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ART. VII.—*Fossil Footprints of Connecticut River.* By JAMES DEANE, M. D.

## Plates VIII and IX.

The footprints of the new Red Sandstone of Connecticut river, clearly indicate that birds existed in multitudes during the deposition of this rock. Their vestiges are preserved with such remarkable fidelity, that no difficulties occur in assigning to them their true place in the scale of animal organization. Their relation to existing types is susceptible of unquestionable proof upon the application of the laws of comparison. It consists in the corresponding number and arrangement of the toes and their appendages, and in the impress of the heel. The law of correlation of structure, or rather of configuration of structure, is distinctly shown by several figures in the accompanying plate VIII. The massive foot, fig. 2, and the more slender one, fig. 1, illustrate this principle in the clearest manner. They are both right feet, and the inner toe is distinguished by the impress of two articular lobes, the middle three and the outer four, which with the terminal joint or that of the nail is in exact correspondence with the phalangeal divisions of the feet of living birds. Posteriorly to the toes is the impress of the distal extremity of the tarso-metatarsal bone, and this completes the harmonious relations of the fossil footprint with that of living birds having an equal number of toes. The comparison is corroborated by the method of progression. The movement of the extinct birds is invariably by successive and alternate steps of the right and left foot, each pointing in the direction of its successor. It consequently happens that the inversion of the foot is in proportion to the length of the step. When the step is comparatively long, the footprints point directly forward and fall in a direct line or nearly so, whereas if the step be short, each foot points more or less inward, and falls considerably outward of the direct line of progression. It is so in living birds, and these are the points of comparison that connect them with their remote ancestors. In rare instances the impress of the dermoid papillæ is exquisitely preserved.

It is obvious that the footprints were impressed upon the margins of such bodies of water as were subject to considerable fluctuations of level, and it is impossible to say whether this disturbance was due to the action of tides or of floods. It is difficult to understand how the strata should become sufficiently hardened by exposure during the period between the ebbing and flowing of tides, to retain impressions. The birds trod upon the impressible mud when in condition to retain the form of the foot, and

ere it became obliterated or injured, it in turn was overspread and preserved by materials deposited by the succeeding overflow of waters. In this way, stratum upon stratum was superimposed in an inclined position, each one a vivid register of the movements of the animal that trod upon it. The vast thickness of these accumulated deposits is amazing. Footprints, however, only occur at occasional intervals in the order of deposition. It is usual to find several thin fossil-bearing layers in contact, and this species of rock is separated by wide intervals of non-fossiliferous strata, a fact that suggests the idea that the visits of the birds were periodical. It is usual to see upon the same surface considerable variety in the character of the footprints, but being simultaneously impressed it is certain that the birds, although specifically distinct, were gregarious, and that their instincts were harmonious. A stratum may contain several species of ornithic footprints, one or two species of quadrupedal impressions, while its entire surface is completely spotted by the indentations of falling rain.

When a fossil stratum is raised from its bed, its inferior surface is seen to be an exact cast of the impressions upon the stratum beneath, which are consequently in relief and disclose the precise form of the plantar surface of the foot. It sometimes happens that the impress upon the upper stratum is transmitted to several inferior layers, often as many as five or six, a phenomenon that has been explained upon the supposition that each stratum yielded to the weight of the bird. But the disproportion between the size of the footprint and the thickness of the strata forbids this solution. Such impressions are always *imperfect*; an unblemished imprint never transmits its form to the layer beneath, unless it be so extremely thin as to bend by the weight of the bird. An explanation which is undoubtedly correct has been suggested by Mr. Marsh. He thinks it due to the plastic state of the strata at the time of the animal's transit; the foot in sinking perforated the strata, which closed again upon the withdrawal of the foot, and thus left rude representations of its outline. In such cases there is no evidence of the articulations of the foot, a depression representing each toe is all. It is not unusual in this class of impressions to see upon the upper layers a depression projecting backwards from the heel, much longer than the foot itself, made by the *leg* in sinking through the unresisting medium, which has led to the belief of peculiar species.

The existence of the ancient birds in respect to size embraced a vast scale. Many families were small, and others of stupendous proportions, far exceeding those of modern times, and only approximated by those gigantic remains recently disclosed in the island of New Zealand. From the character of the fossil footprints, it is inferred that the birds belonged to those orders that resort to the shores of accumulated waters for subsistence and reproduction. Their feet were massive and were terminated by blunt nails; their stride was extensive, and as a whole they were evidently waders,

yet a considerable proportion of the footprints sustain a close resemblance to the feet of existing struthious birds. Most of the footprints are tridactylous, a few have a fourth toe, and others still are characterized with obscure brushy tarsal appendages. But as a general thing the clear unequivocal impressions display three massive toes, a massive heel, and three blunt claws.

