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ART. I.—*Remarks on the Geology of the Lakes and the Valley of the Mississippi, suggested by an excursion to the Niagara and Detroit Rivers, in July, 1833; by JOHN BANNISTER GIBSON, Chief Justice of the Supreme Court of Pennsylvania.*

It is known that the principal geological formations in Pennsylvania, so far as the series extends, occur in the order of superposition in which the same formations are arranged in Europe. We have, with their subordinates, granite, gneiss, mica slate, clay slate, graywacke including the old red sandstone, transition and mountain limestone, and the great coal formation which traverses the state from north-east to south-west, and which ought by analogy to lie immediately on the mountain limestone, instead of the stratum of rock salt* on which it is proved to lie by the borings on the Ohio and its tributaries. At Pittsburg, the salt is found under three distinct seams of coal, at an average depth of five hundred feet below the bed of the river.

In the north-western part of the state, in the western part of New York, in Upper Canada, Ohio, Michigan, and regions further west, two superior formations occur. The inferior of these, is the new red sandstone of the English geologists, and is scarcely distinguishable by its external character from the old, which has, in this country, been usually confounded with it, although admitted in Europe to be the undermost member of the carboniferous group, if not a ferruginous graywacke. The other, however, is here in place, resting on the basset edges of the coal strata which crop out along

* The statement of the author is doubtless correct as a general fact; but, it may be added, that the salt of the West is found also above the coal, as well as below it. See Dr. S. P. Hildreth's memoir and sections in our last number. Salt does not occupy, invariably, the same position in Europe, for it is found both higher and lower than the new red sandstone.—*Ed.*

The American Journal
of Science and Arts:
Caricography, by C. Dewey;
Ornithichnology, by Hitchcock;
geology, fossils, Fata Morgana
Vol. 29, No.2
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This is a copy of the hard-to-find publication *The American Journal of Science and Arts*; it is the complete issue of Volume XXIX, Number 2 (conducted by Benjamin Silliman, printed by Hezekiah Howe & Co., 1836); it has 200 pages (numbered 201 to 400), plus 4 plates of botanical engravings, three fold-out plates, and a 4-page index; there are a number of illustrations in the text as well. This issue was originally bound with Number 1 of the volume, so it looks more like a broken book than a publication. Includes a total of 22 articles, plus 36 short articles under the title *Miscellanies*.

There are several outstanding articles here, most notably the following:

CARICOGRAPHY, by Prof. C. Dewey, 10 pages of text, plus four plate engravings showing 18 figures (Caricography is the study of *SEDGES*, a taxon of monocot flowering plants that superficially resemble grasses or rushes. The family is large, with some 4,000 species described in about 70 genera. These species are widely distributed, with the centers of diversity for the group occurring in tropical Asia and tropical South America).

ORNITHICHNOLOGY - Description of the **FOOT MARKS OF BIRDS** on new Red Sandstone in MASSACHUSETTS, by Prof. Edward Hitchcock, 33 pages of text, plus three large fold-out plates - these show *Ornithichnites Giganteus* and *Ornithichnites Diversus a Clarus*; a chart with 24 numbered figures of bird foot mark examples; and the third, which is unfortunately missing the top portion, titled *Proportional View of the Ornithichnites* (it's hard to tell how much is missing).

Other articles of interest:

FATA MORGANA AT GIBRALTAR - a 5-page letter by an officer of the American Navy, an incredible description of several eye-witness accounts of this natural visual phenomenon, a type of mirage that creates a distorted vertical image of relatively flat objects so that they appear incredibly tall or high - in the case of this article (which kind of blew my mind) it is refracted or inverse images of sailing ships, reported here as an incredibly tall vessel, with another inverted in the sky over it; another, with two spectral vessels in the sky, one inverted and one upright, above the true vessel, of which one could only see the top of her sails above the fog.

Researches on the **COMMERCIAL POTASH** of the STATE OF NEW YORK, by Lewis C. Beck (14pp);
Remarks on the **GEOLOGY OF THE LAKES AND THE VALLEY OF THE MISSISSIPPI**, by Judge Gibson of Pennsylvania (13 pages);

Remarks on the **TOPOGRAPHY, SCENERY, GEOLOGY, ETC.**, of the Vicinity of the **CAPE OF GOOD HOPE, SOUTH AFRICA**, by **GEORGE CHAMPION** (7pp);

Physical Observations on the **U.S. SHIP ERIE** in 1834 (4pp);

Visit to the **QUICKSILVER MINES OF IDRIA** (4pp);

SALT MOUNTAINS OF ISCHIL (5pp);

Notice of Some **AMERICAN BIRDS** (3pp);

The **TRAUN STEIN ROCK** (2pp);

and others.

No covers, bound pages measure 5.5 by 8.5 inches, with remnants of leather and glue to spine; the pages and engravings are in good condition overall - there is scattered minor and moderate foxing throughout, some minor corner bumping; one folding plate has come free from the page section so it has a rough edge; the one fold-out is missing a top portion as previously mentioned, and the engravings all have moderate foxing; the two folding plates attached at the rear are starting to pull free. Condition, as is, is Good.

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his manifesting an unusual uneasiness, and frequently thrusting his head against and between the wire grates of his prison, as if endeavoring to effect an escape. After striving and chafing against the wires a few minutes, the skin at the point of the head began to cleave off and turn back over the head on to the neck, in an inverted form. After the animal, by pressing the part against the wires, had succeeded in thrusting back the skin three or four inches upon the neck, he left the wires, and throwing his body into a coil around itself, so as to embrace with the last fold the inverted skin, with a strong muscular pressure, made at the same time a powerful effort, shot his body forward through the coils, which unfolded, one after another, and thus drew off the entire skin. This is, in all probability, the *modus operandi* of the whole race, and of whom it may be truly said, "they are all turncoats."

To the enquiring mind, the question might naturally suggest itself—for what reason, and by what necessity, is it, that the serpent, different from other creatures in the animal kingdom, throws off his skin annually? To this it might be replied, the condition to which this animal is doomed, "Upon thy belly shalt thou go," &c. renders it necessary to his comfortable existence, that he be furnished with a covering suitable to that condition. Hence nature has provided for him a complete *coat of mail*, wonderfully contrived in all its parts. Plates, greaves, scales, joints, and ligatures, are all employed in the construction of this protecting armor.

The nicely polished scales, which cover the under side of the body, enable the reptile to glide along upon the ground, among grass, weeds, and other obstructions, with astonishing facility. This coat, however, is necessarily composed of a *material*, the nature of which renders it incapable of distension or expansion. At the return of the warm season of the year, the snake awakens from his torpidity, issues from his winter lodging, and having a full supply of food, which that season affords, soon begins to thrive, and his dimensions increase. He now finds himself too straitly *laced*, and takes measures to rid himself of so uncomfortable a garment.

I have inclosed a specimen of the cast skin of the garter snake, by which you will perceive the inverted convexity of the crystals of the eyes and form of the head; a fragment also of the skin of a small adder. You will notice a difference in the belly scales, as to their proportions.

ART. XX.—*Ornithichnology.—Description of the Foot marks of Birds, (Ornithichnites) on new Red Sandstone in Massachusetts;* by Prof. EDWARD HITCHCOCK of Amherst College.

THE almost entire absence of birds from the organic remains found in the rocks, has been to geologists a matter of some surprise. Up to a very recent date, I am not aware that any certain examples of these animals in a fossil state have been discovered, except the nine or ten specimens found by Cuvier, in the tertiary gypsum beds near Paris. In the third volume (third edition) of his *Ossemens Fossiles*,* he has examined all the cases of fossil birds reported by previous writers, and he regards them, nearly all, as deserving little credit.

For this paucity of ornitholites, geologists have, indeed, assigned probable reasons, derived from the structure and habits of birds. These render them less liable, than quadrupeds and other animals, to be submerged beneath the waters, so as to be preserved in aqueous deposits; and even when they chance to perish in the water, they float so long upon the surface, as to be most certainly discovered, and devoured by rapacious animals.†

But although these circumstances satisfactorily explain the fact, above referred to, they do not render the geologist less solicitous to discover any relics of the feathered tribe, that may be found in the fossiliferous rocks: and I have, therefore, been much gratified by some unexpected disclosures of this sort, during the past summer, in the new red sandstone formation on the banks of Connecticut river, in Massachusetts.

My attention was first called to the subject by Dr. James Deane of Greenfield; who sent me some casts‡ of impressions, on a red micaceous sandstone, brought from the south part of Montague, for flagging stones. Through the liberality of the same gentleman, I soon after obtained the specimens themselves, from which the casts were taken; and they are now deposited in the cabinet of Amherst College. They consist of two slabs, about forty inches square, originally united face to face; but on separation, presenting four

* P. 302.

† Lyell's Geology, Vol. II, p. 246, first edition.

‡ The editor of this Journal was early indebted to Dr. Deane, for similar casts of these tracks.

most distinct depressions on one of them, with four correspondent projections on the other; precisely resembling the impressions of the feet of a large bird in mud. Indeed, among the hundreds who have examined these specimens, probably no one doubts that such was their origin. Having never been injured by exposure, they are perhaps the most perfect specimens, that I have been able to obtain. They were dug from a quarry in the southwest part of Montague, less than half a mile from Connecticut river, and elevated above that stream, not more than one hundred feet. The strata there, dip easterly, not more than five degrees; and the layer containing the impressions, was several feet below the surface. Only one variety of track has yet been discovered at that spot.

Not long afterwards, Col. John Wilson of Deerfield, pointed out to me similar impressions on the flagging stones in that village. Having ascertained that these were brought from the town of Gill; from a quarry on the bank of Connecticut river, at a place called the *Horse Race*, nearly three miles higher up the stream than Turner's Falls, and eight or nine miles north of the quarry in Montague, above described, I visited the spot, and was gratified to find several distinct kinds of similar impressions; some of them very small, and others almost incredibly large. This quarry lies immediately upon the northern bank of Connecticut river; the strata dipping southerly at an angle of 30° , and passing directly under the stream, without any intervening alluvium. The rock is a gray micaceous sandstone, very much resembling, in hand specimens, some varieties of mica slate, with about the same degree of hardness and not very fissile.

