[*From the* Quarterly Journal *of the* Geological Society *for November* 1890, Vol. xlvi.]

On Burrows *and* Tracks *of* Invertebrate Animals *in* Palæozoic Rocks, *and other* Markings.

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Contents.

§ I. Introduction.

The present paper is intended to contribute some recently acquired facts to the solution of questions connected with these often problematical markings; and it will consist rather of short notes, illustrated by photographs, than of a connected discussion of the subject. I propose to notice the nature of certain markings sometimes referred to plants, under the name of *Bilobites*,—to the true nature of the *Scolithus canadensis* of the Potsdam Sandstone,—to certain tubes similar to those of modern *Sabellæ*,—to cylindrical concretions resembling trunks of trees,—and to imitative markings, and peculiar trails of doubtful origin.

§ II. Bilobites, Rusichnites, Protichnites, and Climactichnites. (Figs. 1 to 6.)

The name *Bilobites*, proposed by Dekay in 1823, was, as Newberry has shown,* originally applied not to objects of this kind, but to casts of certain bivalve shells. It was therefore dropped in America; but it has been revived and has gained currency in Europe †, as a term including various forms of markings referred to different genera. The dominant characters are a band, or an oval mass, with a median longitudinal furrow or ridge, and marked with transverse or oblique furrows or striæ, and with or without a marginal ridge.

The writer was enabled to show in 1864 ‡ that one of the most remarkable of these impressions, *Rusophycus grenvillensis* of Billings, and *Cruziana*-like markings associated with it, were really

* 'Science,' vol. v. no. 124, 1885, p. 508.

† In Senhor J. F. N. Delgado's 'Etude sur les Bilobites et autres Fossiles des Quartzites de la Base du Système Silurique du Portugal,' 4to, Lisbon, 1886, and the 'Supplément,' 1888, numerous bibliographic references to other authors treating of these and some allied fossils are given in full.

‡ 'Canadian Naturalist,' n. s. vol. i. pp. 363, 458.

burrows and tracks of marine animals, probably Crustaceans. He arrived at this conclusion by a careful study of the impressions made by the recent *Limulus polyphemus* on muddy and sandy bottoms, and by the application of these results to the explanation of a very fine exposure of the impressions above-named in the works undertaken for the enlargement of the Grenville Canal, on the Ottawa River. In this paper, descriptive of the facts observed at Grenville, it was proposed to substitute the generic name *Rusichnites* for *Rusophycus* or *Rysophycus*, and it was pointed out that the so-called fucoids of the genus *Arthrophycus* were probably of like nature, and might be placed in the same category with the impressions described by Logan as *Climactichnites* from the Potsdam-Sandstone *. These observations were supposed to have conclusively settled the question as to the nature of all the *Bilobites*; but little attention seems to have been given to them by European Palæontologists. Nathorst has, however, arrived at similar results, in a somewhat similar manner, by comparison with modern impressions †; and Williamson has described as casts of animal-tracks markings of this nature from the Yoredale rocks ‡. Bureau has also adduced some striking evidences in favour of the theory that some at least of the *Bilobites* are the work of Phyllopod Crustaceans §. Saporta, Delgado, and others still regard the *Bilobites* as true Algæ, and Schimper describes one form as a plant, under the name *Crossochorda*. In so far as American examples are concerned, it may be considered as settled that they may best be explained in the way above indicated. The following genera may be included in this general statement:—

Rusichnites = Rusophycus, *Hall.*
Arthrichnites = Arthrophycus, *Harlan.*
Cruziana, *D'Orbigny.*
Climactichnites, *Logan.*
Fræna, *Rouault.*
Crossochorda, *Schimper* (in part).

These impressions pass into *Protichnites* of Owen through such forms as *P. Davisi* of Williamson ‖, and the *Scærichnites* of Billings¶ and *Diplichnites* of the author**. They are connected with the undoubted worm-tracks of the genus *Nereites* by specimens of *Arthrichnites*, of which I have several in my collection, and in

* Canad. Nat. Geol. vol. v. p. 279

† Kongl. Svenska Vetenskaps-Akad. Handlingar, vol. xviii. No. 7, 1881; eleven plates, 104 pages, including an Abridgment in French. The List of Books and Memoirs treating of Trails and Tracks, from 1823 to 1881, occupies six of the quarto pages in this work. Also 'Nouvelles Observations sur les Traces des Animaux;' Stockholm, 1886.

‡ Mem. Manchester Lit. & Phil. Soc. 3rd series, vol. x. 1885, pp. 19–29, 3 plates.

§ Comptes-rendus, vol. 104, 14 Février et 4 Juillet, 1887, page 7 of the author's reprint.

‖ *Op. cit.* pl. i. fig. 4. ¶ Catal. Sil. Foss. Anticosti, 1866, p. 73.

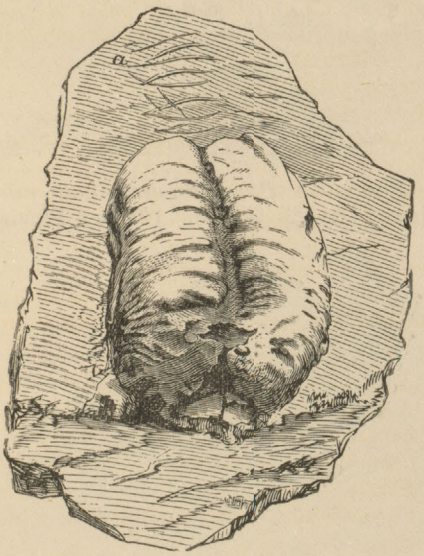
** Amer. Journ. Sci. ser. 3, vol. v. 1873, p. 19, and p. 23, fig. 3.

which the central furrow becomes obsolete, and by the genus *Gyrichnites* of Whiteaves, and other forms destitute of a median groove *.

They cannot be sharply divided into genera or species, because of their variability in passing over different kinds of bottom, and of the changes which occur in consequence of the various modes of progression employed by the animals.

Fig. 1 represents a typical specimen of *Rusichnites*, from my paper

Fig. 1.—*Rusichnites grenvillensis*. The cast of a Crustacean Burrow, with part of a trail leading to it, or from it, at *a*. Cambro-Silurian ; Grenville, Canada.



of 1864, and shows traces of the trail leading to or from the cast of the deep burrow or excavation. Fig. 2, *Rusichnites acadicus*, from the Carboniferous, I now regard as a result of successive strokes of a crustacean tail, with marks of the carapace and limbs. The specimen represented in fig. 3, which is from the Clinton Formation of Canada (and from the collection of Lieut.-Col. Grant, of Hamilton, Ontario), illustrates the probable origin of these markings, but also suggests the idea of some of them having been the trails or castings of worms rather than marks of crustaceans. It is evident indeed that these markings are closely connected with those named *Nereites* by Hall, and of which he has figured several kinds from the Clinton formation, ascribing them to Mollusca. Similar objects have been named *Psammichnites* by Torell, and are supposed by him to resemble

* Trans. Roy. Soc. Canada, vol. i. 1883 ; Section iv. 1882, pp. 109-111.

Fig. 2.—*Rusichnites acadicus.* A Crustacean Track, showing the marks of the edge of the carapace. Carboniferous; Cape Breton.

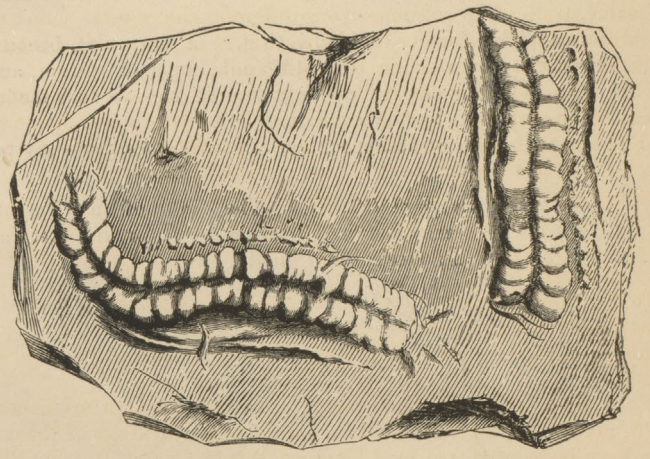


Fig. 3.—*Rusichnites* (*Psammichnites*) *clintonensis*, sp. nov. Silurian of Ontario, Canada. (From a Photograph.)

castings of the Lobworm *. I am indebted to Lieut.-Col. Grant for an extensive series of these markings, on which it can be seen that the same trail often assumes very different characters, sometimes resembling *Crossochorda* or *Cruziana*, and at others passing into the ordinary *Nereites* or even into a simple trail.

The *Protichnites* † of the Potsdam Sandstone are indubitable tracks of Crustaceans; yet it is possible, as I have shown in the case of *Limulus*, that the same animals which produced *Protichnites* may also have been the authors of the transversely ridged *Climactichnites* so often associated with them (figs. 4 and 5). It is also to be observed that such forms as my *Protichnites acadicus* ‡ or the *Pr. scoticus* of Salter § form connecting links between this kind of track and *Cruziana*.

