions, especially *Ammosaurus major*, bipedal though with fore-limbs proportionately larger than in the carnivores of later geologic time, and still well fitted for grasping their prey. There is no evidence, however—and their footprints are known by the hundreds—that they ever placed the hands upon the ground even while resting. The teeth in the skull of *Anchisaurus colurus* are not of the piercing and cutting type seen in the larger, more aggressive carnivores known elsewhere, but are somewhat spatulate, amply sufficient, however, for the feebler reptilian and amphibian creatures which doubtless formed their prey. The light, hollow bones, together with complete bipedalism, imply swift movement over a wide range of territory.

Of the known anchisaurs *Anchisaurus solus* is the smallest with an estimated length of about 3½ feet. *A. colurus* reached 7 feet, and *A. polyzelus* was of nearly equivalent size, the former being slightly the larger, while *Ammosaurus major* was an animal of perhaps 8¾ feet in length. A restoration of *Anchisaurus colurus*, both skeleton and flesh, is here shown (figs. 2, 3).

With the exception of the type of *Anchisaurus polyzelus*, which is preserved at Amherst College, the Yale Museum contains all the known material pertaining to this group.

Podokesaurus holyokensis represents the latest discovery of dinosaurian remains in the Connecticut valley region. It was found by Miss Mignon Talbot during 1910. This animal, known from the entire skeleton of the trunk and much of the tail and limbs but unfortunately lacking the head and anterior portion of the neck, has been restored by the writer (fig. 4) as a long-limbed type with an excessively long and slender tail. The head is restored from that of *Compsognathus* of the middle Jurassic of Bavaria, but the rest is based almost without exception upon the skeleton. The estimated length of *Podokesaurus* is 3¾ feet.

Podokesaurus was essentially a slender, cursorial animal, carnivorous in habits, but from the very slenderness which gave it such celerity of movement necessarily confined to feeble prey of which the various footprints manifest so great an abundance. That it was related to the group represented

FIG. 4.

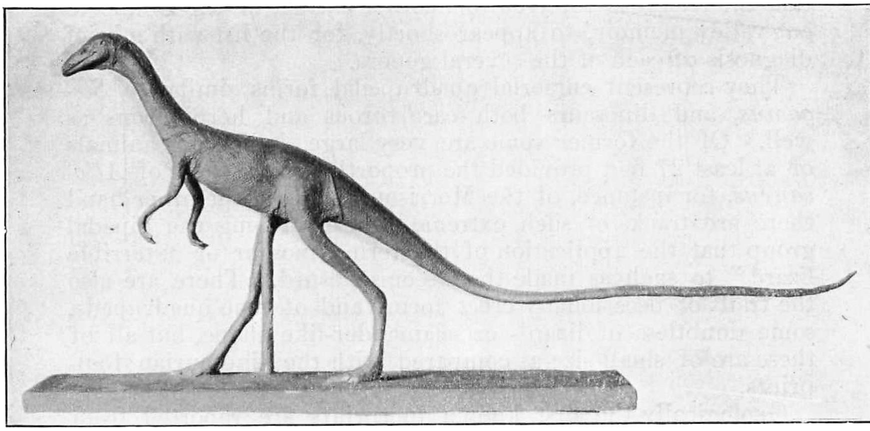

FIG. 4. *Podokesaurus holyokensis* Talbot. Restoration about one-tenth natural size. Modeled by R. S. Lull.

later by *Ornitholestes* from the Morrison and *Ornithomimus* from the close of the Cretaceous seems certain ; in fact, I see

FIG. 5.

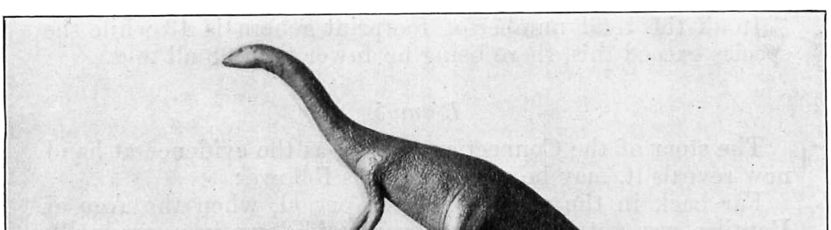

FIG. 5. *Anomœpus scambus* Hitchcock. Restoration of a plant-feeding dinosaur, based upon footprints and the skeleton of *Hypsilophodon foxii* from the British Wealden. About one-fourteenth natural size. Modeled by R. S. Lull.

no feature to debar it from a more or less direct ancestry to its American successors in time.