In passing over the side walks at Northampton, during the summer, I discovered several examples of similar impressions upon the flagging stones. These stones were obtained from a quarry in the southeast part of the same town, on the east side of Mount Tom: and on resorting thither, I found numerous examples, some of them very fine, of several kinds of tracks. The strata at this spot, dip to the east, not more than 10° , and pass directly beneath Connecticut river, by which they are washed. There are three varieties of the rock on which the impressions occur at this locality: 1, a reddish shale, or rather a fine micaceous sandstone passing into shale—the red marl, I suppose, of geologists: 2, a gray micaceous sandstone: 3, a very hard sandstone, not very fissile and quite brittle, composed of clay and sand. These varieties are interstratified in a rather irregular manner. By the water, and the quarrymen, the rock is

here laid bare, in length forty or fifty rods, (even double this distance at low water,) and several rods in width; but it has not been extensively wrought for economical purposes. This spot is more than thirty miles south of the Horse Race; and these are the two extreme points of that region, in which I have discovered these impressions. Near the village at South Hadley canal, however, among the fragments of hard gray shale, blasted out for the canal, I found a single specimen; and a fine specimen has been found in the north part of South Hadley, near Mount Holyoke, on a coarse gritstone. South Hadley lies on the east side of Connecticut river, opposite to the quarry above described, on the east side of Mount Tom.

I know of no reason why these impressions, should not occur in any part of the valley of the Connecticut, where slaty sandstone, similar to the varieties above described, exists; (and this rock does extend southerly from Mount Tom, sixty or seventy miles); but I have examined the quarries in the vicinity of Hartford, and at Enfield Falls, as well as the flagging stones in Hartford and Springfield, and have made no discoveries. I have some reasons, however, to suppose that such impressions have been found in Wethersfield; and I should think it very strange, if they are not brought to light in that place, or in Middletown, or perhaps at Chatham.

It will be seen from the preceding statement, that I have ascertained the existence of these impressions in five places, near the banks of Connecticut river, within the distance of about thirty miles. Having repeatedly visited these localities within the few last months, I shall now present the results of my examination: and I shall first give a more general account of the impressions, and then attempt a classification and specific description.

Where the surface of the rock has been exposed for a great number of years, to the action of the weather, I have never found any of these foot marks. They occur only where the upper layers have been removed by human, or aqueous agency. And I know of no reason, why they might not be found in a hundred other places along this river, were quarries to be opened in so many places.

At the quarries above named, these impressions are exhibited on the rock in place, as depressions, more or less perfect and deep, made by an animal with two feet, and usually three toes. In a few instances, a fourth or hind toe, has made an impression, not directly in the rear, but inclining somewhat inward; and in one instance, the four toes all point forward. Sometimes these ternate depressions

run into one another, as the toes approach the point of convergence: but they also sometimes stop short of that point, as if the animal had not sunk deep enough to allow the heel to make an impression. Nay; at that point the stone is in some cases irregularly raised, as if the weight of the animal had caused the sand or mud to crowd upwards in the rear of the step. In a few instances, also, behind this slight elevation, there is a depression as if a knobbed heel had sunk slightly into the yielding mass.

In a large number of instances, also, there is a remarkable appendage to the hind part of the impression. There radiates from it in the rear, in the larger tracks to the distance of several inches, the apparent impression of stiff hairs, or bristles. The drawings appended, will convey as good an idea of this appearance, as I can give.

In all cases where there are three toes pointing forward, the middle toe is the longest; sometimes very much so. In a majority of cases, the toes gradually taper, more or less to a point: but in some most remarkable varieties they are thick and somewhat knobbed, and terminate abruptly.

In the narrow toed impressions, distinct claws are not often seen, although sometimes discoverable. But in the thick toed varieties, they are often very obvious. Much, however, in respect to this appendage, depends upon the nature of the rock. If it be composed of fine clay, the claws are usually well marked. And then again, if we chance to cleave the rock a little above, or a little below the layer, on which the animal originally made the impression, the claws will be very likely not to be visible; as I shall show more clearly farther on.

If we lift out of its bed a portion of the rock, several inches thick, on which one of these impressions exists, and break it so that the fracture shall pass across the toes, we shall see on the edge, the successive layers of the rock bent downward, often two, three, or even four inches in thickness. If we carefully cleave open the specimen thus raised, on one face we shall have a ternary depression, as has been described; and on the other face, a correspondent figure, projecting more or less, sometimes in high relief. And these specimens *in alto relievo* often give us a better idea of the structure of the foot that made the impressions, than those that are depressed. For often it is difficult to cleave a specimen so perfectly, that the portions of the rock which fills the depression, shall all be got out; and in do-

ing it with a chisel afterwards, the natural face of the layers is apt to be marred: whereas it seems to have been often the fact, that the sand and mud which filled the original track, are more firmly concreted than the rock generally, and are thus rendered scarcely fissile at all; and while the rock around the track becomes shaly, so as easily to be cleaved off, the track itself remains unaffected; and thus with care, a fine specimen may be obtained. I doubt not, but the quarrymen, had they known the nature of these relics, might have saved in times past, many specimens of this kind: as I found fragments of this sort among the rubbish thrown out of the quarry.

There is one case, in which we do not see the layers of the rock conforming to the depression produced by the track. It is when the track was made in very fine mud, or clay, and the depression is filled by the same material in a concreted form. If in these circumstances, a layer of coarser materials, is superimposed, this layer often exhibits no traces of the impression beneath. And I can easily conceive how such a change of circumstances, (perhaps a sudden rise of the waters,) as brought on the coarser materials, should have so filled up the depressions as to leave a level surface for the deposition. In such cases, we obtain specimens only in relief.

In descending into the rock in a quarry, by splitting up the successive layers, we first meet with the track in rather an imperfect state, the toes being short and blunt. But by cleaving off a layer or two, the impression becomes larger and more distinct; and sometimes claws are visible. If we continue to cleave off layers beneath where the impression is most perfect, we may find, perhaps, some traces of it; as for instance, the thickest or middle toe; but it is much sooner lost in descending, than in ascending from the layer where it is most perfect.

I early directed my attention to the enquiry, whether these tracks could be traced in succession: that is, whether they were made by an animal in the act of walking; and I have been agreeably surprised to find so many examples of this sort, of the most unquestionable kind. Drawings of some of the most remarkable of these, accompany this paper, (Figs. 1 to 10, with Fig. 15, 16, 17, 23 and 24.) But a particular description of them will come in more conveniently, in another place. In one instance, (Fig. 6.) it will be seen, that no less than ten tracks succeed each other in such a direction, and with so nearly equal intervals, that it is impossible to doubt that they resulted from the continuous steps of an animal. Nor does there

seem to be any reason why they may not be traced farther, except that the layer of rock containing them, is not laid bare beyond the tenth track. It is also impossible to doubt that this, and all other continued tracks, were made by a biped. For we search in vain to find any corresponding or parallel row of impressions. They are not, indeed, exactly on a right line; but the alternate tracks deviate a little to the right, and the remaining ones to the left, sometimes more and sometimes less, the toes being ordinarily turned outwards. The interval, also, between the different steps, varies; sometimes several inches in the smaller impressions, and even a foot or two in the layer: just about as much, indeed, as we should expect in an animal moving at different paces.

It has been interesting to observe, in almost every case where the impression is distinct, how easy it is to determine whether it were made by the right or the left foot of the animal. Even in an insulated impression, this can be generally decided; and where the tracks are continuous, it is easy to see that the left and right foot alternate. In the right foot, the toes, especially the middle one, are slightly curved towards the left, so as to make the exterior side of the bow on the right side of the track; an effect resulting from the effort of the animal to throw the body forward. The same effort causes the outer part of the heel in the large tracks to appear as if thrown behind the inner part, and the reverse of all this, is true of the track made by the left foot. (See the plate appended, exhibiting a proportional view of the tracks.)

The inclination, or dip of the rock at the different quarries, varies from 5° to 30° . Yet the animals seem to have passed over it, while in a plastic state, in every direction with equal facility. At the Horse Race, where the dip is 30° , they sometimes appear to have ascended, and sometimes to have descended, and sometimes to have passed diagonally; yet the tracks are not at all changed by the steepness of the declivity. There is no appearance as if the animal had scrambled upwards, or slid downwards, except in one or two tracks of great size, where the mud appears to have been rolled up a few inches before the feet. But in this case, the animal was moving horizontally, that is, along the line of bearing of the strata; and even on level ground, a heavy animal, moving at great speed, will produce this effect upon plastic matter. So that upon the whole, the evidence is quite decisive, that these tracks were made before the rock was elevated to its present situation; that is, while it was hori-

zontal, or nearly so; a conclusion, to which the geologist would come, from evidence independent of the impressions.

I have stated, that often the tracks can be traced in regular succession: but this is by no means always the case. Sometimes different species of animals, and different individuals, have crossed one another's tracks so often, that all is confusion; and the whole surface appears to have been trodden over; as we often see to be the case, where quadrupeds, or ducks and geese resort, upon the muddy shores of a stream or pond. Fig. 10 exhibits a case of this kind on a specimen of sandstone in my possession from the Horse Race.

I trust I have proceeded far enough in these details, to justify me in coming to the conclusion, that these impressions are the tracks of birds, made while the incipient sandstone and shale were in a plastic state. This is the conclusion, to which the most common observer comes, at once, upon inspecting the specimens. But the geologist should be the last of all men to trust to first impressions. I shall, therefore, briefly state the arguments that sustain this conclusion.

1. These impressions are evidently the tracks of a biped animal. For I have not been able to find an instance, where more than a single row of impressions exists.

2. They could not have been made by any other known biped, except birds. On this point, I am happy to have the opinion of more than one distinguished zoologist.

3. They correspond very well with the tracks of birds. They have the same ternary division of their anterior part, as the feet of birds. Frequently, and perhaps always, the toes, like those of birds, are terminated by claws. If the toes are sometimes slender and sometimes thick and blunt, so are those of birds. If they are mostly wanting in the hind toe, so are many genera of birds, especially the Grallæ.