To the same category may be referred the trails with wave-like transverse markings and no central line, found both in the Upper Cambrian and Devonian, and which Whiteaves has named *Gyrichnites*‖.

I copy here the remarks on *Rusophycus* (*Bilobites*) in my paper of 1873, merely adding that I now believe some markings of this kind may have been produced by Chætopod Worms, as well as by Phyllopods:—

"In a paper published in the 'Canadian Naturalist,' 1864, I showed that the singular bilobate markings with transverse striæ, named *Rusophycus* by Hall, and found in the Chazy of Canada and the Clinton group of New York, are really casts of burrows connected with footprints, consisting of a double series of transverse markings, and that a comparison of them with the trails and burrows of *Limulus* justified the conclusion that they were produced by Trilobites. I proposed for these, and for similar impressions of small size found in the Carboniferous, the name given above. The Carboniferous examples, I supposed, might have been produced by the species of *Phillipsia* found in these beds. A specimen recently obtained from Horton shows this kind of impression passing in places into a kind of *Protichnites*, as if the creature possessed walking feet as well as the lamellate swimming feet which it ordinarily used."

I can scarcely doubt that the *Cruziana semiplicata* of Salter, and *C. similis* of Billings from the Primordial of Newfoundland, must have been produced by Crustaceans not dissimilar from those to which *Rusichnites* belongs.

To *Rusichnites*, rather than to *Protichnites*, ought perhaps to be

* Lunds Univ. Årsskrift, vol. vi. p. 31, 1869.

† Logan and Owen, Quart. Journ. Geol. Soc. vol. viii. 1852, pp. 199–225. In the 'Geologist,' vol. v. 1862, pp. 128–139, and pp. 454–456, the probability of *Climactichnites* having been the infallen gallery-tracks made by *Paradoxides* burrowing in the sand of the old sea, like *Sulcator* and *Kroyera* (as shown by Albany Hancock) burrow in the present sea-sands, has been suggested. A similar explanation was given in Prof. Dana's 'Manual of Geology,' 1863, p. 189. This does not, however, seem applicable to the Canadian specimens. See figs. 4 & 5, and further on.

‡ Amer. Journ. Sci. ser. 3, vol. v. 1873, pp. 17,18, 23, fig. 2.

§ Quart. Journ. Geol. Soc. vol. xii. p. 243, fig. 2.

‖ 'Trans. Roy. Soc. Canada,' *loc. cit.*

Fig. 4.—*Climactichnites* and *Protichnites*, associated on the same slab. From the Potsdam Sandstone of Ontario (in the Peter-Redpath Museum). About $\frac{1}{12}$ of natural size. The large slab is the *overlying* impression ; the small one, placed below, is the *underlying* surface. (From a Photograph.)

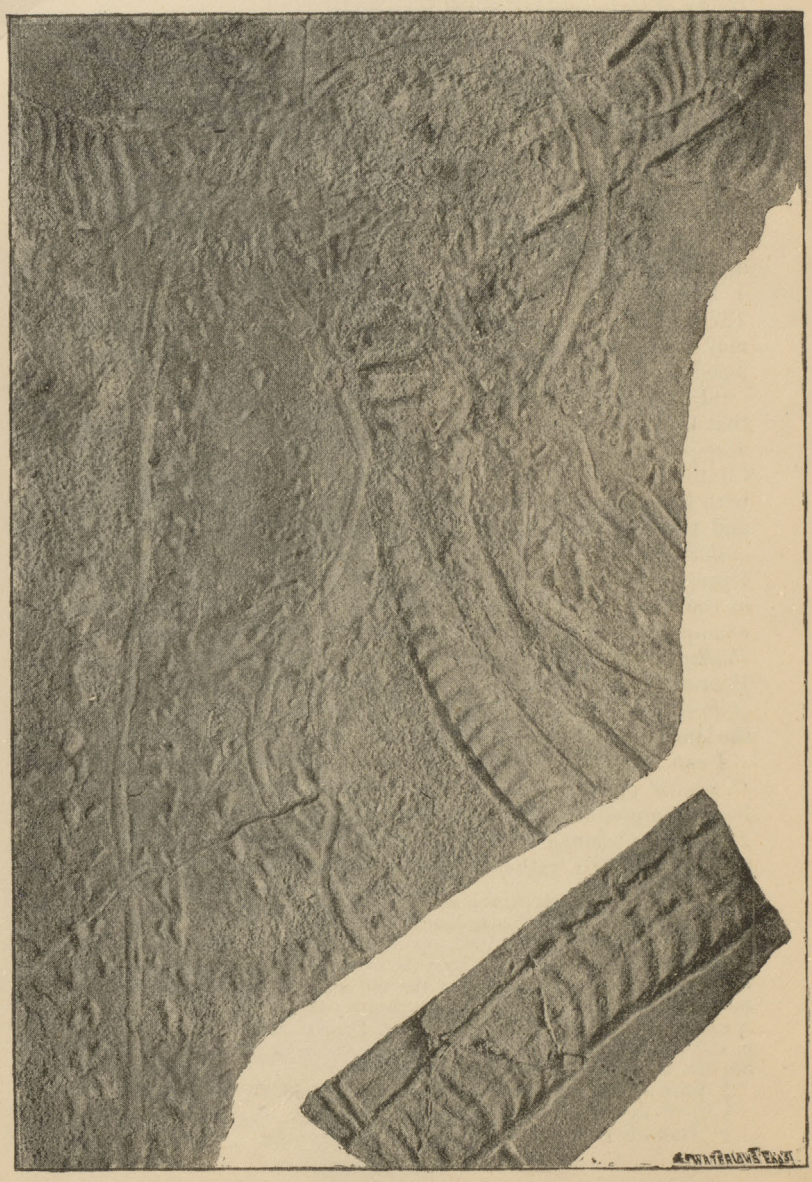
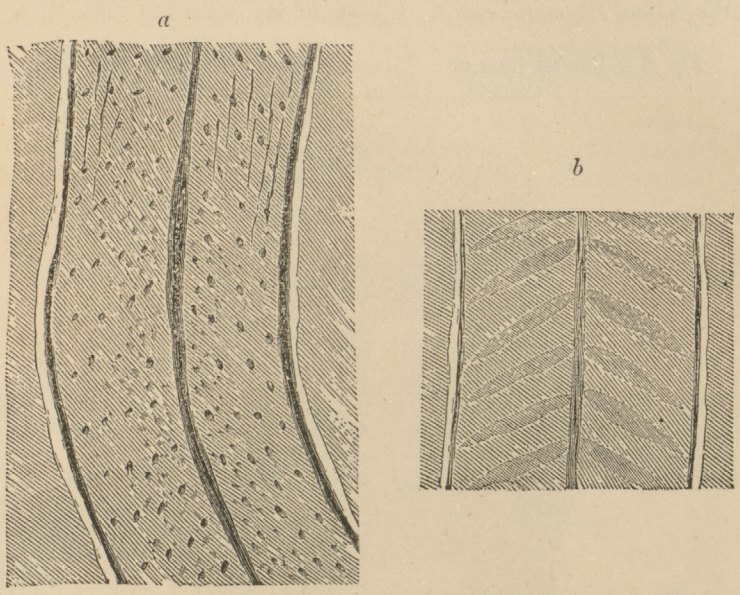


Fig. 5.—*a*, Protichnite-like ; *b*, Climactichnite-like Trails of *Limulus polyphemus*. Modern. Coast of Maine.



referred certain transverse linear impressions with a broad central groove from the Lower Carboniferous of Horton, which occur at that place under different modifications, and sometimes seem to change into light scratches, or touches of feet employed in swimming, or end abruptly, as if the animal had suddenly risen from the bottom.

Nathorst * and Bureau have further shown that impressions similar to *Bilobites* may be produced by the successive strokes of the tail of certain Crustaceans (*Crangon* and *Palæmon*). From all the phenomena attending the Potsdam *Climactichnites*, I am now inclined to regard them as of this nature, and as implying the existence of a large Crustacean with a truncated tail divided into two movable lobes. This would account for the ridge sometimes dividing the furrows and transverse ridges, and for its change of position from side to side of the mesial line,—also for the interrupted ridges on each side of the trail, which would be the natural result of the successive strokes of a flat organ,—and for the appearances presented when the tracks turn abruptly † (see fig. 4).

There is confessedly some difficulty in separating the marks known as *Phymatoderma* from Fucoids allied to *Caulerpa*, and even from

* Trans. Roy. Acad. Sweden, vol. xviii. no. 7, 1881.

† "Impressions of Aquatic Animals," 'Amer. Journ. Sci.' ser. 3, vol. v. 1873, p. 16.

stems of the coniferous genus *Brachyphyllum*; but Zeiller has recently described a roofed tunnel or burrow made by the mole-cricket, which completely reproduces some of the forms known under the name *Phymatoderma*.* I have in my collection (fig. 6) a

Fig. 6.—Roofed Burrow: *Phymatoderma*. Silurian; Ontario, Canada. (From a Photograph.)

specimen, collected by Col. Grant in the Clinton formation, which shows that some Silurian animal, possibly a Crustacean, made covered burrows of this kind.