The Vertebrate Footprints.

The vertebrate tracks are so numerous and so varied withal that the reader is referred to another extract of the Connecticut valley memoir, to appear shortly, for the list with a brief diagnosis of each of the several genera.

They represent cursorial quadrupedal forms similar to *Stegomus*, and dinosaurs both carnivorous and herbivorous as well. Of the former some are very large, indicating animals of at least 27 feet provided the proportions were those of *Allosaurus*, for instance, of the Morrison, while on the other hand there are tracks of such extreme delicacy among the bipedal group that the application of the term dinosaur or "terrible lizard" to such as made them seems absurd. There are also the trails of occasionally erect forms and of true quadrupeds, some doubtless of lizard- or salamander-like shape, but all of these are of small size as compared with the dinosaurian footprints.

Geologically the first known footprints are reported from the anterior shales and are all apparently referable to carnivorous dinosaurs. The posterior shales are of interest in that here are found the first plant-feeding dinosaur tracks in the Newark rocks. It is not until the upper series of sandstones and shales is reached that the great profusion of tracks is manifest, not that the animals were necessarily any more numerous, but that the acme in the perfection of track preservation for which this region is so noted was reached.

In all the total number of footprint genera is 43 while the species exceed this, there being no fewer than 98 all told.

Résumé.

The story of the Connecticut valley, as the evidence at hand now reveals it, may be summarized as follows:

Far back in the remote Triassic period, when the Age of Reptiles was yet young, there were laid down in a gradually deepening trough in the older rocks the great accumulations of gravels, sands, and clays, interbedded with vast lava sheets, which constitute the sediments of the Newark system. The older notions of the submarine or estuarine origin of these rocks have been abandoned on the ground of their containing no relics whatever of marine or even brackish water origin, and of the difficulty of accounting for the deposition of the sediments except by tidal currents of far greater transporting power and governed by laws of movement at variance with any on earth to-day. On the other hand, evidence seems to point to continental deposits, the result of the ordinary subaërial agencies of winds and rains and rivers, such as require no ingenious straining of nature's laws to account for the accumulation of vast deposits in the course of time. The origin of the sediments was the wasting of the older rocks which formed the limiting highlands on either side of the depression: and the organic remains, all of fresh-water or terrestrial origin, testify to the presence, from time to time at least, of standing bodies of water of considerable extent; of seasonally, if not continually, flowing rivers; and of extensive land areas with slowly drying pools left after the infrequent, but torrential showers characteristic of arid to semi-arid regions of the present day. That there were climatic cycles, such as Huntington (1907, 1911) has observed in the Near East, I have no doubt, and I have reason to believe from the evidence of the fossil vertebrates that the climate during the earlier part of the Newark period may have been less arid than toward its close.

The vegetation bore the mark of antiquity in its monotonous sombre greens, for brilliantly colored flowering plants had not yet appeared, and apparently there was that sparseness and lack of profusion, except locally, which characterizes our great Southwest. The plants were of three main sorts: ferns, cycads, and conifers, looked upon by existing animate life as undesirable food, but which for utter want of a better must have tempted some of the denizens of Triassic time, for we have evidence of mild-mannered herbivores among the rapacious devourers of flesh.

Of the organic remains, those of vegetable origin consist of the impressions and casts of the trunks of trees, some of the latter found at Portland being of such size as to indicate a stream of no mean transporting power; and of the impressions of leaves, twigs, and fruits, occasionally containing a delicate film of carbon which preserves the most intricate detail with wonderful fidelity. Here and there the vegetable remains were of sufficient abundance to influence the production of black bituminous shale bands of 60 to 100 feet in thickness, formed during periods of the accumulation of waters which supported a teeming population of fishes; but never within this area were conditions ripe for the formation of beds of coal such as are found in the Newark strata from Virginia southward.

Animate life left its record rarely in the form of shells or bones, but in marvellous abundance in trails and footprints, some of such clarity of meaning that he who runs may read, others of more difficult and questionable interpretation, yet others exasperating in their baffling obscurity.

