XI. *An Account of the Tracks and Footmarks of Animals found impressed on Sandstone in the Quarry of Corncockle Muir, in Dumfriesshire.* By the Rev. HENRY DUNCAN, D.D. Minister of Ruthwell.

(Read January 7. 1828.)

THE sandstone quarry of Corncockle Muir is situated between the rivers Annan and Kinnel, about a mile and half above their confluence, and not quite three miles from the town of Lochmaben in Dumfriesshire. It is near the top of a low, round-backed hill, which stretches about half a mile in a westerly direction, almost in the line of the rivers. This hill rises out of a valley of irregular surface, terminated, at the distance of some miles, on the north and north-west, by a mountainous range of transition rock; on the south by an arm of the same range; and on the east, at a greater distance, by lower elevations, consisting, according to Professor JAMESON *, partly of floetz-trap and partly of the independent coal-formation. The valley itself is said by the same authority to be of the independent coal-formation, lying on the transition rock, and contains considerable quantities of sandstone interspersed in various parts, and stretching as far as the bottom of the mountains.

The sandstone of which the quarry in question is composed is, like most other sandstone in the county, of a reddish-brown colour, and is believed to be what is called in England the *new red sandstone*. Its texture is friable, and its strata of very un-

* In his Mineralogical Survey of Dumfriesshire.

equal thickness. It lies in the direction of the greater part of the sandstone of the district, which is from west-north-west to east-south-east, with its dip southerly at an angle of 38°.

The remarkable phenomenon which I am now about to describe as existing in this quarry, is that of numerous impressions, frequently distinct and well defined, bearing, both in their shape and in their position with relation to each other, so close a resemblance to the foot-prints of quadrupeds, as to leave no doubt respecting their identity, which have been found by the workmen on the surface of certain strata, when the superincumbent layers have been removed in the progress of quarrying. This fact, so extraordinary, and I believe *unique*, has not hitherto attracted the share of public attention which it deserves, and indeed has not as yet been noticed in any scientific work, though it is fifteen or sixteen years since the discovery was first made.

The casts and specimens which accompany this will convey an accurate idea of the nature of the impressions; but it may be necessary to mention, that considerably greater variety than I have yet been able to procure, has been observed, not only in their dimensions, but shape, the magnitude varying from the size of a hare's paw to that of a foal's hoof.

Description of the accompanying Casts.

No. I. represents part of a slab *, formerly in the possession of Mr CARRUTHERS of Dormont, who procured it about four years ago from the quarry, and is now built into a summer-house in the garden belonging to the manse of Ruthwell. On the slab, which is 5 feet 2 inches in length, there are twenty-four continuous

* The accompanying engraving (Plate VIII.) is taken from the cast No. 1, and is on a reduced scale.

impressions of feet, forming a regular track, which make twelve of the right feet and as many of the left, being of course six repetitions of the mark of each foot. The impressions of what I take to be the fore-feet, are a little more than two inches in diameter, both from claw to heel and across; and those made by what appear to be the hind-feet are of much the same size, but somewhat differently shaped. The marks of five claws are discernible in each fore-foot, the three in front being particularly distinct. The three front claws of the hind-foot may also be plainly traced, and are placed nearer to each other than those on the fore-foot. There has obviously been no division in the sole of the foot, as is the case in the canine and feline species, as well as in some other quadrupeds; but a gentle convexity of surface may be observed, especially in the fore-paw, occasioned chiefly perhaps, by the act of sinking in the wet sand. The depth of the strongest impression is about half an inch, and it is observable that, in this specimen, the fore-feet have made somewhat deeper marks than those behind,—a fact which may either indicate a considerable length in the animal's neck, or the more than ordinary weight of its head and shoulders; for had it not been for one or other of these circumstances, the chief pressure would have been thrown on its hinder paws; because the surface up which it appears to have been moving was of considerable steepness.