I am not aware that the tracks of living birds have been much noticed; and I regret that it has not been in my power to make more observations of this sort, than I have done. But so far as I have examined them, they bear a striking resemblance to the impressions under consideration. I was particularly struck with the resemblance at two of the quarries, that have been described; viz. at the back side of Mount Tom, and at the Horse Race. The rock at these places, passes under the river, whose waters have deposited a thin stratum of mud, just at the margin of the stream. Here in the summer, a few small species of Grallæ, particularly the snipes, resort for

food. Their tracks of course, are numerous; and, were the mud to be suddenly hardened into stone, they would scarcely be distinguished from some of the tracks on the sandstone in the immediate vicinity. Indeed, in one instance, the process was well nigh completed: for the water had fallen several feet and left the mud with the tracks exposed for some weeks to the sun in a dry season; so that it was almost as hard as stone; and had I taken a cast of the impressions, as I might have done, I am sure it would easily have passed for the tracks in sandstone.* I merely took a sketch of a few of the impressions, which is given in Fig. 14. I could not, however, but feel, that I was witnessing a repetition of the very process by which the tracks in the stone were produced.

Fig. 12, is a sketch of two steps of the common goose, (*Anas Canadensis*) on mud. The length of the foot is four inches, and of the step, seven inches. The space beneath the web connecting the toes, is quite obvious on the mud; it being sunk below the general level, but not so deep as the toes. The entire absence of any such appearance in the fossil tracks, makes it almost certain, that none of them were produced by web-footed birds. The lateral distance of the successive tracks in Fig. 12, to the right and left of the central line of the bird's course, is much greater than that of any of the fossil tracks of the same size.

Fig. 13, exhibits the tracks of a bird, probably of the genus *Tetrao*, which I met with last summer; but I caught only a glimpse of it. The length of the foot, not including the hind toe, is one inch and a half, and of the step, five inches.

Fig. 14, has already been referred to, as exhibiting the steps of a small species of snipe, wanting in the hind toe. Its foot is only an inch long, and its step two and a half inches. The same tracks are shown in Fig. 11, laid off from the same scale as the fossil impressions in the first two figures, in order to exhibit their relative size in respect to the fossil foot marks.

Fig. 20, shows a case of the tracks of the domestic hen (*Phasianus gallus*) in mud. The foot, without including the hind toe, is nearly three inches long; the length of the step, six inches. This is the ordinary distance between the tracks of this species. Only the alternate track shows the hind toe; owing to the foot's not sinking deep enough in all cases.

* Such tracks as are the subjects of this paper.

A few tracks of the domesticated turkey, (*Meleagris gallipavo*), are shown in Fig. 18, taken from impressions in snow. The foot (that of a large cock turkey,) is four inches long, and the step twelve inches. The hind toe points inward, so as to be nearly on a continuation backward of the outer toe.

In Fig. 19, a view is given of the tracks of the peahen, (*Pavo cristatus*.) They very much resemble those of the turkey, except that in those of the peahen, the impression of the hind toe appears rather as a hole made by the end of a stick, and does not extend so as to reach the other toes, except where the snow is deep. Not including the hind toe, the length of the foot is three and a half inches; and of the step nine inches.

The tracks of living birds on Figs. 12, 13, 14, 18, 19 and 20, are laid down on a much larger scale, than the fossil foot marks. But the resemblance between them, cannot escape notice; and it is much more obvious in the real specimens. The Gallinæ, however, present a more distinct impression of a heel, than I have seen in the fossil species, except one. This is shown by the small circle near the point, from which the toes diverge. Where the impression was very perfect, I have observed all the little protuberances and depressions of the bottom of the foot; but generally they are not visible, and the claws are very rarely seen, as a distinct part of the impression.

Assuming it then as established, that the tracks under consideration on stone, were those of birds, I shall proceed to give a more specific description of the several sorts, which, I think I can recognize. And since this is a department of oryctology hitherto unexplored, I suppose I shall be justified in proposing some new terms.

I include all the varieties of tracks under the term *Ornithichnites*; (*ορνις* and *τιχνοσ*) signifying *stony bird tracks*: and if it be convenient to speak of the subject as a distinct branch of knowledge, I should call it *Ornithichnology*.

All the varieties of tracks which I have discovered, I include under two divisions: 1, the *Pachydactyli*, or thick toed: 2, the *Lep-
todactyli*, or slender toed. In the former, the toes are of almost equal thickness through their whole extent, except that they are somewhat tuberos; and they terminate rather abruptly; not, however, without a claw. In the latter, the toes are far narrower, and less thick, with an equal span: and, indeed, some of them are quite delicate, (Ex. gr. Fig. 15.) They taper gradually to a point, and the claw is not often distinctly perceived. Under these divisions, I

repose much confidence in the distinct existence of the following species and varieties. Indeed, had I followed my own impressions, I should have regarded some of the varieties, as species. But I prefer to make the number too small, rather than too large.

When I speak of species here, I mean species in oryctology, not in ornithology. And I doubt not, that in perhaps every instance, what I call a species in the former science, would be a genus in the latter; that is to say, these different tracks were made by birds that were generically different.

I am aware, that even where the whole skeletons of birds are found, it is very difficult often to distinguish species. "The difference," says Cuvier, "between two species, is sometimes entirely inappreciable from the skeleton. Even the genera cannot always be distinguished by osteological characters."* Is it not then presumptuous to speak of distinct species when we have nothing but a mere impression of the foot? I presume that in following the indications derived from this single source, we cannot always avoid confounding several distinct species of birds under a single species of ornithichnites: and observation upon the striking resemblance between the tracks of several living species of birds confirms me in this opinion. But if we take into the account the size and form of the track, and the distance between the successive steps, I am confident we can distinguish, often between those birds that were considerably unlike one another. "The places where birds live, and the manner of their moving forward," says Duméril, "are, so to speak, indicated beforehand by the disposition of their feet. Indeed, it is by the form, the length of the feet, and the disposition of the toes, that birds are divided into six orders, &c."†

ORNITHICHNITES.

1. *Pachydactyli.*

O—— giganteus.

O—— tuberosus.

α dubius.

2. *Leptodactyli.*

O—— ingens.

α minor.

* Ossemens Fossiles, Tome troisieme, p. 524, third edition.

† Elemens des Sciences Naturelles, Tome II, p. 258, fourth edition.

- O——— diversus.
 α clarus.
 β platydactylus.
 O——— tetradactylus.
 O——— palmatus.
 O——— minimus.

Specific Descriptions.

O. giganteus. Toes three; length of the foot, fifteen inches, exclusive of the claws. In one specimen, the claw is at least two inches long, and even then a part of it appears to be missing: in general it is not more than one inch, but seems to be broken off. The whole length of the foot, consequently, is sixteen or seventeen inches! Length of the successive steps, between four and six feet! toes somewhat tuberculated; the inner one, in some specimens, distinctly exhibiting two protuberances, and the middle one three, although less obviously. Average thickness of the toes, one inch and one fourth; breadth of do. two inches. Occurring only at the quarry in Northampton, on the east side of Mount Tom, where it is abundant. I found in one spot, six tracks of this species in succession, the average distance between them, being four feet. This case is represented in Fig. 1, along with three other tracks of the same size, and one of smaller size, on the same rock. Indeed, I suspect from the numerous examples which I have seen of tracks at the distance of four feet, that this was the ordinary step of the bird when walking; while it was able to lengthen it to six feet, when moving rapidly. The examples where the steps are six feet, are not common.

In one part of the quarry above referred to, I found the steps of four individuals of this species, all pointing in the same direction, and nearly parallel to one another; showing that four birds must have moved along nearly together; and rendering it probable, that this species was gregarious. The distance between the several rows of tracks, is four or five feet. An attempt is made in Fig. 21, to represent the *O. giganteus* of the natural size, as it extends out in bold relief, on a specimen in my possession. The claws are broken off. It is the under side of the foot, that is shown in the figure. Incredible almost as this description may seem, the specimens which I have obtained of this enormous species, are nevertheless more satisfactory, perhaps, than of any other species. The whole

cavity made originally in the mud by the foot of the bird, has been filled by a siliceous concretion, differing somewhat from the surrounding rock; so that the latter may be in a good measure detached, and the former be left standing out very naturally from the rock—presenting in fact a petrification of the entire foot. Such specimens, indeed, are not common, but I have obtained a few of them; and by means of gypsum casts, they may be multiplied to any extent.

O. tuberosus. Toes, three; length of the foot, seven to eight inches; claw distinct in some specimens; from one inch to one and a half long; tuberos swellings on the under side of the toes, quite distinct. Heel very obvious. In one or two specimens in my possession, the inner toe presents two prominences, and the middle one, three; those on the outer toe not being distinguishable. This corresponds, so far as the inner and middle toes are concerned, with the number of joints in the three toed living *Grallae*. Length of the step in this species, twenty four to thirty three inches; occurs in Northampton, east side of Mount Tom; and I have seen a loose specimen of apparently the same species, obtained in the vicinity of the Horse Race, in Gill.

The most important difference between this and the last species, consists in its smaller size. It might, indeed, be thought that the *O. tuberosus* is but the young of the *O. giganteus*. But I have not noticed intermediate specimens; and besides, the middle toe of the former is longer in proportion to the others, than in the latter species; while the toes of the latter are a good deal more divaricate than those of the former.

α. dubius. I have lately obtained from the quarry on the east side of Mount Tom, in Northampton, a few specimens a good deal worn, which have the general form of *O. tuberosus*, but they are much smaller, the foot being only four inches long, and the steps twelve inches. Not improbably, it is a distinct species; but at present I shall regard it as made by the young of *O. tuberosus*.

Fig. 2, exhibits two rows of the tracks of *O. tuberosus*, pointing in opposite directions; the impressions at one extremity interfering with one another. The length of the foot in the right hand row, as well as of the three insulated tracks, near the upper left hand corner of the figure, is eight inches, and the length of the step is twenty eight inches; but the foot of the left hand row is scarcely seven inches long, and the step is twenty four inches. The feet of different species, and sometimes of different genera of living birds, differ

even less than these impressions; yet as the smaller ones might have been made by the young of the larger birds, I shall regard them only as varieties.

Fig. 5, exhibits three tracks of *O. tuberosus*, on a flagging stone, directly in front of the door of the Court House in Northampton. The foot is eight inches long and the step thirty three inches; the longest I have noticed in this species. This stone was brought from the quarry on the east side of Mount Tom.

O. ingens. Three toed; length of the foot, exclusive of the hairy appendage, fifteen to sixteen inches. No claws visible in any specimens that I have found. Toes much narrower than in *O. giganteus*, and tapering gradually to a point; quite divaricate. The best specimen that I possess, exhibits, at a few inches behind the heel, a depression nearly an inch deep, and several inches across; the anterior slopes to which, in the rear, appears if large bristles had been impressed upon the mud. I have been led to suspect that the bird possessed a sort of knobbed heel, covered with wiry feathers, which sunk into the mud when the track was deep. Yet I do not feel very confident as to the nature of this appendage. The impression of the bristles extends backwards from the heel, at least eight or nine inches; so that the whole length of the track is not less than two feet! The length of the step appears to have been about six feet; although I have had but few opportunities to ascertain this fact.