Other creatures co-existed with the numerous tribes of birds, but their numbers as at present understood were not great. Their footprints indicate animals of inferior dimensions as compared with their biped cotemporaries. They are referrible to several species of Batrachian and Chelonian reptiles, the former being characterized by the great disproportion between the size of the posterior and anterior feet, and the latter by their trail. I have elsewhere given drawings of five distinct species of batrachian footprints, and the list might be somewhat extended by recent discoveries. That multitudes of amphibious and other inferior creatures inhabited the ancient seas there is abundant proof, but as the destruction of their organization has been complete, our knowledge of their character is very obscure. Fishes abound in the new red sandstone; and thus during the deposition of this rock three great classes of the animal kingdom were represented, Aves, Pisces, and Reptilia, and the presumption is irresistible that the superior class, Mammalia, was contemporaneous.

The accompanying plates illustrate five undescribed species of ornithic footprints, derived from Turner's Falls.

Fig. 2, plate VIII, is an elegant impression. The toes are massive and display the order of articulation. The outer or long toe is somewhat imperfect at the terminal joint. Projecting backward from the toe is a deep circular impression of the outer tubercle of the tarso-metatarsal bone; the central one is embraced by the first joints of the lateral toes, while the inner one falls behind the short toe. The same arrangement is observed in fig. 1, and thus the aggregate of depressions in good examples is fifteen; namely, for the inner toe two, middle three and outer four, three for the nails and three for the heel.\* Fig. 1 shows this method very clearly. It will at once be seen that this footprint is specifically different from that of fig. 2. The toes are slender, widely separated, and the foot is much smaller. The stride in fig. 2 is fourteen inches, and in fig. 1 it is ten inches. Either of these footprints may be taken as a model for comparison, for in each every essential feature is accurately impressed. They do not differ materially from many other impressions; still to the practised eye the form of the foot and individual toes, length of stride, &c., separate them from all others hitherto discovered. The toes in fig. 2 are extremely fleshy and stout, whereas in fig. 1 they are tapering and slight.

Fig. 3, is a singular impression lately discovered by Mr. Marsh, and added to his magnificent collection of sandstone fossils. He believes it to be a palmated foot, but

\*It rarely happens, however, that the inner tubercle of the tarso-metatarsal bone is impressed.

I do not feel certain of this. No unequivocal specimen of a webbed foot has ever been seen. The divarication of the lateral toes is much greater than is usual. The toes and heel are very massive, and in such proximity at their junction as to convey the appearance of a membraneous connection. The impression although striking is not perfect, as it is not easy to make out the phalangeal impressions, still it is sufficiently so to render it specifically distinct from all others. It is a right foot, but the length of step cannot be determined as it is a solitary impression.

Fig. 4 differs entirely from the foregoing, as it does not display the phalangeal or tarsal depressions, but in place of the latter there is an impression of a bushy appendage projecting from the heel. This example was taken from a row of six impressions each identical, and in all, the only impress of the central toe is its extremity. The step is ten inches. The expression of this footprint is striking and peculiar, and the specimen from which it was taken is regarded as a very interesting one.

The footprint upon Plate VIII is remarkable for its immense proportions, although it falls far short of other gigantic impressions, which are sometimes found from fifteen to eighteen inches in length. The specimen from which the drawing was taken exceeds in dimensions the foot of any known existing bird. This species is rare, but I have seen rows of six or seven consecutive impressions. The stride is four feet, and the immense weight of the bird caused it to sink into the stratum, and consequently its footprints are invariably deep. The peculiar feature of this impression is the vast size of the heel. It does not display the usual bilobed divisions, but is large, circular, and very deep. The lobes of the inner and central toes are sufficiently distinct. The toes are in close proximity, and the weight of the bird compressed the resisting medium into an unusual degree of smoothness. There are, however, some slight fractures in the long toe caused by the separation of the strata.





Fig 2



Fig 1



Fig 3



Fig 4

On Stone by J. Deane.

T. Sinclair's Lith. Phila.

FOSSIL FOOTPRINTS OF BIRDS.













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