The distance from the claw of the hind-foot to the heel of the nearest impression of the fore-foot on the same side, varies from an inch to an inch and a half. This, however, merely marks the position of the two feet when the hinder one was brought forward in moving; and if we would ascertain the animal's step, that is, the length between the hind and fore foot when the former was thrown back and the latter advanced *, we

* It is not meant that the quadruped has actually been in this position; for the hind-foot would of course be moved forward before the fore-foot was lifted.

must measure from the hind-foot forward to the second impression of the fore-foot on the same side. Now, this gives a distance of between 13 and 14 inches, which is considerably more, however, than would have been the case had the animal been standing still. If we compare this with the distance between the line of the right and left feet (which is as to the fore-feet nearly $6\frac{1}{2}$ inches, and as to the hind-feet something more than $7\frac{1}{2}$ inches), we shall see that an extraordinary thickness of the animal's body in proportion to its length, is clearly indicated.

No. 2. is a cast from another slab of sandstone, which was taken from the quarry under my own eye, and which is also fixed in the wall of the summer-house at **Ruthwell Manse**. It contains the track of a smaller quadruped, perhaps a variety of the same species; for in some respects a resemblance may be traced. In both of them the sole of the foot is undivided; and in both, a more than ordinary thickness of the body, in proportion to its length, is shewn by an unusual distance between the marks of the right and left feet, before as well as behind. In this specimen, however, the latter peculiarity is not proportionally so great as in that of No. 1. nor do the feet appear to have been of a similar shape, except in the circumstance already mentioned; and indeed the relative proportions of the two are far from corresponding throughout. Nor is it less worthy of observation, that although in No. 1, as has already been remarked, the unusual length of the neck, or weight of the head and shoulders, seems to be indicated by the deep sinking of the fore-feet, the very reverse appears in No. 2, the impression of the fore-feet being in this specimen only very slight, while that of the hind-feet is strong and well defined. Whether or not these differences can be accounted for by a difference of age in two animals of the same family, I must leave to more skilful inquirers to determine.

The measurements are as follow :

Breadth of the impressions across the toes,	1½ inch.
Length of the step, as above explained *,	8
Distance directly across between the line of the right and left foot-marks behind and before, about - - -	3
Distance from the claws of the hind-foot to those of the nearest mark of the fore-foot, about - - - -	2

In both of the specimens already mentioned, the track of the animal was in an upward direction, that is, from the bottom to the top of the quarry, almost in a direct line, along a smooth surface, inclining like the rest of the strata of the sandstone at an angle of 38°. This at least I can aver, from personal observation, to have been the case with No. 2, which I saw removed from its original bed. The track continued along the whole face of the flag as it lay in the quarry till it disappeared in the earth at the top. It had been recently uncovered in the course of working, by the removal of a thick superincumbent layer, which, I was informed, had, in this as in other instances, the *counter* prints distinctly marked in relief on its under surface, these upper projections corresponding to the cavities below as exactly as a cast to its mould. The whole length of the track, which was quite regular, was from 14 to 16 feet, scarcely visible at first, as if the sand had been too dry to receive the impression, but becoming in a few steps perfectly well defined, and continuing so to the very top. The surface on which the footsteps were impressed was what the workmen technically call a *clay-face*, being, from a more copious admixture of clay than ordinary in its outer coat, harder than the rest of the rock, and the seam between it and the upper stratum having less adhesion, and con-

* That is, when the fore-foot was advanced, and the hind-foot thrown back in the act of moving forward.

taining sometimes, though not in the present instance, a thin layer of soft clay altogether distinct from the stone. I was told by the son of the tacksman of the quarry, a person of some intelligence, that the tracks never appeared on a surface not of this kind. Another remark of some importance, derived from the same source, is, that all the tracks are constantly in a direction either up or down, sometimes inclining a very little either to the right or left, but never running across the slope in any considerable degree. This my own observation, so far as it goes, fully confirms.