The rock on which this species of track appears, is composed of a fine blue mud, such as is now common in ponds and estuaries; and where the bird trod upon it, in some cases, it seems that the mud was crowded upwards, forming a ridge around the track in front, several inches in height. Indeed, I hesitate not to say, that the impression made on the mud appears to have been almost as deep, indicating a pressure almost as great, as if an Elephant had passed over it. I could not persuade myself, until the evidence became perfectly irresistible, that I was examining merely the track of a bird.

O. ingens, a minor. Length of the foot, about twelve inches; step from forty two to forty five inches. In other respects, it corresponds with *O. ingens*: and although I was at first inclined to regard it as a distinct species, I prefer upon the whole, to put it down as a smaller variety of *O. ingens*. Fig 3, exhibits a series of tracks of this variety, copied from the face of the rock in the quarry at the Horse Race. The hairy appendage is scarcely visible on the rock, and is therefore, omitted in the figure. It is wanting, probably be-

cause the layer of rock now laid bare, is either above or below that on which the bird originally trod. The foot is twelve inches long, and the step varies from forty two to forty five inches. The smallness of the foot may result merely from the situation of the layer containing it; in the manner that has been already explained. Yet as the length of the step is also less than four feet, I conclude these tracks to have been made by the young of *O. ingens*, or by a different species of the same genus.

The *O. ingens*, has been found only at the Horse Race. Several of these impressions, brought from the same place, may be seen on the side walks in Deerfield.

O. diversus. Three toed, with a hairy appendage in the rear; length of the foot, exclusive of the hairy appendage, from two to six inches; length of the step, from eight to twenty one inches.

Under this species, I have embraced a great variety of specimens; because I could not draw between them so definite a line of demarcation, as would be desirable. The two following varieties, however, are too distinct to be passed unnoticed; and I have little doubt, that they were produced by distinct species of birds. Indeed, I am persuaded that several species must have been concerned in making all the foot marks, that I have grouped together under this species.

α clarus. Foot, exclusive of the hairy appendage, from four to six inches long. Toes generally somewhat approximate and acuminate; inner toe shorter than the outer one. Hairy appendage very distinct, from two to three inches long; perhaps a knobbed heel. Step from eighteen to twenty five inches. Found in the south west part of Montague; also at the Horse Race, and probably also in Northampton, and at South Hadley canal. The specimens from Montague and Gill, are sometimes exceedingly distinct, so as to arrest the attention of every one. Fig. 22, exhibits one from the former place of the natural size. I have represented it in relief, because I found I could thus make the drawing more distinct.

Fig. 17, is a sketch of several tracks of this variety, on a slab of red micaceous sandstone, between three and four feet square, from Montague, now in my possession. The impressions are exceedingly distinct and striking, and appear to have been made by two birds walking side by side, at the distance of eighteen inches; one of them, taking steps two feet long, and the other, but eighteen inches. In the right hand row, a third step just begins to appear on the mar-

gin of the stone. The length of the toes, exclusive of the hairy appendage, is about five inches.

Fig. 16, is a very similar case to the last, except that the side toes are scarcely visible; probably because the layer of rock containing them, was somewhat below the layer on which the bird originally trod. The steps in the right hand row are twenty one inches, and in the other, eighteen inches. From the Horse Race on gray micaceous sandstone.

Fig. 10, was sketched from a specimen in my possession, from the Horse Race. The tracks are exhibited very distinctly in relief, and also on the opposite side of the stone as depressions. There are at least two varieties, as to size, of *O. diversus*; and the tracks are irregularly situated upon the stone. The length of the foot varies from four to six inches.

Fig. 23, represents a similar specimen from the same place, and of the same species. The tracks are depressions, and most of them very distinct. There are at least, three pairs of tracks connected by dotted lines; that is, they are the steps of birds moving in different directions. The length of the step, varies from twelve to fourteen inches. Six of the tracks are insulated; that is, not connected with others upon the specimen. The length of the foot in all the tracks, except *n*, is four inches; that of *n*, six inches. The rock is fine gray micaceous sandstone.

Fig. 24, shews another similar group of the same species and size as in the last figure; *n* being six inches long, and the other tracks four inches. Three tracks on the lower part of the figure, and two along the central part, are obviously the steps of birds moving in different directions; the shorter steps being twelve inches, and the longer one eighteen inches. Four of the tracks, from the Horse Race quarry, on gray micaceous sandstone, are insulated.

β platydactylus. Middle toe from two to three inches long, swelling out towards the extremity in an unusual manner. Hairy appendage behind very large and distinct. Length of the step six to eight inches. At the Horse Race; rather common. The five small tracks crossing Fig. 6 diagonally, belong to this variety; a sixth being wanting to complete the series. It differs from the variety *α clarus*, chiefly in the swelling of the middle toe, and in its diminutive size.

Since the radiating lines behind the foot in *O. ingens* and *O. diversus*, are much fainter than the furrows made by the toes, we

might expect, that by the deposition of new matter, when the rock was forming, these lines would sooner be obliterated. And such I find to be the fact; for I have sometimes taken a specimen, which, although quite distinct, exhibited no traces of a hairy appendage, and by carefully cleaving off successive layers of the rock, have come at length to a layer that exhibited it. Hence, I have learned to refer a specimen to *O. diversus*, which was destitute of a hairy appendage, if in other respects it corresponded to that species. So that, for the most part, the examples of continued tracks of that species given in the drawings, are represented as destitute of this scopiform appearance; because, in fact, they do not exhibit it on the rock.

Fig. 4 was sketched from a flagging stone, brought from the east side of Mount Tom, and lying on the side walk in front of the north door of the first parish church in Northampton. The tracks, although a good deal worn, are yet remarkably well characterized. The right and left feet are very distinct; and the toes have almost exactly the same divergence in each track. The foot is six inches long, and the toes are much nearer to equality, as to length, than in *O. diversus*, *a clarus*; so that I have been almost disposed to regard these tracks as a distinct species. But I supposed it most safe to refer them to *O. diversus*. The length of the step is twenty one inches.

Fig. 6 has been already referred to. The toes of the two principal rows of tracks are shorter and more divaricate than is usual in *O. diversus*, *a clarus*; and no marks of a hairy appendage are present, yet I rank them under that species. The length of the foot is four inches, and the average length of the step twelve inches, varying from that not more than two or three inches. On the left is the commencement of another similar row of tracks, of the same species, and one insulated track. I found this example in the quarry at the Horse Race; and by enlarging the sketch, I might have brought into view many other tracks. But none of them would have exhibited so many steps in succession, as are shown in the present drawing.

Fig. 7 was sketched from a specimen about three feet long, in the possession of Dr. Dwight of South Hadley. He obtained it, twenty years ago, from a farmer in the north part of that town, who had used it as a step stone, before the door of his house, and it was found in the vicinity. It is a coarse gritstone, much coarser than any other rock on which I have found these impressions. The foot is between three and four inches long, and has no hairy appendage. Length

of the step ten inches. The tracks exist on this stone in relief, and are very distinct. Dr. Dwight informs me, that one has been broken off; and this is supplied in the figure by dotted lines.

The roc from which Fig. 8 was taken, is a gray micaceous sandstone, or rather shale, brought from the Horse Race, and now forming a flagging stone, in the village of Deerfield. The foot is about four inches long, and the toes are a good deal divaricate, and there appears no scopiform appendage behind. The average length of the step is twelve inches. The third track is nearly obliterated, and it appears that the bird moved in a somewhat curvilinear direction.

It will probably be suggested, that *O. diversus*, with all its varieties, was made by the young of the species that produced *O. ingens*. And I confess, that it is not easy to point out any other distinction than in size. But my specimens of *O. ingens* are few, and much more imperfect than those of *O. diversus*; so that it is only in their general features that I can compare the two species; and I suspect, that better specimens would bring to light other differences. For I can hardly believe that the young of a bird, with a foot sixteen inches long, would accompany their mother, in search of food, along the margins of estuaries, while their feet were only two inches long, if, indeed, they could ever have been so short as this; and I hope to show, in another place, that all these tracks must have been made by birds, thus wading along the shores of estuaries or lakes. Besides, the *O. diversus* is fifty times more common than the *O. ingens*; and can we suppose, that in such circumstances, such a great disproportion would exist between the old and the young birds? Is it so with living species? I suspect it is not, although I confess myself but little acquainted with the facts in the case.

O. tetradactylus. Length of the foot, exclusive of the hind toe, from two and a half to three and a half inches. Toes divaricate; more slender than in *O. diversus*; the hind one turned inward, so as to be nearly in the line of the outer toe, prolonged backward. A space, however, usually remains, between the heel and the hind toe, as if its insertion were higher on the leg than the other toes, and its direction obliquely downwards. Length of the step, ten to twelve inches (?) Hairy appendage wanting. At the Horse Race. Probably several kinds of birds are embraced under this description, for the size of the tracks, and especially the direction of the hind toe, vary considerably. Indeed, in existing birds, these differences are sometimes the only marks, exhibited by their tracks, between different species and genera. In the tracks of the domestic hen,

(Fig. 20,) the pea-hen; (Fig. 19,) and the turkey, (Fig. 18,) we see the hind toe turned inward, almost exactly as in the fossil specimen, as shown on the Proportional view of the Ornithichnites appended. But in the foot marks of a bird, probably of the genus Tetrao, that I lately met with, (see Fig. 13,) the hind toe seems to be merely a prolongation of the middle toe backwards. In the tracks of the hen, exhibited in Fig. 20, it will be noticed, that the hind toe is seen only in some of the tracks, because it is situated so high up the tarsus, that it made an impression only when the bird sunk deep into the mud. In the tracks of the pea-hen, the hind toe appears sometimes only as an insulated and rounded impression, as if made by the end of a stick; because of its peculiar position, form, and direction, in that bird.

These facts render it probable, that some of the specimens of Ornithichnites, which I regard as produced by a three toed bird, may have been made by one with four toes; indeed, in some instances, in which I had referred the specimen to *O. diversus*, careful cleavage has brought to light the fourth toe. Yet I am confident that such a discovery would rarely be made. And in regard to the larger tracks, I have not noticed any thing that resembles a fourth toe, even if it should turn out that *O. diversus* is possessed of one.