Both vertebrates and invertebrates are thus represented. Of the latter the actual fossils are impressions of at least two species of shells, allied to the modern fresh-water Unios, a small crustacean, and a single aquatic insect species, the last occurring in profusion of numbers, and bearing the unique distinction of being the oldest true insect *larva* known. Some of the trails are worm-like as though made by annelids, others show serially repeated footmarks in pairs of fours or sixes or more, indicating the presence of other arthropods than *Mormolucoides*, many of which were doubtless insects, others myriapods, perhaps spiders and scorpions, and fresh-water crustaceans as well. Some of these are small and of wondrous delicacy, others larger than the trails of any insects of fresh-water crustaceans known, which must represent giants among their race.

The fishes, all of the old-fashioned armored sort, have been alluded to as occurring in abundance from time to time in the black shale bands, representing lake deposits with a luxuriant growth of plants.

The terrestrial vertebrate skeletons are all reptilian remains; three those of phytosaurs, remotely related to living crocodiles, and, in one instance at least, economically equivalent to the fish-eating gavials of the Far East. The others are all dinosaurs of average size and representative kinds, neither the largest nor the most specialized which lived during the time of which we speak being known to us. Unfortunately, too, the dinosaurian skeletons were those of contemporaries and, therefore, in themselves throw no direct light upon evolutionary history. Of the five species four are so nearly related as to be of one family and three of one genus, while the other represents a different race, which in its ultimate culmination was far apart from the group for which the others stand, though all were sanguinary devourers of flesh.

The footprints represent two, possibly three, great classes of terrestrial beings. Amphibia of salamandrine form were perhaps present, and doubtless representatives of the more archaic armored stegocephalians as well, though one cannot indicate the track of either with assurance. Of the reptiles, the possibilities of time and place would indicate lizards, turtles, and dinosaurs among the more familiar forms, and these unquestionably were represented in the fauna, and among those less known the Rhynchocephalia, phytosaurs, aëtosaurs, and theromorphs are within the possibilities.

Whether or not birds were present is still a mooted question. The elder Hitchcock considered all of the bird-like tracks unquestionably to have been of avian origin, but the discovery of dinosaurian remains soon swung popular, if not scientific, opinion to the opposite extreme, and all the tracks were believed to have been made by dinosaurs. I believe, in most instances, this group of footprints is demonstrably dinosaurian. There are some, however, of which I am not so sure; but the only final proof of the existence of Triassic birds will be the actual discovery of their remains, for the earliest yet known, *Archæopteryx*, of the uppermost middle Jurassic, lived thousands of years subsequent to the close of Newark time. If Professor Osborn is right in supposing the pro-avian to have been arboreal, I should not look for its trail over the sands of the Connecticut valley, and I seriously question whether at so remote a time degenerate terrestrial birds had been evolved. On the other hand, the cursorial origin of birds is conceivable, and if true would be possible within the environment we are discussing.

Of the mammals, though known apparently in *Dromotherium* and *Microconodon* from contemporaneous rocks of not very remote geographical locality, we have no record. Their known habitat in the Triassic had a very different climatic and vegetal environment from that of the Connecticut valley; and this, as in the case of birds, would seem to debar them from the limits of this area.

Geologically, the history of Newark times was a tremendous drama of which the prologue speaks of the degradation of the ancient hills and the setting of the stage in the form of an extensive though relatively slight depression, with the establishment of the sediment-bearing drainage from the environing upland. Four great acts, of which the first and last were much the longest, succeed each other in time, separated by interacts of appalling grandeur, when vast sheets of molten rock welled from the depths and spread far and wide, blotting out the old and preparing the stage for newer and different players. Of the sequence of the scenes within the acts, the order is not so surely recorded, since they differed in their position in the valley, in the nature of the sediment in which their record is written and in the forms that peopled the stage. The whole drama is incredibly long as we measure time, for each succeeding day with its dawning, morning hours, high noon, declining sun, and long night added but the smallest increment to the gradually accumulating sediments, though, as has been said, "Neither time nor space flow evenly," and there were tempestuous days whose contribution to the mass made up for the calm passage of those to follow, yet when one thinks of the two and one-half miles of accumulations which these days represent, he can feebly grasp at a realization of the extent of Newark time.