No. 3. is a cast taken from a block which was also removed from the quarry while I was present, and, like the other two, is in my possession. The impressions it contains seem to be those of an animal's feet in the act of descending the steep face of the moist sand. The inclination of the slab as it lay in the quarry, was I think greater than the ordinary inclination of the rest of the strata, and might be upwards of 40° . It was at all events so steep as to render it necessary for an animal descending the declivity to insert its fore-feet firmly in the sand before it could move with safety ; and this the quadruped in question appears to have done, by cautiously sliding one paw downwards, till its footing became secure, and then extending the other in the same way, while its hinder feet, following alternately, rested on the surface of the sand. Assuming this to be the case, we might expect to see the prints of the hind-feet also ; and accordingly, in the very places where such marks might naturally be looked for, slight depressions of the stone are discoverable, sufficiently well defined to justify the opinion that they are foot-marks. If it be objected that these depressions are too slight to correspond with the deep cavities supposed to be made by the fore-feet, it must be remembered that the weight of the animal's body would necessarily be thrown much forward, and that the whole of its security would lie on the efforts made with its fore-feet, the hind-feet being

merely used to keep it steady ; so that the comparative slightness of these impressions is just what might have been anticipated. It may be proper to mention, that the block from which this specimen was taken was but a few feet in length, and contained two other sliding impressions, precisely similar to those which I carried away, affording the strongest conviction to my mind that they were a continuation of the same track. I have in my possession other specimens of similar prints, taken from a different part of the quarry, one of which I transmit* ; but these are not so deep, and I have in vain endeavoured to discover any depressions in them corresponding to those which I take to be made by the hind-feet of this animal. It is probable that in these instances the weight with which the hind-feet rested on the surface was too little to make a durable impression on the sand in its half indurated state.

I persuade myself that a simple inspection of the casts and specimens I transmit along with this, will be sufficient to satisfy any reasonable inquirer that the cavities they contain are the actual foot-marks of quadrupeds, and justify me, without farther proof, in having assumed them to be so ; but should any doubts on the subject remain, I must refer to the quarry itself, where several specimens are still left exposed, and others are occasionally uncovered, of a nature to remove all scepticism, though it is greatly to be regretted that so many of the very finest have, by the carelessness of the quarrymen, who regarded them as of no value, been utterly destroyed.

One of the tracks still to be found in the quarry is too remarkable to be passed over without notice, being considerably larger than any of those I have mentioned. The prints are so much filled up, indeed, as to leave the shape of the foot undefined ; but yet the nature of these impressions cannot be mis-

* Specimen marked A.

taken, when they are compared with those which are more distinct. I have unfortunately taken no accurate measurement of this track ; but from an imperfect specimen now transmitted *, it appears that the distance from the hind to the fore foot, when most nearly in contact, was about 1 foot 9 inches, while the breadth across from the line of the right foot track to that of the left, was somewhat more than 7 inches ; and if I might be allowed to speak from recollection, I should say that what I have loosely called the animal's step, for want of a better word, that is, the distance between the fore and hind feet, supposing them to be at their stretch, could not be less than five feet. The layer on which the impressions are made, happens to be only a little more than half an inch thick, and it has naturally no adhesion to the under stratum. In attempting, however, to raise a specimen from its bed, I found that the two strata were so intimately united wherever the prints of the feet occurred, that it was impossible to separate them without breaking. It seemed as if the weight of the animal, or its efforts in ascending, had occasioned the thrusting of its feet entirely through the upper into the under layer ; and on forcing the strata asunder, this supposition was confirmed by the curious fact, that the matter of the under layer, displaced doubtless by the sinking of the feet, was discovered to be heaped up in a ridge-like form round the insertion of the animal's heel, having made way for itself, when forced back, by causing a corresponding concave impression on the under face of the upper stratum.

With regard to the species of animals whose tracks have been so wonderfully preserved, I do not think myself competent to offer any conjectures of my own ; but having been in correspondence with one of the first geologists of the age (to whom I

* Specimen marked B, on which there is also the track of a small animal ascending.

sent casts similar to those now transmitted, besides a small specimen of the rock itself, containing one or two foot-prints), I think it may be interesting to state the opinion with which his politeness has favoured me as to three of the tracks.