§ III. Scolithus, &c. (Figs. 7 to 10.)

This genus, proposed by Haldimand as early as 1840, though the name would indicate that it refers to a worm, was originally placed with Fucoids; and both Hall and Billings regarded the cylindrical cavities, designated by the title, as representing "stems." No evidence, however, has been found of any organic matter in connection with *Scolithus*; the tubes being usually filled with a sandy argillaceous or calcareous material, which weathers out of the hard matrix, leaving cylindrical holes.

* Bull. Soc. géol. France, sér. 3, vol. xii. 1884, pp. 676–680.

Two species have been recognized in the Potsdam Sandstone of Canada and the United States, *Scolithus linearis* of Hall and *Sc. canadensis* of Billings. The former is usually straight, at right angles to the bedding, and smooth, or with obscure striation. The latter is rather smaller, tortuous, and unequal in diameter, sometimes branching and curving, and occasionally showing slight transverse ridges on the sides of the cylinders.

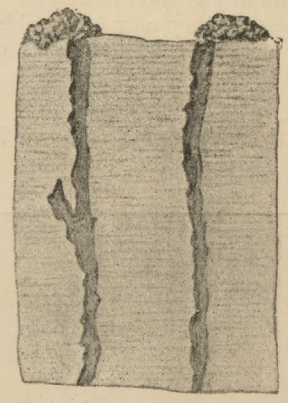
The latter species is very abundant in the Potsdam of St. Anne's on the Island of Montreal, where many varieties can be collected; but none of them shows any distinct structure. So far as indicated by the ordinary specimens, they may be moulds left by the decay of plants, sponges, or corals, or by the stems of *Lingulæ*, or the burrows of worms.

Fig. 7.—Slab with castings of *Scolithus*. Perth, Ontario. (From a Photograph.)

Their true nature is made evident by a fine slab kindly presented to the Peter-Redpath Museum by Mr. W. J. Morris, of Perth, Ontario. A portion of the upper surface of this slab is represented in fig. 7, which shows rounded pellets and ridges of hardened sand, very

similar to those ejected by many modern worms from their burrows. From these the tubes of *Scolithus* descend into the sandstone in the manner represented in fig. 8. It is, I think, quite evident that this variety of *Scolithus* represents burrows with castings at their entrances; and, since it is referable to *Sc. canadensis*, I have no hesitation in affirming that this interesting specimen indicates that

Fig. 8.—Sectional view of *Scolithus*, showing castings at the orifices. Perth, Ontario.



that species at least must be regarded as a worm-burrow. From the forms of these burrows it is not improbable that they may have been lined with a fine membrane sufficient to protect the body of the animal from the roughness of the sand, and that this lining may have aided in preserving their forms.

It is to be observed with reference to burrows of this kind, that under different circumstances their orifices may present very different appearances. Where the castings from them have been removed by a rapid current, they may have merely a simple opening at the summit. Where the animal has moved inward and outward, enlarging the opening, they may be funnel-shaped at top, like the burrows to which the term *Monocraterion* (Torell) has been applied; and, where the worm has made grooves radiating from the orifice, forms similar to *Scotolithus mirabilis* of Linnarsson *, or the forms which have been named *Pyrophyllites* and *Asterophycus*, may have been produced. I do not maintain that the forms indicated by the above names are identical with *Scolithus canadensis*, but I have seen in connection with that species appearances resembling these forms. Fig. 9 shows a form of this kind; but it is from a higher horizon, the Clinton, from which formation I have also funnel-topped burrows, like those of the Cambrian *Monocraterion*.

The singular radiating markings, from the Cambrian of Nova Scotia, which I have described as *Astropolithon Hindii*, and which

* Trans. R. Swed. Acad. Sci. vol. ix. 1871, p. 18, pl. v. figs. 21, 22.

Fig. 9.—*Radiating Burrow.* Silurian ; Ontario, Canada.
(From a Photograph.)

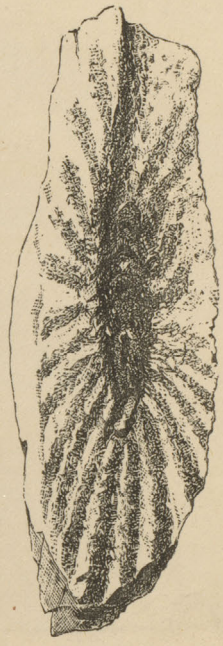
also occur in the Quebec Group at Metis, Canada, may possibly have the character of mouths of large burrows with radiating trails, though the radiating marks in this case seem to be of the nature of vertical plates, rather than of grooves (see fig. 10).

§ IV. Sabellarites, gen. nov. (Figs. 11 & 12.)

The modern genus *Terebella*, which constructs tubes of grains of sand and fragments of shells attached to a membranous lining, has been recognized by its tubes as low as the Lias (*T. capilloides*, Goldf.), and I have ascertained the existence of similar tubes as low as the Siluro-Cambrian ; though, as the tubes do not necessarily indicate the precise affinities of the animal, I prefer to designate them by the name above given, and to define this as indicating elongated tubes composed of grains of sand and calcareous organic fragments,

associated with carbonaceous flocculent matter, indicating a horny or membranous sheath. I have long suspected the existence of such tubes, and their connection with many of the cylindrical bodies often confounded with fucoids of the genera *Palæophycus* and *Buthotrephis*, but have only recently been able actually to demonstrate the fact.

Fig. 10.—*Astropolithon Hindii*, a burrow or organism from the Lower Cambrian of Nova Scotia. ('Acad. Geol.' 3rd ed. Suppl. 1878, p. 83.)



In the Black-River Limestone (Trenton group of the Siluro-Cambrian) at Pointe Claire, on the St. Lawrence, near Montreal, certain layers of grey limestone contain numerous dark-coloured, cylindrical, tortuous bodies, from $\frac{1}{10}$th to $\frac{1}{8}$th of an inch in diameter. When broken across, they are seen to be filled with crystalline calcite, as if they had been tubes; and, when thin slices are prepared for the microscope, the character of their walls, as composed of fragments of stone and broken shells &c., cemented by an organic material, now carbonised, becomes apparent. Figs. 11 and 12 show the appearance of the tubes on the weathered surfaces, and in section. The species may be thus described:—

The tubes are 1 to 3 millimètres in external diameter, and 3 centimètres or more in length, tortuous, irregular as if sometimes compressed, and sometimes in groups of two or more attached together. This would show a fixed or sessile condition as in *Sabellaria* or *Sabella*, rather than freedom, as in the *Terebellidæ*.

Fig. 11.—*a*, *b*, *c*, *Sabellarites trentonensis*. *a*. On a weathered surface; nat. size. *b* and *c*, enlarged. Black-river Limestone; Pointe Claire, near Montreal.

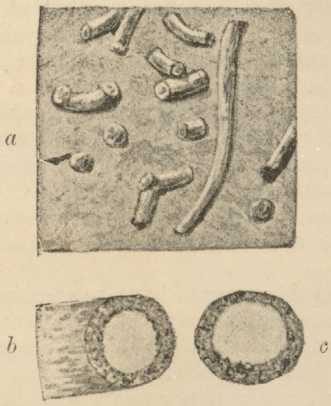
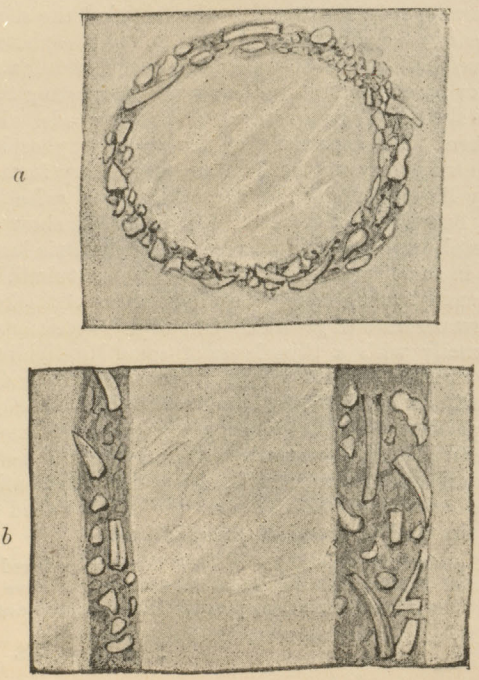


Fig. 12.—*a*, *b*, Transverse and Longitudinal Sections of *Sabellarites*. (Enlarged.)



The wall of the tube is somewhat thick and composed of fragmental matter, cemented by a dark-coloured organic substance. It is to be observed that in the case of tubes, as distinguished from mere burrows, like *Scolithus*, when two or more are attached together an appearance of branching results.