To the examples above named of living birds, I might have added that of the whooping crane, (*Ardea Americana*,) the tallest bird in the United States. Its hind toe does not reach the ground where it is hard; but in deep mud it may make an impression.

O. palmatus. Four toed, and *all the toes directed forward*. The fourth toe is very short, proceeding from the inner part of the foot. The heel is broad, and the toes proceed from it somewhat in pairs; that is, the two inner and the two outer ones are closer together, and radiate less, than the two middle ones. Toes very slender: foot from two and a half to three inches long. Length of the step, in the only specimen where it could be measured, eight inches.

This is a remarkable species, and as I discovered it only on my last visit to the Horse Race, I do not feel certain that I may not have mistaken its characters; yet the specimens in my possession are very distinct. One in particular contains two tracks, and as naturalists may probably doubt whether they were made by a bird, I have given in Fig. 15, as accurate a sketch of them as possible, and of the natural size, although the distance between them, which on the stone is eight inches, is much diminished on the drawing. The toes in one of the tracks are turned slightly to the left, and on the other

to the right, (scarcely visible in the drawing,) corresponding exactly to the step of a bird, but not to that of a quadruped. The thumb, or short toe, also, is on opposite sides in the two tracks, proving the animal that made them to have been a biped; for had they been produced by the two right or the two left feet of a quadruped, the short toe would have been on the same side in both tracks.

I am aware, that these impressions do not correspond to the foot of any existing bird; at least, I cannot find any one of this description in the ornithological works within my reach. Four toed birds are, indeed, the most common, but in no instance do they all point forward.* Yet, since peculiarities of structure occur in most other animals, found petrified deep in the secondary rocks, ought we to be surprised to find them in the birds of early times? And can any one suppose, that the slight addition of a short inner toe; ought to exclude the animal, when the proof of its being a biped is so clear, from the class of birds?

O. minimus. Three toed; destitute of a hairy heel; foot from half an inch to an inch and a half long; toes spreading widely; nearly of equal length; step three to five inches; quite common at the Horse Race. Generally, the foot is rather over an inch long, but one very distinct specimen is only half an inch.

Fig. 9 exhibits a succession of tracks of this species, four inches apart, found at the Horse Race.

It will probably be suggested, as I have already intimated in one case, that all the smaller tracks were made by the young of the larger species of birds; and although I doubt very much whether this is the fact to any great extent, yet it will be seen, that I have regarded no track as a distinct species, that does not differ from the others, by some other peculiarity than the size, except perhaps *O. ingens* and *O. diversus*, about which I have already remarked. And besides the peculiarities that have been named, there are others, which will be obvious to a practiced eye, but which it is not easy to express in language.

Naturalists may perhaps doubt as to the nature of the appendage that produced the radiating impression in some of the species that have been described. Yet it is well known that some species of living birds have the tarsus very low down covered with hair like

* In some drawings of the feet of the genus *Paradisea*, especially that in Rees' Cyclopaedia, it would seem as if all the toes were directed forward; but ornithologists inform us, that this is not the case. See Dictionnaire Classique d'Histoire Naturelle, Art. *Paradisea*.

feathers, as, for instance, the sharp tailed grouse,* (*Tetrao phasianellus*), and I do not see why such an appendage would not produce precisely the impression on soft mud which the fossil specimens exhibit.

In comparing the descriptions that have been given of the species, it is interesting to observe how the length of the step increases in proportion to the size of the foot; from the huge *O. ingens*, with a foot sixteen inches long, and a step of at least four feet, down to the *O. minimus*, with a foot one inch long, and a step between three and five inches. In order, however, to present this correspondence before the mind at glance, as well as to give an idea of the peculiarities of the different species, I have prepared the appended "Proportional view of the Ornithichnites." On this the proportional size of the different tracks is shown as well as the comparative length of the steps. The whole is laid down from a scale of five inches to an inch. The plate does not present the appearance of any one specimen; but a connected view of the results obtained by an examination of all the specimens that have come under my notice. Very few single specimens are as perfect as those here represented; but a careful examination of various specimens has brought to light new characters, so as to justify me in exhibiting the tracks of as perfect a form as those on the plate. Where rows of several tracks are given on this plate, the toes are represented as turned outwards, and slightly curved, as they are seen in the most perfect specimens.

The two first species on this comparative view are exhibited in relief; and the others as depressions. This was done in order to give a more distinct sketch of the protuberances on the under side of the toes of the two first species. It should be recollected that such a representation will invert the position of the feet; so that what appears to be the left one is in fact the right one, and *vice versa*.

In the series of figures extending from 1 to 9, and including 16, 17, 23 and 24, an attempt is made to exhibit the tracks just as they appear on the rock. Yet the scale (twenty four inches to one inch,) from which they are laid down, is so small, that the representation probably falls short of the truth; since no attempt has been made to show the claws, which do sometimes appear. Yet in general, where the rock has been for some time exposed, these and other more delicate parts of the impression are obliterated; and it is only by cleaving down insulated specimens that I have discovered them.

* Also the Bantam domestic fowl.—*Ed.*

Being laid off from a scale, the figures above referred to, exhibit to the eye the relative, although not the real size of the different species. Fig. 15 is the only one drawn of the natural size.

It is a natural enquiry, whether the facts that have been stated, will enable us to refer these birds, of the new red sandstone era, to any of the families of existing birds. The idea, that they belonged to existing species, can be indulged only by those unacquainted with the history of organic remains. Judging from that history, the geologist will expect only slight resemblances to existing species. I cannot, however, but believe that several of them, at least, were Grallæ. They correspond with this tribe of birds in two respects; first, in having but three toes; as is the case with several genera of the existing waders. The great length of their step, also, proves them to have been very long legged; another characteristic of the Grallæ. I have had but few opportunities for making a comparison; but I am satisfied that the step of our common birds, not belonging to the Grallæ, is generally shorter with the same size to the foot than in the Ornithichnites. Thus, the common domestic hen, with a toe three inches long, takes a step of only six or seven inches; while the step of *O. diversus*, of the same size, will average ten or twelve inches. The domestic goose, with a middle toe four inches long, takes a step of only seven or eight inches. The turkey, however, with a foot four inches long, takes a step of just about the same length as that variety of *O. diversus* shown in Fig. 6, (with a similar foot,) that is, twelve inches long; and the pea-hen, with the same length of foot as the *O. diversus*, shewn in Fig. 7, falls but an inch or two short of the fossil tracks in the length of the step; but the turkey and the peacock are birds with rather unusually long legs among the Gallinæ.

I have not been able to obtain any examples of the length of the step of the larger existing Grallæ. And of the smaller species I can mention only a few. The small snipe, whose tracks are represented in Fig. 11 on a small scale, and in Fig. 14 on a larger scale, takes a step of only two and a half inches, with a foot an inch long. And as I am informed by Dr. Richard Harlan, the step of the *Ardea Canadensis*, with a foot three inches long, measures from four to six inches. On comparing these steps with those of *O. minimus*, whose foot is one inch, and its step four inches long, and with *O. diversus*, β *platydactylus*, whose foot is from two to three inches long, and its step from six to eight inches, we perceive that the steps of the existing species are shorter than the fossil foot

marks. As to the larger species of Ornithichnites, however, we can make no comparison with existing species; because no birds now on the globe have feet which approximate in size to *O. giganteus* and *ingens*. One cannot but see, however, that birds which measured from four to six feet at each step, must have had very long legs, and were therefore waders.

But the zoologist will object, that some of them appear to have had their legs covered, even to the toes, if not with feathers, yet with bristles; while all the known Grallæ have naked legs. This is certainly a very strong presumptive evidence against their having been waders in the literal sense, and perhaps it is an insuperable objection against ranking them among the Grallæ at all. Yet I would remark, in the first place, that it is not certain I understand the nature of this peculiar appendage to the heel, although I cannot explain it in any other way than I have done, and I do not see why that is not satisfactory. Again, since we should expect *a priori*, great peculiarities of structure in animals that inhabited the globe so early, is it incredible that even the genuine wading birds of that epoch might have had an appendage to their feet of filaments like bristles? We may not be able to see their use; nor can we understand that of the thoracic filaments attached to the genus *Polynemus* among fishes; nor to the byssus of the *Pinna*, among shells. Once more, these Ornithichnites, with the appendage under consideration, might have been produced by that portion of the Grallæ denominated *Cursors* by Temminck, and which might have frequented the shores of lakes and estuaries for food. Between the genus *Rhea* of these birds, and the *O. ingens*, there is one point of resemblance which I ought perhaps to notice. The *Rhea* has a callous knob in the place of a hind toe; and in the *O. ingens*, a protuberance of that sort seems to have left an impression. But finally, whatever we may think of the radiating appendage, I think it quite certain, and in the sequel shall endeavor to prove, that all the tracks which I have described must have been made either beneath the waters of an estuary, lake, pond, or river, or on their margin, where the waters would often overflow the place. If so, the habits of all these ancient birds must have corresponded to those of the modern Grallæ.

I have stated in the commencement of this paper, that the rock on which these Ornithichnites are found, is the new red sandstone; or perhaps I ought to call it the equivalent of that group of rocks in Europe; that is, it seems to have been formed under similar circumstances, and probably at nearly the same geological epoch.

However strenuously, geologists, a few years ago, contended for the perfect identity of the rock formations of different continents—this opinion, especially in the case of the secondary and tertiary rocks, is now abandoned. All we can hope for, in respect to two such rocks, in different countries, is, that there may be so much similarity between their lithological characters, mineral contents, and organic remains, as to show that they were the result of similar causes, and produced under similar circumstances as to temperature, climate, &c. In respect to the sandstone of the valley of the Connecticut, on which these Ornithichnities occur, there are peculiar difficulties in determining precisely its position on the geological scale. But having examined it with no small care for the last twenty years, with reference to this very point, I have come to the full conviction, as above expressed, that at least the higher beds of this sandstone belong to the new red sandstone of De la Beche and other geologists. The reasons of this opinion I have given in full in my report on the geology, &c. of Massachusetts, made to the government of that state. But it may be desirable to give a summary of these reasons in this place.