Concurring with Mr JAMESON, as he assures me he does, in the belief that the rock is what is called the *new* red sandstone, which is supposed to have been deposited at an era when it is the received opinion that no quadrupeds existed on our earth of a higher order than reptiles, he was induced to look to our present crocodiles and tortoises as the species most nearly resembling those whose footsteps have marked the stone. This led him to make a rough experiment with some live tortoises which he has in his possession, the result of which was to make him conjecture that the impressions must rather belong to the tortoise than the crocodile tribe. He did not, however, speak positively ;—not that he thought the prints too indistinct to enable him to form an opinion, but because he had not sufficient time and opportunity for examination *. As to the deep tracks occasioned, as I had sug-

* Since the above was written, I have had the pleasure to receive a letter from Professor BUCKLAND, containing the following account of his experiments :

“ *Oxford, 12th Dec. 1827.*

“ *1st*, I made a crocodile walk over soft pye-crust, and took impressions of his feet, which shew decidedly that your sandstone foot-marks are *not* crocodiles.

“ *2d*, I made tortoises, of three distinct species, travel over pye-crust, and wet sand and soft clay ; and the result is, I have little or no doubt that it is to animals of this genus that your impressions on the new red sandstone must be referred, though I cannot identify them with any of the living species on which I made my experiments. The form of the footstep of a modern tortoise corresponds sufficiently well, but the relative position of the impressions to each other does not entirely coincide, and this I attribute to the different pace at which the animal was proceeding ; for I found considerable variety in these positions as my tortoises moved more or less rapidly ; and as most animals have three distinct kinds of impression for their three paces of walk, trot, and gallop, so I conceive your wild tortoises of the red sandstone

gested, by the sliding of the animal, he fully adopted my theory of their origin. The track of the large animal I had not then described to him; and any account of it I am even now able to give, is so vague as to lead to no certain conclusion. The only thing yet discovered which can afford any idea of the nature of the foot, is the ridge formerly mentioned as curling round the animal's heels, on the surface of the under stratum, corresponding to which, but a little above it, there is, in one instance, on the surface of the upper layer, a depressed line of the shape and dimensions marked below :

a fact which contradicts the commonly received opinion of geologists respecting the position of sandstone in its original

age would move with more activity and speed, and leave more distant impressions, from a more rapid and more equable style of march, than my dull torpid prisoners on the present earth in this to them unnatural climate.

“ I found, also, that, on walking down hill on soft sand, my tortoise scooped out long and somewhat oval cavities, like those of which you sent me a cast, leaving no impressions of the toes or heel. Each foot successively floundered forwards to the lowest point of the groove, producing the posterior part of the excavation, and was then dragged out, producing a similar removal of the sand from the anterior part of the groove in question. The difficulty is to explain why sand so soft did not subside and obliterate the cavities, before or during the arrival of the next superincumbent bed of sand, which filled up and preserved these impressions. Elongated excavations similar to those last spoken of are made by hares and other quadrupeds, in moving over soft and half consolidated snow.”

In a subsequent letter of 17th March, Professor BUCKLAND, in relation to the elongated and imperfect impressions, which Dr DUNCAN attributed to the dragging of the animals as they were moving with difficulty down hill, observes, “ The cause of this variety of impressions I would interpret otherwise, and rather refer them to

state, seems to be deducible from the appearances connected with these impressions. It has been alleged that the materials of which sandstone is composed, were accumulated by successive depositions from the sea or other extensive waters, and that therefore the strata must have been, while in a soft state, nearly horizontal. It seems almost demonstrable, however, that the strata must in this instance have been in a greatly inclined position, if not altogether as inclined as at present, when the impressions were made. On this subject an observation or two may suffice. On inspecting the casts and specimens sent, it will be observed that there are evident remains of the matter displaced by the footsteps. This is the case with almost all the impressions I have seen; and wherever such an appearance occurs, that matter is found to have been carried *downwards*, with reference to the present inclination. In the case of No. 2,* for instance, the track of the animal was directly *up* the face of the steep; and it will be seen that the sand is therefore thrown back, immediately behind the foot-marks. In the case of No. 1, however, the track had inclined a little to the right, and this slight variation is indicated by the direction of the displaced sand, which has precisely such a position as this circumstance