Tubes apparently of similar character, but of considerably larger size, occur in the same formation; and many obscure cylindrical or flattened bodies, not distinguished from branches of Algæ, may be of the same nature. I would also refer to a similar origin, and provisionally to this genus, the curious primordial burrows from the Hastings group described in the Quarterly Journal of this Society * in 1866, and the phosphatic tubes from the limestone of the Quebec group at Kamouraska, described in the Quart. Journ. Geol. Soc. in 1876†. The latter, however, I fancy are composed of excrementitious matter, or débris of the food of worms feeding on Linguloid shell-fish.

While preparing this paper, I have re-examined these tubes, and have had some new slices prepared. These confirm my previous statements. The thick walls of the tubes are destitute of lamination, and have a finely granular texture, resembling that of the paste of coprolites. They contain a few fine grains of sand, and minute fragments of shells and of carbonaceous fibres. The whole seems to indicate that they are formed, as already stated, of the phosphatic dejections of animals subsisting on *Lingulæ*, *Trilobites*, *Hyolithes*, and other creatures having coverings of calcium-phosphate.

In the same paper I referred to the fact that the shells of *Hyolithes* ‡ [*Hyolithellus*, and *Salterella*] are rich in phosphates, and that some of these shells are thick-walled with concentric lamination and with tubes or pores penetrating their walls, suggesting the idea that they may be shells of Worms rather than of Pteropods. I have since compared them with specimens of the singular phosphatic tubes found not infrequently in the Trenton and Chazy formations, and described by Billings under the name *Serpulites splendens* and *S. dissolutus*. Specimens of these tubes, when sliced, show a structure not fragmental, but composed of very fine concentric laminæ, with indications, in some specimens, of minute sinuous tubuli. They are smooth internally, and without show indications of thickened ridges and of transverse lines of growth. One of my specimens has been coated externally with a thin layer of some Monticuliporid coral. If these are worm-shells, of which there seems little doubt, they suggest affinities with the phosphatic *Hyolithellus* and *Salterella*.

It may, perhaps, be useful to suggest provisional names for the arenaceous and phosphatic worm-tubes resembling those of *Sabellaria* and here described. Those from the Black-River formation may be named *Sabellarites trentonensis*; and the thick-walled phosphatic tubes, from the Quebec group, *S. phosphaticus*.

* Vol. xxii. p. 608. In the paper of 1866 these are referred to as from the Laurentian of Madoc, Ontario. Since then these beds have been recognized as being later than Laurentian, possibly Huronian, and designated the "Hastings group."

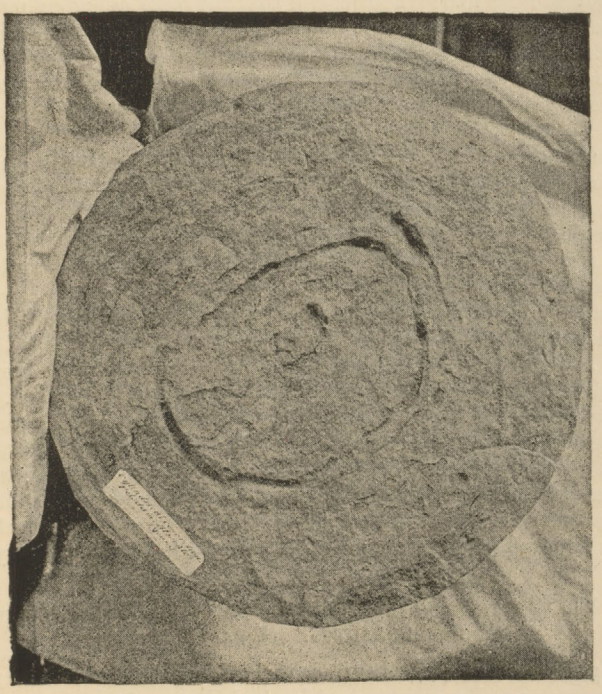
† Vol. xxxii. p. 286.

‡ *Op. cit.* p. 288.

§ V. Trunk-like Concretions in the Potsdam Sandstone. (Fig. 13.)

Many years ago specimens were obtained from the Potsdam Sandstone of Ontario, by the late Sir William Logan, which presented the aspect of large cylindrical trunks, a foot or more in diameter. They were casts in sandstone, without any external bark or organic matter, though showing obscure concentric lines on the ends. No opinion was, I believe, hazarded at that time respecting their origin; and more recently fine specimens have been collected by Dr. Selwyn on the bank of the Rideau Canal near Kingston; and Mr. A. Young, a student of McGill University, obtained others at Almonte, which he presented to the Peter-Redpath Museum. One of these is represented in fig. 13.

Fig. 13.—*Trunk-like Concretion.* Potsdam Sandstone; Almonte, Canada. $\frac{1}{6}$ nat. size. (From a Photograph.)



An incidental light seems to have been thrown upon their nature by the study of certain recent concretions, now forming in the alluvial clay of the St. Lawrence, by Rev. Prof. Kavanagh, of Montreal. These are small cylindrical bodies with a minute per-

foration in the centre, often containing a little vegetable matter. They were thus described * :—

"These little bodies are evidently clay concretions formed around vegetable fibres, and hardened by a small percentage of calcium carbonate, since when treated with hydrochloric acid they effervesce feebly and become disintegrated. They probably originate in the molecular aggregation of the calcareous matter in the clay around any foreign body included in it. They are about half-an-inch in diameter, and the largest may have been two inches in length; with rounded ends. When broken, they show a small central canal containing a little sand and strips of epidermal tissue, the remains of a root or stem. One shows three branches, apparently proceeding in a verticillate manner from a central stem. In the centre, the light reddish-brown colour of the clay has assumed a greenish hue, owing to deoxidation of the peroxide of iron by decay of the vegetable nucleus."

On comparison of these recent concretions with the Potsdam cylinders, it becomes apparent that they resemble each other very closely in form and structure, and that the older cylinders may have been formed in a similar manner, though on a gigantic scale. In confirmation of this view, it may be mentioned that in the Pleistocene clays of Green's Creek, on the Ottawa, cylindrical concretions surround twigs of poplar, which have been imbedded in the clay, and that in the Permian Sandstones of Prince-Edward Island ferruginous matter has cemented the sand into cylindrical concretions around stems of Calamites. This view as to the origin of the Potsdam cylinders is further confirmed by the rounded ends of some of them, and by the conformity of the internal concentric structure to this rounding. One of the smaller specimens in the Peter-Redpath Museum shows this peculiarity very well.

In the case of the Potsdam concretions, the nucleus of the concretion must have been an erect stem of some kind, possibly a *Chorda*-like *Alga*. So far as appears, this central stem must have been very slender, but no distinct traces of it have yet been observed. Perhaps the most remarkable fact in the case is that these cylindrical bodies are sometimes several feet in length, and pass through more than one bed of the sandstone. Another peculiarity is the presence is some of them of irregularly rounded cavities, apparently indicating the presence of bodies either concretionary or organic which have been removed by solution or decay. These, however, are very rare.

§ VI. Combinations of Worm-tracks with Ripple-marks and Shrinkage-cracks. (Figs. 14 & 15.)

Fig. 14 shows a rippled surface in Potsdam Sandstone with marks of worms or molluscs, arranged in the hollows of the ripples. The marks are simple trails, of that curious circular or chain-like form sometimes observed, and seem to have been made by animals creeping in the furrows between the ridges of the ripple-marks.

* 'Canadian Record of Science,' vol. iii. No. 5, January 1889, pp. 292–294.

Photograph No. XI. (not figured) shows another combination, where numerous trails formed in soft sediment have been affected by shrinkage-cracks, produced by the drying of the mass, in such a manner as to present a very complicated appearance.

Fig. 14.—*Combination of Worm-trails and Ripple-marks.* Potsdam Sandstone; Canada. $\frac{1}{3}$ nat. size. (From a Photograph.)

Still another appearance which may be placed under this head is that in fig. 15, which represents part of the surface of a large slab of Calciferous Sandstone from St. Anne's. At first sight it seems to be covered with a network of shrinkage-cracks, but on closer inspection these are seen to be cylindrical worm-tracks or burrows planed off and flattened on one side, as if a slab covered with casts of worm-tracks had been rubbed or ground down till the originally rounded sides of all the more prominent were flattened. The only way in which it seems possible to account for such an appearance is to suppose that the tracks were partly filled with mud incapable of hardening into stone, and then completely filled and

covered with a bed of sand, hardened afterwards into rock. The effect would be that, on weathering, all the prominent parts filled with mud would disappear, leaving the slab in its present state.

Fig. 15.—*Worm-burrows seen in section, owing to the manner of preservation and weathering.* Calciferous Sandstone; St. Anne's. (From a Photograph.)

All of these tracks or burrows are of the plain cylindrical forms to which the terms *Planolites*, Nicholson *, and *Arenicolites*, Salter †, have been applied, and which differ from *Scolithus* only in their more tortuous character, and in their usually being casts of mere trails on the surfaces of beds, rather than burrows or tubes penetrating them. I cannot doubt the origin of these markings, if for no other reason, on account of their covering such great surfaces of strata in a uniform manner.