The sandstone in this valley extends nearly one hundred miles, from New Haven in Connecticut to the north line of Massachusetts, varying in width from eight to twenty four miles. It is divided by one or two ridges of greenstone, protruded through the sandstone, and running nearly north and south. The strata of the sandstone have a general easterly dip, varying from 5° to 30° ; so that the lowest or oldest portions of the sandstone lie along the western side of the valley. These lower strata consist, for the most part, of thick layers of red sandstone, not much diversified in appearance. But the upper strata, that is; those on the easterly side of the greenstone ranges, consist of slaty sandstones, red and grey conglomerated sandstones, very coarse conglomerates, shale, and perhaps red marl,* with occasional beds of fetid limestone. These are interstratified in almost endless variety. Now as to the lower strata, some geologists have supposed that they belong to the old red sandstone; and perhaps they do: but as none of the Ornithichnites occur in these strata, we need not discuss this question. In endeavoring to show that they are the equivalent of the new red sandstone, I confine myself, therefore, entirely to the upper strata.

* The red sandstone at Hartford, is decidedly marly—it effervesces with acids and even contains numerous veins of calc spar.—*Ed.*

1. *Their lithological characters.*—De la Beche describes the new red sandstone group, as a “deposit of conglomerate, sandstone and marl, in which limestones occasionally appear in certain terms of the series”—and such a deposit, we have seen, is the sandstone in this valley. I have no doubt in respect to any member of this list, unless it be the marl. There occurs here, indeed, a fine red rock, resembling the English red marl; but not usually containing much carbonate of lime. It is rather a reddish shale, although it will frequently effervesce with an acid. The variegated aspect of the new red sandstone, which in some deposits of that rock is so striking, is frequently present along the central parts of the valley, although I should judge, less common, than in Europe. In fine, I can hardly distinguish a suite of specimens from the Connecticut valley, from a suite obtained in Nova Scotia, from a group of rocks proved to be new red sandstone by containing beds of gypsum.

2. *Their mineral contents.*—Excepting a minute quantity of gypsum, this rock is wanting in that mineral and rock salt—and this seems to be the principal difficulty in deciding whether it is the new red sandstone; since these minerals are so generally present in that formation, and are regarded as characterizing it. But since it is admitted that limestone may occasionally be absent from it, without destroying its geological identity, why may not gypsum and rock salt be sometimes wanting, without taking away its essential characteristics?

In this rock, however, other minerals occur, that are somewhat peculiar to the new red sandstone. Copper may be mentioned, which is frequently found near the junction of this rock with the greenstone; and also to some extent disseminated through its layers. In Germany, it is well known that one variety of this group, the copper slate, is wrought as an ore of that metal. The sulphates of baryta and strontia are found, also, in our rock, as they are in the new red sandstone in England: and the same is true in respect to magnetic iron sand.

3. *Their organic remains.*—A few years since, there were found in one of the coarser varieties of this rock in Connecticut, the remains of a vertebral animal, of what kind, has never been ascertained. But, as no vertebral animal, except perhaps a few fish, has been found below the new red sandstone, the presumption is, that the rock in the valley of the Connecticut, containing these remains, cannot be older than the new red sandstone. The occurrence of birds, so low down in the rock series, however, contrary to all pre-

sumption, shows us that little dependence is to be placed upon such an argument as this, to prove the rock in question, to be new red sandstone. But the Ichthyolites occurring in it, present a much stronger case. They belong to the genus *Palaeothrissum*, and are found in bituminous shale, or what used to be called bituminous marlite; and the specimens, both of the fish and the rock, so exactly resemble those from the new red sandstone of Mansfeld, in Germany, that an able European geologist, to whom specimens were sent, could not distinguish them. This genus, also occurs at Autun in France, and at one or two places in Great Britain, in the new red sandstone, and in that alone. How can it be doubted, especially when the other evidence to the same point is considered, that it is the same rock in Massachusetts, in which they are found? It ought to be stated, that one of the localities of ornithichnites, occurs only a mile distant from the most abundant locality of ichthyolites in Sunderland, and almost on the same continuous layers of rock.

These statements, it seems to me, decide, beyond all reasonable doubt, the geological situation of the ornithichnites that have been described. But if any are not satisfied, it ought still farther to be stated, that no geologist, who has examined the sandstone of this valley, has ever suggested that it is more recent than the new red sandstone. For the most part, they have placed it lower in the series; regarding it either as the coal formation, or the old red sandstone. So that all would agree that these ornithichnites are at least, as low down as the new red sandstone. If they are lower, their situation is still more surprising.

Since the deposition of this sandstone, no geological change seems to have taken place in this valley, except the deposition of a thin and apparently very recent tertiary, or quaternary formation, composed of horizontal layers of clay and sand; and afterwards those diluvial and alluvial agencies succeeded, which have been in operation in every part of the globe.

Having now given such a statement, as I am able, of the facts in this case, and shown, if I mistake not, the geological position of the ornithichnites, I trust, I may be indulged in a few theoretical considerations.

The circumstances under which these tracks were made, furnish a topic of enquiry that will suggest itself to every mind; and it seems to me that the true theory on the subject, can hardly be mistaken by any intelligent man, even although not acquainted with the princi-

ples of geology. He sees that the rock on which the impressions are made, is composed of mud and sand; and although he may not be able to explain how these materials were consolidated, yet he can hardly doubt but this rock was once in a soft state, and that these tracks were then made.

Thus far, it seems to me, all must agree. And when, as already remarked, we see upon the mud that covers these rocks, where they pass under the waters of the Connecticut, the tracks of living birds, exceedingly analagous to those upon the dry rocks, can we doubt that we witness the precise mode in which the ornithichnites were produced;—and especially when we find that the character of the foot, and the length of the step, indicate that most of the birds that formed them, must have had the habits of the existing waders or Grallæ, we cannot but infer that the impressions on the ornithichnites were made by the birds of the new red sandstone era, that frequented the margins of estuaries, streams and lakes, whose muddy shores, where they trod, were afterwards converted into the existing rock.

I know it has been usual, to regard the early geological changes on the globe, as having taken place in a very different manner, from those which are now going on; and I cannot resist the conviction, that the intensity of the causes has varied exceedingly at different times; but this could affect only the magnitude, not the similarity, of the results; and I have been struck with the remarkable resemblance between the state of things, as shown by these ornithichnites, to have existed so many thousands of years ago, and that now passing before our eyes. Our imaginations are carried back by these relics, to that immensely distant period, when the new red sandstone birds were travelling along the shores of the then existing estuaries or lakes, just as is now done by congeneric races.

There is, however, one striking point of difference between the ancient and the modern races. I refer to the enormous size of many of the former. Some, indeed, appear to have been no larger than the smallest of existing birds of their class: but what shall we say of those that produced the *O. giganteus* and *ingens*, taking strides of four feet, as their ordinary step! As to their real size, we may forever be left to conjectures. But I am not sure that a practiced comparative anatomist, could not determine the size of a bird, having the size of the feet, and the length of the step given. I shall not attempt the problem any farther than to state one fact by way of comparison. The African ostrich, (*Struthio camelus*) the largest of known birds, has a foot only ten inches long, reckoning from the back.

part of the heel to the extremity of the claw;* and yet, it sometimes weighs eighty or one hundred pounds, and in walking, its head is as high as that of a man on horseback; or from seven to nine feet. May we not infer, that some of these ancient birds, whose feet are sixteen or seventeen inches long, must have been almost twice as heavy and high as the ostrich? I do not believe that any man will doubt this, after having examined their tracks. From a few trials, I do not believe that the legs of a bird, (including the thigh,) whose ordinary step was four feet, could have been much less than six feet.

Such must have been the feathered tenants, that once occupied the now delightful valley of the Connecticut. At that time, we have every reason to believe that valley to have been an estuary: for the organic remains of the new red sandstone, are chiefly marine, as is shown in my Report on the Geology of Massachusetts. And to show that other organic beings, that were cotemporaries with these huge birds, were their compeers in size, I would refer to a description in that work of a sea fan, (*Gorgonia Jacksoni*), found in the new red sandstone of West Springfield, that has been uncovered without reaching its limits, eighteen feet in length, and four feet in width! Indeed, the colossal bulk of these birds, is in perfect accordance with the early history of organic life in every part of our globe. The much higher temperature that then prevailed, seems to have been favorable to a giant like development of every form of life.

The enquiry is often put, by those who examine these ornithichnites, how near the spots are, where they are found, to Connecticut river: and when told, that for the most part, they occur upon its immediate banks, they often infer, that the rock was deposited by that stream; but the geologist knows that the Connecticut river, certainly not then in existence, has had nothing to do with the deposition of the new red sandstone, that forms its banks; and from the facts mentioned in the last paragraph, he infers, with strong probability, that it was deposited beneath the ocean, and has since been elevated.

Another enquiry often made, is, how deep in the quarry the tracks are found? But this in the view of the geologist, is of less impor-

* For this fact, I am indebted to Prof. Mussey of Dartmouth College, which he obtained from a skeleton of the ostrich in his museum. He adds, also, that "the length of the leg, viz. the distance from the hip joint to the ground, is four feet and one inch, and the distance of the head from the ground is seven feet and eight inches. The elevation of the head, it is obvious, must vary with the direction of the axis of the body, which, as the skeleton now stands, is not quite horizontal, but rises a very little anteriorly." All that is now wanting, to enable us to form a probable estimate of the size and height of the bird that produced the *O. giganteus* and *O. insignis*, is the length of the ordinary step of the ostrich. If I may be allowed to conjecture, I should say, that the head of the new red sandstone bird must have been elevated from twelve to fifteen feet above the ground!

tance than their situation, in respect to the formation generally. In point of fact, they occur only a few feet below the immediate surface of the rock, where the excavations are made. But they are found on the western margin of a formation some miles in extent, reckoning across the strata; and those strata dip to the east several degrees; so that in fact, all those strata whose edges crop out to the east of the quarries containing the tracks, were deposited above the *Ornithichnites*, making a perpendicular thickness of rock of several hundred feet, over these relics, instead of six or eight feet. Indeed, at the locality in the south west part of Montague, the layers containing the *Ornithichnites* pass laterally under Mount Toby, which rises six or seven hundred feet above the spot, so that it is perfectly fair to say, that these foot marks are found several hundred feet deep in the rock. But this statement, although adapted to make a popular impression, is by no means as striking to the geologist, as the fact that they occur in the new red sandstone at all; for he knows, that since the deposition of that rock, there has been time enough for the formation of those vast masses of rock, constituting the oolitic, cretaceous, and tertiary groups, each of them many thousand feet in thickness, and formed by slow processes; and the only reason that they are not piled immediately above the *Ornithichnites* is, that the causes, by which those particular sorts of rock have been formed, have not here operated. In other words, after the new red sandstone was deposited, no new rocks were added, in this part of the world, during the immense periods in which the groups above named were in the process of formation in Europe.