the more than usual soft condition of the sand at the time and place where these imperfect marks were made. Marks exactly like those made by my living tortoises, on sand that was wetted too much for a sound impression, viz. holes into which the foot had sunk so deep that it could not be lifted out and moved forward by the advancing animal without displacing by its toes a quantity of the sand that was in front of the line of motion of each foot, and the result being a series of scoopings such as the track of a hare or rabbit exhibits in soft and deep snow. If this idea be correct, the impressions may have been made on horizontal beds of soft sand, ere they had received the high degree of inclination they now possess. Thus the problem will be relieved of some portion of its difficulty, namely, that which attends the hypothesis of all the impressions having been made on the sand-beds whilst inclined at the same angle they exhibit at present."

* The casts and specimens here alluded to are deposited in the Museum of the Society, and may be inspected by application to any of its members.

accounts for ; while in the case of No. 3, the wet sand has evidently run down before the descending prints. It will be observed, too, that the claws and fore-part of the ascending foot have been more deeply inserted into the sand than would have been natural, had the surface been nearly horizontal ; and indeed a slight glance at the *sliding* foot-marks in No. 3, seems to settle the question. But there is another circumstance already mentioned, which can scarcely be accounted for, but on the supposition that the surface of the sand had a very considerable inclination,—I mean the fact that the tracks run all from the bottom to the top of the slope, or *vice versa*, and *never* across. An inclination of 38° is so considerable, that it could only be with extreme difficulty that an animal could make its way across the steep ; but it would obviously find a much less effort necessary in moving up and down.

With regard to the state of the sand, in point of tenacity and moisture, at the time the impressions were made, a few remarks seem to be called for. In the first place, the surface could not have been entirely dry, otherwise the displaced sand would have been rough and uneven, whereas it is quite smooth, indicating a state inclining to mud, which may be explained on the supposition already mentioned, of a considerable mixture of fine particles of clay ; but on the other hand, had the matter been very soft, it could not have retained its precipitous face, nor could the animals have moved over it, without sinking much deeper than they appear to have done, neither could the impressions have remained so distinct as we find them actually to be. There seems to be an indication, too, of a certain degree of toughness in the surface. This is particularly remarkable in No. 2, where it would appear that the clayey sand had already become slightly indurated externally, having been skinned over, as it were, with a stiffening coat ; for it will be observed that the claws of the animal as it ascended, seem to have rent the surface asunder at every step of

its hind-feet, forcing it downwards by the pressure. It may be noticed, too, that, in Nos. 1. and 3, where no such disruption appears to have taken place, a similar tenacity is indicated; for, when the hind-feet of the animals have happened to rest on the sand that had been newly displaced by the fore-feet, their pressure has not altogether obliterated the appearance of superadded matter, but has merely caused a depression of the part rested on. These indications are precisely what would have taken place on a surface composed of stiffening putty or other tenacious matter, and mark with curious precision the peculiar state of the sand.

There is a circumstance not yet adverted to, which cannot fail to make a strong impression on those who are not familiar with the wonders of geology. I allude to the position of these impressions, with relation to the superincumbent strata. In the direction of the dip of the strata, the rock is continuous for at least a quarter of a mile from the quarry where the impressions are found. Now, as the strata in the whole of this extent are nearly parallel to those of the quarry, it is obvious that they must lie upon each other like volumes in the shelf of a library when all inclining to one side; and as these strata rest on others in which the foot-marks are found, they must of course have been deposited since the animals whose tracks they indicate moved on the sand then forming the surface of the ground. This fact leads the mind into the remotest antiquity, and perplexes it in a maze of interminable conjectures as to the state of the earth's materials when these living creatures walked on its surface, and bathed in other waters, and browsed on other pastures, and not less as to the extraordinary changes and convulsions of nature which have since taken place, and which have broken up, overturned, and remodelled all things.