* 'Proceed. Roy. Soc.' vol. xxi. 1873, p. 289; 'Manual Palæont.' edit. 2 vol. i. p. 320.

† 'Quart. Journ. Geol. Soc.' vol. xiii. 1857, p. 204.

§ VII. Branching Tracks. (Fig. 9, page 605.)

It is very puzzling to the Ichnologist to find so many impressions which he would regard as of animal origin branching in a manner to simulate plants. The distinction, however, between branching plants and branching tracks is usually sufficiently obvious to an experienced eye. The latter are generally of the nature of more or less cylindrical bodies, diverging or radiating from a common centre; while the former display either alternate ramification or bifurcation. As examples I may refer to Photograph No. xiii. (not figured) of *Buthotrephis gracilis*, and *B. Grantii*, figs. 16 and 17, true Fucoids, in

Fig. 16.—*Buthotrephis Grantii.* A true Fucoid, from the Silurian of Canada.

comparison with fig. 9 (above referred to), of radiating Annelid marks, or Photograph No. xv. (not figured), which represents a *Licrophycus*, probably a burrow with diverging tracks. Simple and branching trails of these kinds cover large surfaces of the Cal-

ciferous formation at St. Anne's, and are similar to markings of this kind which I have described from the Lower Carboniferous of Nova Scotia *.

Fig. 17.—*Buthotrephis Grantii.* A true Fucoid: carbonaceous. Niagara Formation. ½ nat. size. (From a Photograph.)

§ VIII. Rill-marks, as distinguished from Animal- or Plant-impressions. (Figs. 18 & 19.)

In my 'Acadian Geology' I have described the remarkable appearances simulating Algæ, or even gigantic trees, produced in the sloping banks of fine mud in the tidal channels of the Bay of Fundy. These are formed by minute rills, oozing from the wet sand or mud, and trickling in fine streams along the slimy surfaces, and uniting into larger and larger streams so as at length to produce the likeness of impressions of flattened trees, with large trunks and branches, dividing into twigs of extreme tenuity. Similar surfaces are often found in the Coal-formation, and sometimes on quite as large a scale as in modern tidal estuaries. Their forms and arrangement differ according to the slope and character of the sediment, and the amount of water it contains; but all show very delicate and often regular branching impressions. Figs. 18 and 19 represent two types of these in my collection from the Carboniferous of Nova Scotia, and

* 'Acadian Geology,' p. 256.

taken from surfaces unquestionably sculptured by water. A curious complication of such markings sometimes occurs when shrinkage-cracks, overflowed by a succeeding tide, have their edges sculptured by minute rill-marks. *Dictuolites Beckii*, of Hall*, is a remarkable example of this.

Fig. 18.—*Rill-mark.* Carboniferous; Nova Scotia. $\frac{1}{2}$ nat. size. (From a Photograph.)

It would be invidious to refer to the numerous species of imaginary fossil plants that have been founded on such markings as those referred to above and shown by figs. 18 and 19. I may merely mention the genera *Dendrophycus*, *Delesserites*, *Vexillum*, *Aristo-*

* 'Palæontology of New York,' vol. ii. 1852, p. 6, pl. 2. fig. 1.

phycus, *Chloëphycus* *, *Tricophycus* of authors as examples of genera which contain, or consist of, examples of Rill-marks.

I may add that I have discussed other forms of such impressions in my papers on Footprints of *Limulus*, and on the genus *Rusichnites*, in the 'Canadian Naturalist,' and in that on "Impressions of Aquatic Animals in the Carboniferous Rocks"†. In my work, 'The Geological History of Plants', I have also endeavoured to state the criteria for

Fig. 19.—*Rill-mark*. Carboniferous; Nova Scotia. ½ nat. size. (From a Photograph.)

separating such markings from true Algæ, and have referred to instances in which, while, on the one hand, mere markings have been elevated into marine plants, on the other, true land plants, imperfectly preserved, have been degraded into Algæ. I may also state that in America the Clinton formation, intervening between the Medina Sandstone and the Niagara Limestone, and containing many thin-bedded arenaceous and argillaceous deposits, is remarkably rich in such impressions. Many of these have been figured by Prof. Hall ‡ and referred to worms, crustacea, and gastropods. In the vicinity of Hamilton, Ontario, large collections have been made by Lt.-Col. Grant, who has enriched the Peter-Redpath Museum of

* Miller now admits that this is not an *Alga*.
† Amer. Journ. Sci. ser. 3, vol. v. 1873, pp. 17, &c.
‡ 'Palæontology of New York', vol. ii. 1852.

McGill University with a very large and instructive series of slabs including a vast variety of forms, a few only of which have been noticed in this paper.

[I desire also to remark that the facts above detailed, together with the discoveries of Annelid-jaws by Hinde and others, show that the Marine Worms must have culminated, in regard to size, abundance, and range of organization, at a very early geological period.—*September* 9th, 1890.]

I need not refer to the well-known and important observations of Nathorst, Williamson, Owen, Miller and James of Cincinnati, Zeiller, Salter, and others on this subject, or of the able defence of the Algoid nature of some of them by Delgado, Saporta, and Crié. My object has been merely to give some clear and instructive examples which may tend to settle some of the points which have been in dispute.

The whole of the specimens referred to in the above paper are, with many others, in the Peter-Redpath Museum of McGill University. A number of them are large slabs, of which only a portion or a reduction could be given in the photographs.

§ IX. Notes.—I append, as an interesting impression, Photograph xx. (not figured), which shows part of a rain-marked surface from the Devonian of Gaspé, which has subsequently curled up and cracked in drying, in the manner which may often be seen in modern pools, when dried up.

I should perhaps add that, after many unsuccessful attempts, I have been able to find vegetable structure on only one specimen of any of the so-called Algæ of the Lower Palæozoic rocks. This is a flattened cylinder referable to the genus *Palæophycus*, from the Trenton Limestone. Its structure is somewhat imperfect, but shows long sinuous tubes like those in the stems of some Laminariæ. All the other Algæ of these older formations that I have met with are either reduced to carbonaceous films destitute of structure or are mere impressions without organic matter.

[Since the above paper was written Mr. G. F. Matthew has given (Amer. Journ. Science, ser. 3, vol. xxxix. 1890, p. 145) a notice of some worm-burrows, from the Lower Cambrian of New Brunswick, which he regards as similar to those described by Torell from the Eophyton- and Fucoid-sandstones of Sweden, and certain remarkable markings from the still older Animikie formation of Lake Superior. These last are of two kinds, curved divergent marks (*Taonichnites*), and straight striæ, crossing at acute angles (*Ctenichnites*). The specimens, from the Cambrian of Canada, referred to *Eophyton* seem, so far as known, to be of the nature of the straight markings which I have elsewhere named *Rhabdichnites*.—J. W. D., *September* 9th, 1890.]

[Note.—Lesley ('Dictionary of Fossils,' p. 1195) refers to a specimen, found by Walcott, showing the shell of a large Mollusk at the end of a track resembling *Rusichnites*. Billings and Nathorst have shown that some transversely-wrinkled tracks may have been produced by the foot of Gastropods.—J. W. D., *October* 2nd, 1890.]

Discussion.

Prof. Hughes would like to see a combination of geologists and zoologists discussing each one of the various marks. He had paid most attention to *Cruziana*, and was glad to find that the Author agreed with him that it was impossible to refer it to any surface-track, and difficult to explain it on the hypothesis of its representing the form of any soft-bodied animal such as *Nereis*.

Dr. Hinde observed that for many years the origin of these marks had been discussed. He thought that most of them were the tracks and filled-up burrows of marine organisms. The fact that no carbonaceous matter had been found with these forms in the different countries where they occurred was opposed to the theory of their plant-origin. On the other hand, he had obtained undoubted Annelid remains from some of the very beds containing these markings.

Geological Sciences

[*From the* Quarterly Journal *of the* Geological Society *for November* 1890, Vol. xlvi.]

On Burrows *and* Tracks *of* Invertebrate Animals *in* Palæozoic Rocks, *and other* Markings.

By Sir J. William Dawson, LL.D., F.R.S., F.G.S.

Contents.

§ I. Introduction.

The present paper is intended to contribute some recently acquired facts to the solution of questions connected with these often problematical markings; and it will consist rather of short notes, illustrated by photographs, than of a connected discussion of the subject. I propose to notice the nature of certain markings sometimes referred to plants, under the name of *Bilobites*,—to the true nature of the *Scolithus canadensis* of the Potsdam Sandstone,—to certain tubes similar to those of modern *Sabellæ*,—to cylindrical concretions resembling trunks of trees,—and to imitative markings, and peculiar trails of doubtful origin.

§ II. Bilobites, Rusichnites, Protichnites, and Climactichnites. (Figs. 1 to 6.)

The name *Bilobites*, proposed by Dekay in 1823, was, as Newberry has shown,* originally applied not to objects of this kind, but to casts of certain bivalve shells. It was therefore dropped in America; but it has been revived and has gained currency in Europe †, as a term including various forms of markings referred to different genera. The dominant characters are a band, or an oval mass, with a median longitudinal furrow or ridge, and marked with transverse or oblique furrows or striæ, and with or without a marginal ridge.