Admitting that these tracks were originally produced by birds, travelling upon mud, let us enquire in what manner the process of covering them up, and of their consolidation, would take place. Alluvial deposits, it is well known, are arranged in layers, brought on by the successive charges of mud and sand, diffused in the waters; and these will be finer or coarser, according to circumstances. If a bird be quite heavy, its foot would sink considerably deep into these layers, either breaking through them, or, if plastic, causing several of them to bend downwards. Yet, I apprehend, that the lighter birds would rarely make any such indentation, that would sensibly affect the layers of mud more than an inch deep. But as successive layers of mud were deposited, after the impression had been made, if the movement of the water were very slight, they would be scarcely thicker where the track existed, than in other places; and consequently, the impression would be continued upward for a

considerable distance, the slighter indentations first disappearing, and finally those that were deepest; so that, after the mud had been consolidated into stone, several successive layers might be split off, each one containing an Ornithichnite. In the highest layer the track would be smallest, and its more delicate extremities would be wanting. Each successive layer beneath, would exhibit it more and more perfect, until the precise layer was reached, on which the bird originally trod. A few layers beneath this, might exhibit the track imperfectly, but it would soon be lost. Now, by looking back to my description of the actual manner in which the Ornithichnites occur, it will be seen that the facts correspond to these deductions of theory.

The results above stated, however, would be very much modified by circumstances. The more quietly the deposition took place, after the track had been impressed upon the mud, the longer time would it require, and the greater the number of superimposed layers, before it would be effaced. But if a sudden and more tumultuous rise of waters, either from a land flood, or a violent storm acting on the ocean, should bring a coarser coat of materials over the track, somewhat violently, it might be filled up and effaced at once, as the specimens show was sometimes the case. Or should the matter deposited in the track, assume a concretionary form, so as in fact to become a real petrified foot, the depression in the superimposed layers would almost immediately disappear, as I find to have been the case frequently with *O. giganteus* and *O. tuberosus*.

There is one fact respecting these foot marks, which deserves to be mentioned, and which is not so easy to explain. Where successive layers of the rock are bent downwards by the impression, the curves are sometimes not placed perpendicularly above one another, but they are considerably oblique; so that when the track is visible on both sides of the specimen, on one side it appears thrown forward, or backward, or laterally, an inch or two. I have noticed as great a difference as this, where the rock is not more than an inch thick.

I can conceive of only two modes in which such an effect could be produced. It could result, as it seems to me, in no way, from a slide of the animal's foot in the mud. But suppose the impression made in mud, which was so very yielding that a slight action upon it would cause the upper portion of it, almost suspended by the water, to be carried somewhat forward, in the direction in which the disturbing force impelled it. Suppose now, either winds or floods should produce a gentle current, where a track had been made in such mud; might not the impression be gradually slid a little from its original

position, without injury; and if the cause continued to act, as the successive layers were deposited, might not all the disturbance which we witness, have been thus produced? Or, suppose the track was made on very yielding mud, which had a rapid slope beneath the waters; is it difficult to conceive how, as the new layers of mud were deposited, the mere force of gravity would cause them slightly to descend, and thus carry downward the track, without effacing it?

I have asserted that these tracks must have been made in a spot which was constantly, or frequently, beneath the waters; for if made on dry land, instead of having a new deposit brought over them quietly, to preserve them, they would be exposed to rains, and other denuding and disturbing agencies, that must speedily deface, if not obliterate them. Judging from what we now see of the tracks of living animals, a single month, nay, often a single week, or a day, would be sufficient to destroy them. And even if, in some rare cases, abundant rains and floods might cover the spot with a new deposit, yet ordinarily the action must be so violent, as to ruin the track; but beneath the quiet waters of an estuary, or lake, or even of a large river, after a few layers of mud had been brought over them, they might remain, for aught I can see, age after age, uninjured. The quiet waters above them would be their security. For these reasons, I suspect, that in almost every case, these tracks must have been made beneath still waters. I can, indeed, conceive it possible, that a track might be preserved, although made above low water mark, provided that an early but not violent rise of the waters should cover it with a thick deposit of mud. And yet the chances, even in such a case, are very much against its preservation, long enough to be converted into stone; so that, whatever objections the ornithologist may raise, against admitting that all the tracks which I have described were made by *Grallæ*, it seems to me, that the exigencies of the case require us to suppose them produced by birds, whose habits were those of *Grallæ*.

The most interesting aspect in which the facts that have been stated present themselves to the geologist, is as to the evidence they afford of the very early existence of birds, among the inhabitants of our globe. Heretofore there has been no proof of their existence, until within a comparatively recent period. But it now appears, that they were among the earliest of the vertebral animals that were placed on the globe. The discovery of some monument, that reveals the history of a people, a few hundred years earlier than had before been known, affords a high gratification to the antiquary. But

in these simple foot marks, the existence, and some of the habits, of an interesting class of animals is proved, at a period so remote, that the entire population of the globe has since been changed, at least once or twice, and probably several times more. For, to say nothing of minor divisions of the strata, the animals and plants of the secondary rocks must have all been extinct, before the creation of those in the tertiary deposits, and most of these last must have ceased to exist before the production of the present races. The number of years that have since elapsed, we cannot even conjecture; for, in respect to all the races of animals and plants that have occupied the globe, previous to the existing tribes, the scriptures are silent, giving us to understand merely, that a period of indefinite duration intervened, between "the beginning" and the creation of man; and geological monuments, although they clearly point out successive epochs in the natural history of the globe, yet furnish us with few chronological dates.

It may prove, also, an instructive lesson to the geologist, that the mere foot marks of these early animals should have remained so distinct, although every relic of their skeletons has disappeared.* If birds lived during the deposition of new red sandstone, they doubtless existed during the formation of each successive group of rocks to the highest. Yet, with perhaps one or two very doubtful examples, no trace of them is found in all the wide interval between the red sandstone and the tertiary beds around Paris.† Surely, the geologist will be led to enquire, whether he has not been too hasty in inferring the non-existence of the more perfect animals and plants, in the earlier times of our globe; and whether, after all, it may not be that they did exist, even along with the earliest animals and plants, which we now find imbedded in the strata. The recent discovery of phenogamian vegetables in Scotland, below the coal formation, gives additional force to this suggestion.‡

In pursuing my investigations on this subject, I confess that I was greatly surprised to discover so readily, so many distinct species of the Ornithichnites, or rather distinct genera of birds, for such I can hardly doubt they are. All the present *Grallæ* in Massachusetts do

* Their bones may yet be found.—*Ed.*

† Dr. Mantell has recently described them in the Wealden, below the chalk—above the oolite. See our micellanies.—*Ed.*

‡ Observations on Fossil Vegetables; by Henry Witham, Esq. Edinburgh, 1831.

not exceed twenty genera, and fifty species; yet I have found at least seven tracks, (and were I to express my own convictions, I should say ten,) so distinct that they must have been made by different species, if not genera, and that too, in three or four quarries, that have been opened only a few rods square. I exceedingly doubt, whether any three spots of that size can now be found in the valley of the Connecticut, where the tracks of a greater number of the existing species of birds occur on the mud. Shall we then say, that the birds of the new red sandstone era were as numerous as they now are? Perhaps it would be unsafe, from such premises, to draw such an inference; yet, if any birds existed then, why may they not have been even more numerous, in a climate so favorable to their development, than at present?

I have met with only one account of any thing similar to what I have now described, and that is the statement of the Rev. Mr. Duncan, respecting the foot marks of a quadruped upon the new red sandstone of Dumfries-shire, in Scotland, ascertained with much probability to be those of a tortoise. Judging from his account, and the accompanying lithographic plate, in the eleventh volume of the Transactions of the Royal Society of Edinburgh,* I should infer that these impressions will not compare in distinctness, with those in the valley of the Connecticut. It is interesting, however, to learn, that tracks made on new red sandstone, on both sides of the Atlantic, have been preserved to the present day.†

I am aware that the presumption derived from geological analogies, is decidedly opposed to the facts and inferences, which I have presented in this memoir; for it goes to prove the existence of birds, nearest in the perfection of their structure to the Mammalia, among the very earliest of vertebral animals; a few saurians and fishes only having been discovered, as low as the new red sandstone.‡ Hence I expect that geologists, as they ought, will receive these statements and conclusions, not without hesitation and strong sus-

* For the loan of which I am indebted to the kindness of Dr. N. Bowditch.

† In a catalogue of scientific works that have been published within a few months past, in Europe, lately brought within my reach, I find one by Jabez Allies, printed in London, "on certain curious indentations in the old red sandstone of Worcestershire and Herefordshire, considered as the tracks of antediluvian animals, &c." but I know nothing more of these impressions, besides the title of this work.