During the long first act, in the course of which were laid down the six or seven thousand feet of the lower series of granitic, coarse sandstones, we have but little record of the action; but two entrances are recorded, one of which is at New Haven when the heavily armored *Stegomus arcuatus* appears, whose habits we can scarcely conjecture, as the burial of its body in river sediment means little. The second scene at Simsbury is more intelligible because, while part of a shoulder blade only is preserved, it is from the representative of a genus *Rhytidodon* which is almost completely known, hence we are justified in applying the old Cuvierian principle and reconstructing, not only a long-snouted, fish-eating animal from a single bone, but its fish-supporting, aquatic environment as a stage setting as well.

This act closed with the first lava outpouring, the so-called anterior trap, which was followed immediately by the second act, that of the anterior shales, interesting in being ushered in by the first fish- and plant-bearing black shale deposit, followed in the region round about Mount Holyoke and Mount Tom by the first recorded appearance of dinosaurs in the Connecticut valley. Of these *Eubrontes giganteus*, one of the very largest, was among the first, possibly representing a form like the larger genera well known from their bones in the Old World. Others were the larger species of *Anchisauripus*, indicating the presence of *Ammosaurus*-like dinosaurs as well. This second act, with but a thousand or more feet to its credit, was the briefest of all, and the interact following, as befits the middle of the drama, was the most stupendous with the accumulation of the 500 feet of lava which constitutes the main trap sheet.

Act III, during which the posterior shales were laid down, is still more prolific of animate records, for the known footprints not only increase in number, but here for the first time we find those of *Anomœpus* giving the earliest reasonably sure record of the advent of plant-feeding dinosaurs, while that of *Grallator cursorius* shows that accompanying their larger, fiercer brethren were the lighter, more agile dinosaurs of compsognathoid type. This act closed with another scene, during which the plant- and fish-bearing black shales could be accumulated. The relative duration of these posterior shales was somewhat greater than that of the anterior deposition, but was followed by the smallest of all the lava outpourings, that of the posterior trap.

It is only in the final act that the profusion of the cast becomes evident, for at various levels within the 3,500 feet of its accumulations, but notably toward its close, at Portland, around South Hadley, and within and about Turners Falls, are recorded by far the great majority of the known genera and species of the footprints of the Trias; while equivalent beds, mainly from South Hadley southward to Manchester, Connecticut, have yielded all of the osseous dinosaurian remains. One is impressed with the profusion of trails which imply swift motion, as though conditions were hard and life the antithesis of one of languorous ease, the principal feature which gives rise to the belief of locally increasing aridity of climate.

Here more than in any other act of paleontological history one is conscious of an obscuring drop scene in the middle distance, behind which may be seen with tantalizing clarity the passing and repassing feet of a great host of players: some rapidly, as though impelled by urgent impulse; others slow-moving, ponderous, the like of which the paleontologist has never seen. Occasionally one passes before the curtain and there, while fully exposed to our scientific vision, a tragedy is enacted, for bones are ever symbolical of death; but the footprints are those of creatures in the full tide of life.

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Geologic Section of the Newark System of Connecticut (modified from Schuchert).

Character of sediments	Thickness	Characteristic fossils
Upper series of sandstones and shales with local conglomerates	3,500 ft. +	The great majority of known footprints of all varieties, vertebrate and invertebrate; also *Mormolucoides articulatus*. *Anchisaurus* spp., *Ammosaurus* and *Podokesaurus*, among dinosaurian skeletons. *Stegomus longipes*, skeleton.
Posterior trap sheet	150 ft.	
Black bituminous zone	100 ft.	Plants and fishes
Posterior shales	1,200 ft.	Dinosaur tracks. First plant-feeding dinosaur footprints known. Mt. Tom East, Middlefield, etc.
Main trap sheet	500 ft.	
Anterior shales	1,000 ft.	First known dinosaurian footprints. Carnivores. Mt. Tom West and Mt. Holyoke; Higby, Conn.
Black shales	50 to 100 ft.	Plants and fishes
Anterior trap sheet	250 ft.	
Lower series granitic, coarse sandstone (With intrusive trap sheet, 500–600 feet thick)	5,000 to 6,500 ft.	*Rhytidodon validus*, Simsbury, Conn. *Stegomus arcuatus*, New Haven, Conn. *Estheria* sp. West Holyoke, Mass.
Sandstone	200 to 300 ft.	
Gneisses, schists, and granites Pre-Mesozoic		