The writer was enabled to show in 1864 ‡ that one of the most remarkable of these impressions, *Rusophycus grenvillensis* of Billings, and *Cruziana*-like markings associated with it, were really

* 'Science,' vol. v. no. 124, 1885, p. 508.

† In Senhor J. F. N. Delgado's 'Etude sur les Bilobites et autres Fossiles des Quartzites de la Base du Système Silurique du Portugal,' 4to, Lisbon, 1886, and the 'Supplément,' 1888, numerous bibliographic references to other authors treating of these and some allied fossils are given in full.

‡ 'Canadian Naturalist,' n. s. vol. i. pp. 363, 458.

burrows and tracks of marine animals, probably Crustaceans. He arrived at this conclusion by a careful study of the impressions made by the recent *Limulus polyphemus* on muddy and sandy bottoms, and by the application of these results to the explanation of a very fine exposure of the impressions above-named in the works undertaken for the enlargement of the Grenville Canal, on the Ottawa River. In this paper, descriptive of the facts observed at Grenville, it was proposed to substitute the generic name *Rusichnites* for *Rusophycus* or *Rysophycus*, and it was pointed out that the so-called fucoids of the genus *Arthrophycus* were probably of like nature, and might be placed in the same category with the impressions described by Logan as *Climactichnites* from the Potsdam-Sandstone *. These observations were supposed to have conclusively settled the question as to the nature of all the *Bilobites*; but little attention seems to have been given to them by European Palæontologists. Nathorst has, however, arrived at similar results, in a somewhat similar manner, by comparison with modern impressions †; and Williamson has described as casts of animal-tracks markings of this nature from the Yoredale rocks ‡. Bureau has also adduced some striking evidences in favour of the theory that some at least of the *Bilobites* are the work of Phyllopod Crustaceans §. Saporta, Delgado, and others still regard the *Bilobites* as true Algæ, and Schimper describes one form as a plant, under the name *Crossochorda*. In so far as American examples are concerned, it may be considered as settled that they may best be explained in the way above indicated. The following genera may be included in this general statement:—

Rusichnites = Rusophycus, *Hall.*
Arthrichnites = Arthrophycus, *Harlan.*
Cruziana, *D'Orbigny.*
Climactichnites, *Logan.*
Fræna, *Rouault.*
Crossochorda, *Schimper* (in part).

These impressions pass into *Protichnites* of Owen through such forms as *P. Davisi* of Williamson ‖, and the *Sœrichnites* of Billings¶ and *Diplichnites* of the author **. They are connected with the undoubted worm-tracks of the genus *Nereites* by specimens of *Arthrichnites*, of which I have several in my collection, and in

* Canad. Nat. Geol. vol. v. p. 279.

† Kongl. Svenska Vetenskaps-Akad. Handlingar, vol. xviii. No. 7, 1881; eleven plates, 104 pages, including an Abridgment in French. The List of Books and Memoirs treating of Trails and Tracks, from 1823 to 1881, occupies six of the quarto pages in this work. Also 'Nouvelles Observations sur les Traces des Animaux;' Stockholm, 1886.

‡ Mem. Manchester Lit. & Phil. Soc. 3rd series, vol. x. 1885, pp. 19–29, 3 plates.

§ Comptes-rendus, vol. 104, 14 Février et 4 Juillet, 1887, page 7 of the author's reprint.

‖ *Op. cit.* pl. i. fig. 4. ¶ Catal. Sil. Foss. Anticosti, 1866, p. 73.

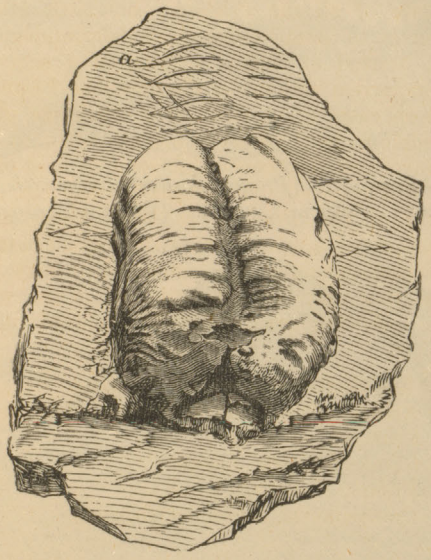
** Amer. Journ. Sci. ser. 3, vol. v. 1873, p. 19, and p. 23, fig. 3.

which the central furrow becomes obsolete, and by the genus *Gyrichnites* of Whiteaves, and other forms destitute of a median groove *.

They cannot be sharply divided into genera or species, because of their variability in passing over different kinds of bottom, and of the changes which occur in consequence of the various modes of progression employed by the animals.

Fig. 1 represents a typical specimen of *Rusichnites*, from my paper

Fig. 1.—*Rusichnites grenvillensis.* The cast of a Crustacean Burrow, with part of a trail leading to it, or from it, at *a*. Cambro-Silurian ; Grenville, Canada.



of 1864, and shows traces of the trail leading to or from the cast of the deep burrow or excavation. Fig. 2, *Rusichnites acadicus*, from the Carboniferous, I now regard as a result of successive strokes of a crustacean tail, with marks of the carapace and limbs. The specimen represented in fig. 3, which is from the Clinton Formation of Canada (and from the collection of Lieut.-Col. Grant, of Hamilton, Ontario), illustrates the probable origin of these markings, but also suggests the idea of some of them having been the trails or castings of worms rather than marks of crustaceans. It is evident indeed that these markings are closely connected with those named *Nereites* by Hall, and of which he has figured several kinds from the Clinton formation, ascribing them to Molluscs. Similar objects have been named *Psammichnites* by Torell, and are supposed by him to resemble

* Trans. Roy. Soc. Canada, vol. i. 1883 ; Section iv. 1882, pp. 109-111.

Fig. 2.—*Rusichnites acadicus.* A Crustacean Track, showing the marks of the edge of the carapace. Carboniferous; Cape Breton.

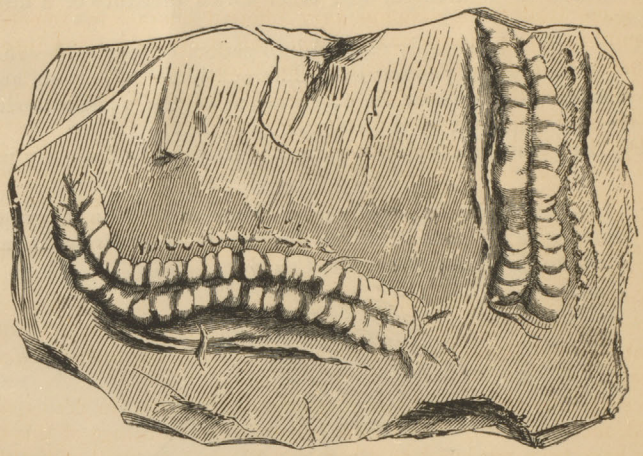


Fig. 3.—*Rusichnites* (*Psammichnites*) *clintonensis*, sp. nov. Silurian of Ontario, Canada. (From a Photograph.)

castings of the Lobworm *. I am indebted to Lieut.-Col. Grant for an extensive series of these markings, on which it can be seen that the same trail often assumes very different characters, sometimes resembling *Crossochorda* or *Cruziana*, and at others passing into the ordinary *Nereites* or even into a simple trail.

The *Protichnites* † of the Potsdam Sandstone are indubitable tracks of Crustaceans; yet it is possible, as I have shown in the case of *Limulus*, that the same animals which produced *Protichnites* may also have been the authors of the transversely ridged *Climactichnites* so often associated with them (figs. 4 and 5). It is also to be observed that such forms as my *Protichnites acadicus* ‡ or the *Pr. scoticus* of Salter § form connecting links between this kind of track and *Cruziana*.

To the same category may be referred the trails with wave-like transverse markings and no central line, found both in the Upper Cambrian and Devonian, and which Whiteaves has named *Gyrichnites*‖.

I copy here the remarks on *Rusophycus* (*Bilobites*) in my paper of 1873, merely adding that I now believe some markings of this kind may have been produced by Chætopod Worms, as well as by Phyllopods :—

"In a paper published in the 'Canadian Naturalist,' 1864, I showed that the singular bilobate markings with transverse striæ, named *Rusophycus* by Hall, and found in the Chazy of Canada and the Clinton group of New York, are really casts of burrows connected with footprints, consisting of a double series of transverse markings, and that a comparison of them with the trails and burrows of *Limulus* justified the conclusion that they were produced by Trilobites. I proposed for these, and for similar impressions of small size found in the Carboniferous, the name given above. The Carboniferous examples, I supposed, might have been produced by the species of *Phillipsia* found in these beds. A specimen recently obtained from Horton shows this kind of impression passing in places into a kind of *Protichnites*, as if the creature possessed walking feet as well as the lamellate swimming feet which it ordinarily used."