‡ Tracks of mammalian or quadrumanian animals have been recently discovered in new red sandstone, in Germany. See our miscellanies.—*Ed.*

picious, that I may have been deceived. I too, at first, was entirely sceptical; for in former geological excursions, I had so often found that the reputed foot marks of animals, were but the result of aqueous or some other alluvial agency, or of human skill, that I would scarcely turn out of my path to see an example;* but I soon perceived that here was something entirely different. Yet had I found only a single specimen, however distinct, I should still have disbelieved. Or had I found the tracks at the quarries, sometimes a depression, and sometimes rising above the surface, I might have styled them concretions. Or had I found little or no correspondence between the impressions, and no regular succession of steps, I should have attempted to account for them in some other way; or have left them unexplained. But when I found that in all these respects, there was no room for scepticism, when I saw that the right and left foot could be clearly distinguished, when I could hardly distinguish

* Encouraged by the facts that have been detailed, and led to hope for success from several very glowing descriptions that I had received of foot marks upon stone in Rhode Island, I was led recently to perform a journey of two hundred and fifty miles, for their examination. They occur about two miles north of the village of Wickford, on the road to Providence; and every person of whom I enquired, within twenty miles of the spot, seemed to be acquainted with the impressions there, under the name of "the Devil's Track." But I saw no evidence of any agency there, except that of water. And it seemed to me that the only reason why every one does not impute the effects to water, is the difficulty of conceiving how a stream could have ever flowed in that spot for a long time, as it must have done, to produce the excavations; for it is near the top of a ridge of gneiss rock, passing into mica slate; and no excavation exists that could have formed the bed of the stream. But the geologist is not surprised to find marks of powerful aqueous agency any where on the earth's surface, even though he cannot explain its *modus operandi*. I could not explain it satisfactorily in this instance; for the direction of the current seems to have been from N. E. to S. W. or the contrary, and I know of no other marks of aqueous agency in New England, (except existing streams,) where the waters moved in either of these directions; but that the excavations called tracks, were the result of running water, I can have little doubt. They extend for several rods in the direction in which the rocks run, and imagination has made some of them resemble the foot of a man, others of a dog, and others of an animal with a hoof. I saw but one or two that had much resemblance to any of these, and in some instances, they were a foot or two in length, and generally from one to four inches deep. But if you found one of them resembling the foot of an animal or a man, you could not find any corresponding impressions in any direction to show a succession of steps. I might proceed much further with this description, and present sketches of some of these excavations; but I judge it unnecessary, as similar ones may be seen wherever water has been running for years with violence over rocks. Yet from the strong impression that exists on the public mind, as to the mysterious if not supernatural manner in which these excavations were made, I should not think it strange if several generations should pass away, before the delusion vanishes.

the tracks of living birds from those on stone, and when among hundreds of examples which I have seen, not one was opposed to the idea of their being the veritable foot marks of birds, it seemed to me that the case was a very strong one. It would be strange if I should not have failed to get at the exact truth, on every minor point of the subject; especially as my insulated situation in respect to Zoological collections, has prevented me from making all the comparisons which I could wish; but I shall be happy to be corrected wherever I am erroneous, even if it be in my fundamental conclusions; and with no little trouble, I have made such arrangements, that for a reasonable return of specimens in natural history, especially petrifications, I shall be able to furnish geologists, who may desire them, with accurate casts of my best specimens colored so as to resemble the rock; and probably with some specimens in the rocks; while my own specimens will always be accessible to their inspection; so that if the views I have presented, are not satisfactory to geologists, I shall at least have put within their reach, the means of arriving at the truth.

Ornithichnites giganteus. (Natural size)

Fig. 12.

Ornithichnites
diversus
& *clarus*
(Natural size)

Fig. 11

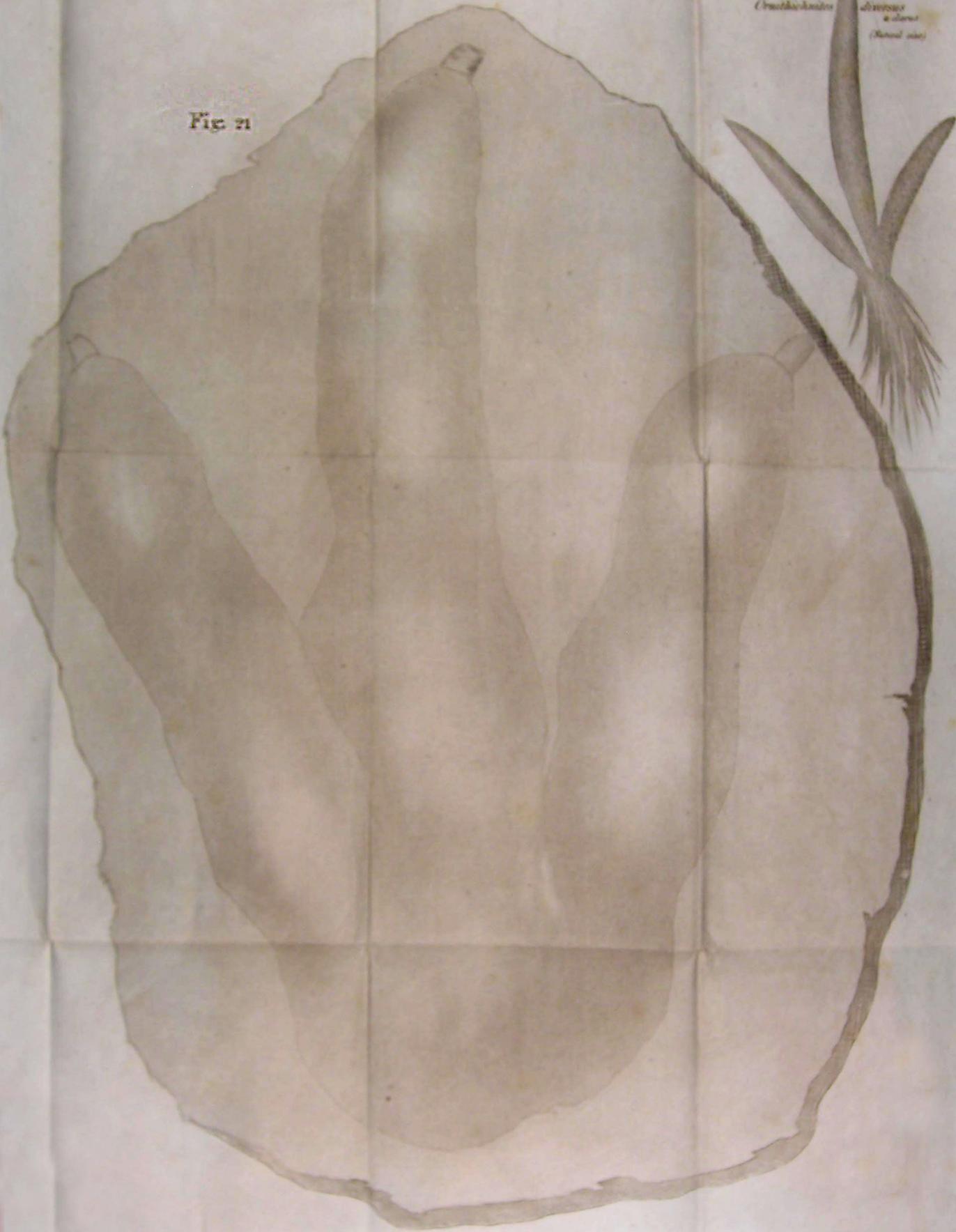


Fig. 1.



Fig. 2.

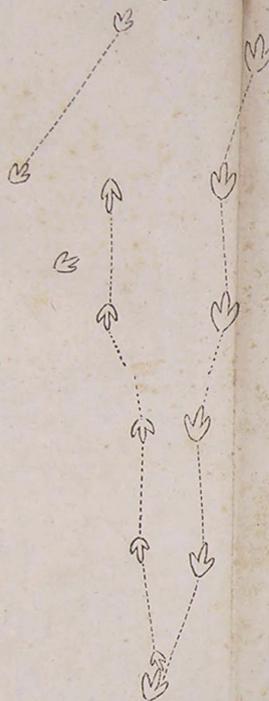


Fig. 3.



Fig. 7.

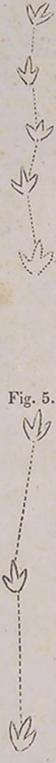


Fig. 8.

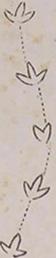


Fig. 16.

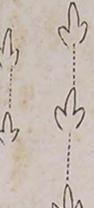


Fig. 17.



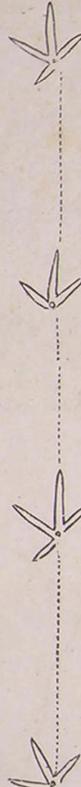
Fig. 18.



Fig. 19.



Fig. 20.



Figs. 13 and 14.



Figs. 9, 10, and 11.



Fig. 5.



Fig. 6.

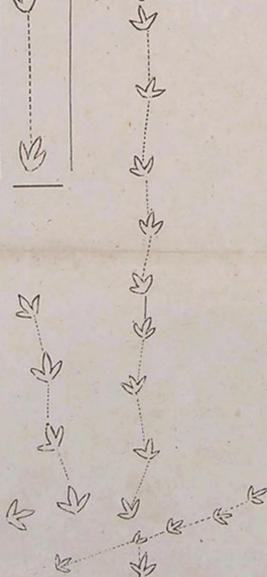


Fig. 12.

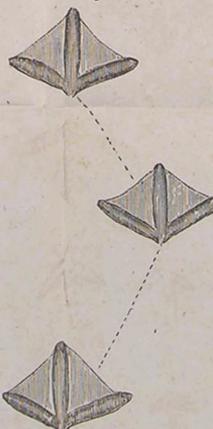


Fig. 15.



Fig. 23.

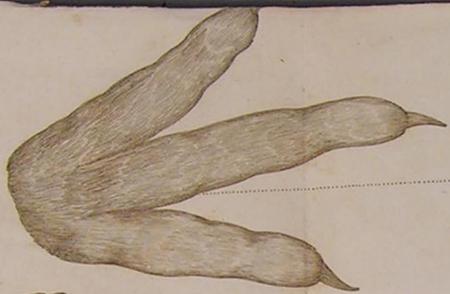


Fig. 24.



Proportional View
of the
ORNITHICHNITES.

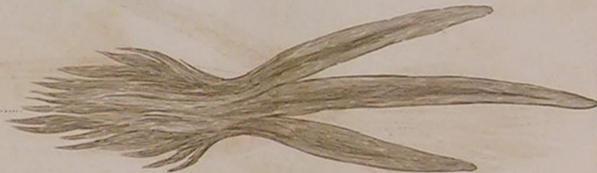
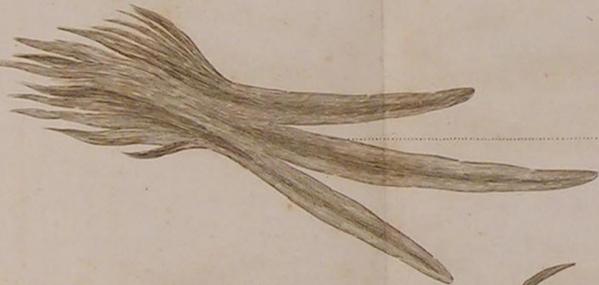
O. giganteus



O. tuberosus



O. ingens



O. diversus
a. clarus



O. diversus
h. platydactylus



O. tetradactylus



Proportional
size of the
O. palmatus



O. minimus