Nor will our surprize and perplexity be lessened, when we attend to other facts connected with this remarkable phenome-

non. The quarry has been worked to the depth of about 45 feet from the top of the rock, and as far down as the labours of the quarrymen have hitherto extended (I speak on the concurrent testimony of several eye-witnesses), similar impressions have been found, and those equally distinct and well defined with such as are nearer the surface. But this is far less remarkable than another fact which I give on the same authority. Although the sandstone at the place where the quarry was originally opened, contained no foot-marks, as it consisted of what is called by the workmen *solid* (*i. e.* imperfectly stratified) rock, yet it soon changed its character, and whenever it assumed the form of regular layers, the impressions began to occur. From this period, as the workmen proceeded in their labours, they have continued to find numerous impressions, particularly in one part of the quarry, and that not on a single stratum, but on many successive strata; that is to say, after removing a layer which contained foot-prints, they found perhaps the very next *clay-face* stratum, at the distance of a few feet, or it might be of less than an inch, exhibiting a similar phenomenon. Since the foot-marks were first discovered, about forty yards of sandstone have been removed in a direction perpendicular to the line of the strata, and throughout the whole of that extent, impressions of precisely the same kind have, at frequently recurring intervals, been uncovered, and are still continuing to be uncovered.

This seems to prove incontestably that the process, whatever it may have been, by which the impressions were buried in the sand, has not been occasioned by any sudden and isolated convulsion of nature, but has been carried on through many successive years, or rather ages. Nor has it been the result of tides on the shore of the sea, which can scarcely be supposed to have flowed to the height of between forty and fifty feet; and, even if they had done so, would certainly have swept away or filled up

any impressions which animals might have made at low water, by moving over the surface of the sands they were depositing.

In the midst of so much difficulty, it is not easy to form even a plausible conjecture as to the manner in which the sand composing the rock was originally accumulated. It might, however, be perhaps worth while to inquire whether or not this successive accumulation could be the effect of the drifting occasioned by violent winds from the south-west. Supposing a sand-hill to be thus formed, a period of rainy weather following the stormy season would soften and diffuse the particles of clay, which may easily be believed to have mingled with the sand-drift, and would not only prevent the sand from being again moved by the wind, but would form it into a substance of some tenacity, resembling mortar, well fitted for preserving any impression it might receive. If, during or immediately after the rainy season, animals were to traverse a hill thus formed, their tracks would be either altogether obliterated, or partially filled up, of which latter state many traces are to be found in the quarry ; but when the surface had begun to dry, the foot-marks impressed on it would remain for a considerable time quite distinct and well defined. Now, supposing the stormy monsoon again to commence, the neighbouring sands, which had not yet been fixed by any strong mixture of clay, and which happened, from their situation, to be easily dried by a few days of favourable weather, would be suddenly drifted on the hill in question, forming a layer which may easily have covered over the half-indurated surface, without being incorporated with it, and without in any way injuring the form of the foot-steps imprinted on it. Let the monsoon be now supposed to continue during the whole course of a dry summer : Fresh layers of sand would be drifted, comparatively pure at first, but mingled again towards the close of the season with the clayey dust swept from an arid soil, which mixture would form the materials of what the quarrymen know in

its present state by the name of a *clay-face*, and would once more, when subjected to the operation of the returning period of rain, both fix the sand, and prepare it for the reception of permanent impressions of the tracks of wandering animals. Thus, from year to year, the same round would be continued, and the same appearances would take place, till, after the revolution of many ages, what was originally sand would be converted, by a common process of nature, into sandstone, and being exposed, in common with the rest of our globe, to those mighty but mysterious convulsions of which there are every where such incontrovertible proofs, would at last, by the submersion of the universal deluge, be buried under its present covering of soil.

RUTHWELL, 15th Dec. 1827.

Binding from Cast R. 1.

Wm. W. L. L. L. L.