I can scarcely doubt that the *Cruziana semiplicata* of Salter, and *C. similis* of Billings from the Primordial of Newfoundland, must have been produced by Crustaceans not dissimilar from those to which *Rusichnites* belongs.

To *Rusichnites*, rather than to *Protichnites*, ought perhaps to be

* Lunds Univ. Årsskrift, vol. vi. p. 31, 1869.

† Logan and Owen, Quart. Journ. Geol. Soc. vol. viii. 1852, pp. 199–225. In the 'Geologist,' vol. v. 1862, pp. 128–139, and pp. 454–456, the probability of *Climactichnites* having been the infallen gallery-tracks made by *Paradoxides* burrowing in the sand of the old sea, like *Sulcator* and *Kroyera* (as shown by Albany Hancock) burrow in the present sea-sands, has been suggested. A similar explanation was given in Prof. Dana's 'Manual of Geology,' 1863, p. 189. This does not, however, seem applicable to the Canadian specimens. See figs. 4 & 5, and further on.

‡ Amer. Journ. Sci. ser. 3, vol. v. 1873, pp. 17,18, 23, fig. 2.

§ Quart. Journ. Geol. Soc. vol. xii. p. 243, fig. 2.

‖ 'Trans. Roy. Soc. Canada,' *loc. cit.*

Fig. 4.—*Climactichnites* and *Protichnites*, associated on the same slab. From the Potsdam Sandstone of Ontario (in the Peter-Redpath Museum). About $\frac{1}{12}$ of natural size. The large slab is the *overlying* impression ; the small one, placed below, is the *underlying* surface. (From a Photograph.)

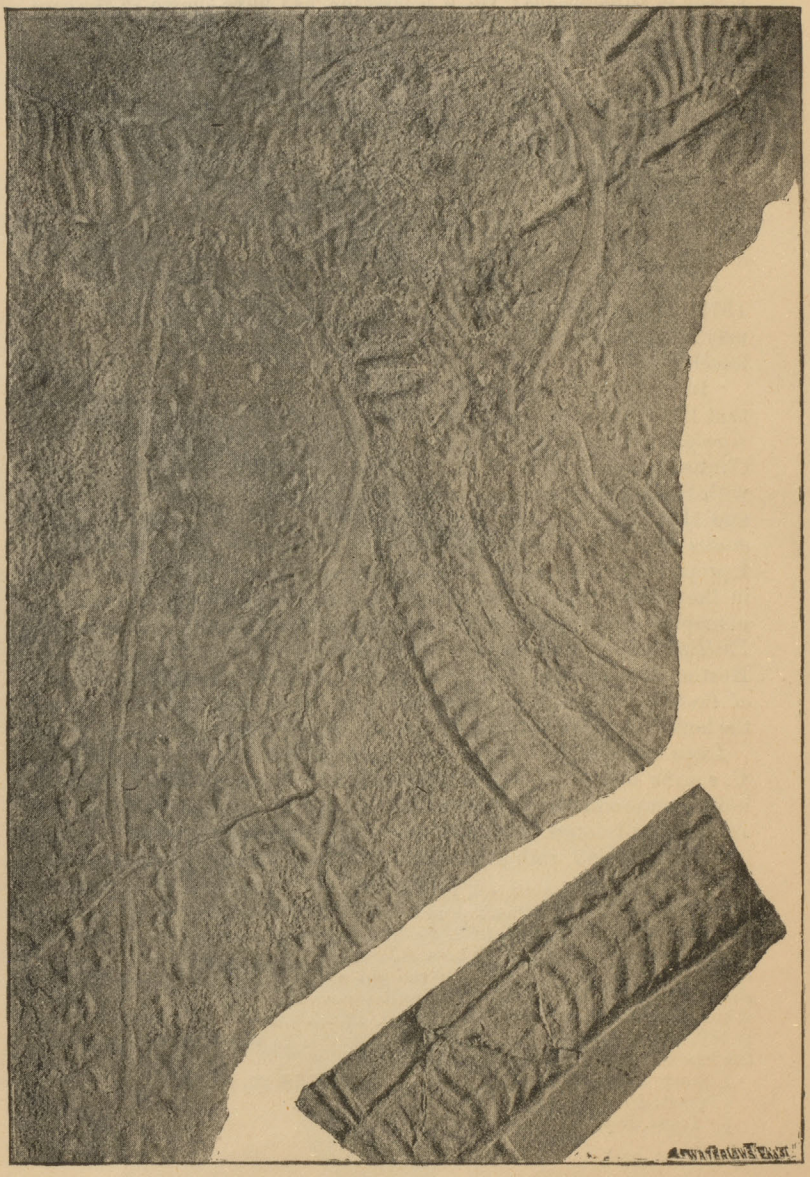
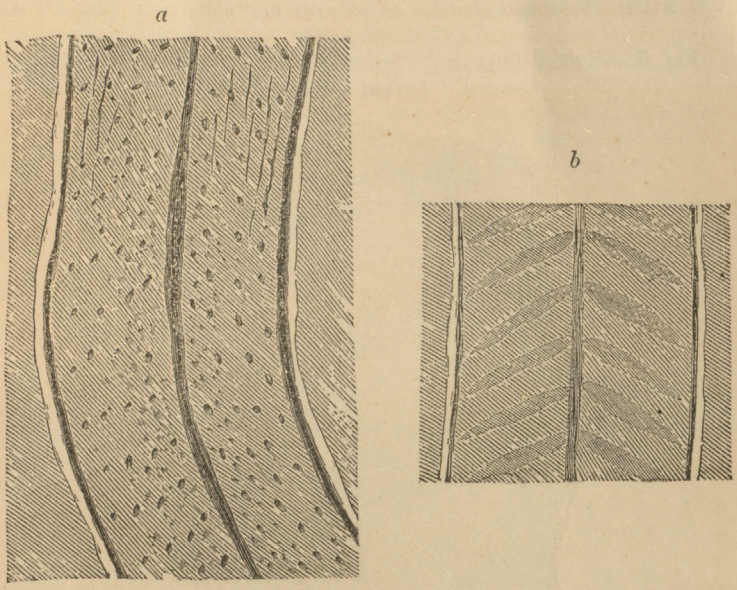


Fig. 5.—*a*, Protichnite-like ; *b*, Climactichnite-like Trails of *Limulus polyphemus*. Modern. Coast of Maine.



referred certain transverse linear impressions with a broad central groove from the Lower Carboniferous of Horton, which occur at that place under different modifications, and sometimes seem to change into light scratches, or touches of feet employed in swimming, or end abruptly, as if the animal had suddenly risen from the bottom.

Nathorst * and Bureau have further shown that impressions similar to *Bilobites* may be produced by the successive strokes of the tail of certain Crustaceans (*Crangon* and *Palæmon*). From all the phenomena attending the Potsdam *Climactichnites*, I am now inclined to regard them as of this nature, and as implying the existence of a large Crustacean with a truncated tail divided into two movable lobes. This would account for the ridge sometimes dividing the furrows and transverse ridges, and for its change of position from side to side of the mesial line,—also for the interrupted ridges on each side of the trail, which would be the natural result of the successive strokes of a flat organ,—and for the appearances presented when the tracks turn abruptly † (see fig. 4).

There is confessedly some difficulty in separating the marks known as *Phymatoderma* from Fucoids allied to *Caulerpa*, and even from

* Trans. Roy. Acad. Sweden, vol. xviii. no. 7, 1881.

† "Impressions of Aquatic Animals," 'Amer. Journ. Sci.' ser. 3, vol. v. 1873, p. 16.

stems of the coniferous genus *Brachyphyllum*; but Zeiller has recently described a roofed tunnel or burrow made by the mole-cricket, which completely reproduces some of the forms known under the name *Phymatoderma*.* I have in my collection (fig. 6) a

Fig. 6.—Roofed Burrow: *Phymatoderma*. Silurian; Ontario, Canada. (From a Photograph.)

specimen, collected by Col. Grant in the Clinton formation, which shows that some Silurian animal, possibly a Crustacean, made covered burrows of this kind.

§ III. Scolithus, &c. (Figs. 7 to 10.)

This genus, proposed by Haldimand as early as 1840, though the name would indicate that it refers to a worm, was originally placed with Fucoids; and both Hall and Billings regarded the cylindrical cavities, designated by the title, as representing "stems." No evidence, however, has been found of any organic matter in connection with *Scolithus*; the tubes being usually filled with a sandy argillaceous or calcareous material, which weathers out of the hard matrix, leaving cylindrical holes.

* Bull. Soc. géol. France, sér. 3, vol. xii. 1884, pp. 676–680.

Two species have been recognized in the Potsdam Sandstone of Canada and the United States, *Scolithus linearis* of Hall and *Sc. canadensis* of Billings. The former is usually straight, at right angles to the bedding, and smooth, or with obscure striation. The latter is rather smaller, tortuous, and unequal in diameter, sometimes branching and curving, and occasionally showing slight transverse ridges on the sides of the cylinders.

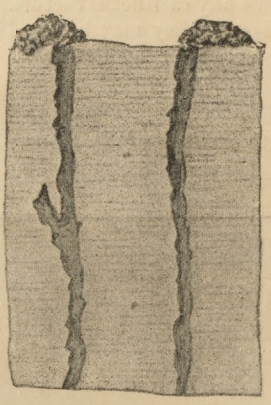
The latter species is very abundant in the Potsdam of St. Anne's on the Island of Montreal, where many varieties can be collected; but none of them shows any distinct structure. So far as indicated by the ordinary specimens, they may be moulds left by the decay of plants, sponges, or corals, or by the stems of *Lingulæ*, or the burrows of worms.

Fig. 7.—Slab with castings of *Scolithus*. Perth, Ontario.
(From a Photograph.)

Their true nature is made evident by a fine slab kindly presented to the Peter-Redpath Museum by Mr. W. J. Morris, of Perth, Ontario. A portion of the upper surface of this slab is represented in fig. 7, which shows rounded pellets and ridges of hardened sand, very

similar to those ejected by many modern worms from their burrows. From these the tubes of *Scolithus* descend into the sandstone in the manner represented in fig. 8. It is, I think, quite evident that this variety of *Scolithus* represents burrows with castings at their entrances; and, since it is referable to *Sc. canadensis*, I have no hesitation in affirming that this interesting specimen indicates that

Fig. 8.—Sectional view of *Scolithus*, showing castings at the orifices. Perth, Ontario.



that species at least must be regarded as a worm-burrow. From the forms of these burrows it is not improbable that they may have been lined with a fine membrane sufficient to protect the body of the animal from the roughness of the sand, and that this lining may have aided in preserving their forms.

It is to be observed with reference to burrows of this kind, that under different circumstances their orifices may present very different appearances. Where the castings from them have been removed by a rapid current, they may have merely a simple opening at the summit. Where the animal has moved inward and outward, enlarging the opening, they may be funnel-shaped at top, like the burrows to which the term *Monocraterion* (Torell) has been applied; and, where the worm has made grooves radiating from the orifice, forms similar to *Scotolithus mirabilis* of Linnarsson *, or the forms which have been named *Pyrophyllites* and *Asterophycus*, may have been produced. I do not maintain that the forms indicated by the above names are identical with *Scolithus canadensis*, but I have seen in connection with that species appearances resembling these forms. Fig. 9 shows a form of this kind; but it is from a higher horizon, the Clinton, from which formation I have also funnel-topped burrows, like those of the Cambrian *Monocraterion*.

The singular radiating markings, from the Cambrian of Nova Scotia, which I have described as *Astropolithon Hindii*, and which

* Trans. R. Swed. Acad. Sci. vol. ix. 1871, p. 18, pl. v. figs. 21, 22.

Fig. 9.—*Radiating Burrow.* Silurian ; Ontario, Canada.
(From a Photograph.)

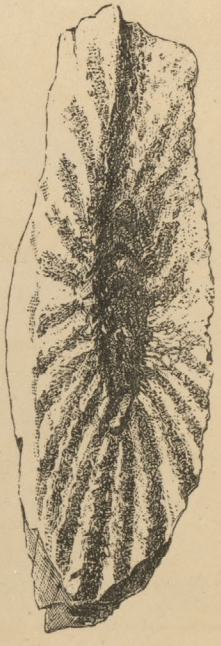
also occur in the Quebec Group at Metis, Canada, may possibly have the character of mouths of large burrows with radiating trails, though the radiating marks in this case seem to be of the nature of vertical plates, rather than of grooves (see fig. 10).

§ IV. Sabellarites, gen. nov. (Figs. 11 & 12.)

The modern genus *Terebella*, which constructs tubes of grains of sand and fragments of shells attached to a membranous lining, has been recognized by its tubes as low as the Lias (*T. capilloides*, Goldf.), and I have ascertained the existence of similar tubes as low as the Siluro-Cambrian ; though, as the tubes do not necessarily indicate the precise affinities of the animal, I prefer to designate them by the name above given, and to define this as indicating elongated tubes composed of grains of sand and calcareous organic fragments,

associated with carbonaceous flocculent matter, indicating a horny or membranous sheath. I have long suspected the existence of such tubes, and their connection with many of the cylindrical bodies often confounded with fucoids of the genera *Palæophycus* and *Buthotrephis*, but have only recently been able actually to demonstrate the fact.

Fig. 10.—*Astropolithon Hindii*, a burrow or organism from the Lower Cambrian of Nova Scotia. ('Acad. Geol.' 3rd ed. Suppl. 1878, p. 83.)



In the Black-River Limestone (Trenton group of the Siluro-Cambrian) at Pointe Claire, on the St. Lawrence, near Montreal, certain layers of grey limestone contain numerous dark-coloured, cylindrical, tortuous bodies, from $\frac{1}{10}$th to $\frac{1}{8}$th of an inch in diameter. When broken across, they are seen to be filled with crystalline calcite, as if they had been tubes; and, when thin slices are prepared for the microscope, the character of their walls, as composed of fragments of stone and broken shells &c., cemented by an organic material, now carbonised, becomes apparent. Figs. 11 and 12 show the appearance of the tubes on the weathered surfaces, and in section. The species may be thus described:—

The tubes are 1 to 3 millimètres in external diameter, and 3 centimètres or more in length, tortuous, irregular as if sometimes compressed, and sometimes in groups of two or more attached together. This would show a fixed or sessile condition as in *Sabellaria* or *Sabella*, rather than freedom, as in the *Terebellidæ*.

Fig. 11.—*a*, *b*, *c*, *Sabellarites trentonensis*. *a*. On a weathered surface; nat. size. *b* and *c*, enlarged. Black-river Limestone; Pointe Claire, near Montreal.

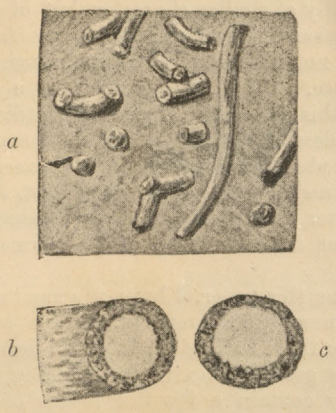
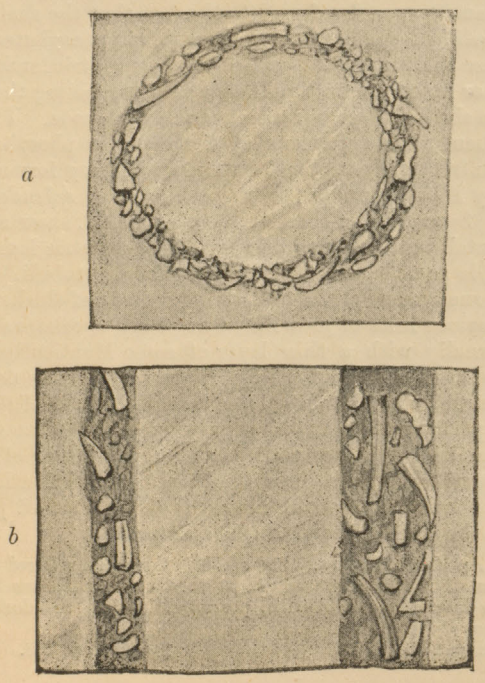


Fig. 12.—*a*, *b*, Transverse and Longitudinal Sections of *Sabellarites*. (Enlarged.)



The wall of the tube is somewhat thick and composed of fragmental matter, cemented by a dark-coloured organic substance. It is to be observed that in the case of tubes, as distinguished from mere burrows, like *Scolithus*, when two or more are attached together an appearance of branching results.

Tubes apparently of similar character, but of considerably larger size, occur in the same formation; and many obscure cylindrical or flattened bodies, not distinguished from branches of Algæ, may be of the same nature. I would also refer to a similar origin, and provisionally to this genus, the curious primordial burrows from the Hastings group described in the Quarterly Journal of this Society * in 1866, and the phosphatic tubes from the limestone of the Quebec group at Kamouraska, described in the Quart. Journ. Geol. Soc. in 1876†. The latter, however, I fancy are composed of excrementitious matter, or débris of the food of worms feeding on Linguloid shell-fish.

While preparing this paper, I have re-examined these tubes, and have had some new slices prepared. These confirm my previous statements. The thick walls of the tubes are destitute of lamination, and have a finely granular texture, resembling that of the paste of coprolites. They contain a few fine grains of sand, and minute fragments of shells and of carbonaceous fibres. The whole seems to indicate that they are formed, as already stated, of the phosphatic dejections of animals subsisting on *Lingulæ*, *Trilobites*, *Hyolithes*, and other creatures having coverings of calcium-phosphate.

In the same paper I referred to the fact that the shells of *Hyolithes* ‡ [*Hyolithellus*, and *Salterella*] are rich in phosphates, and that some of these shells are thick-walled with concentric lamination and with tubes or pores penetrating their walls, suggesting the idea that they may be shells of Worms rather than of Pteropods. I have since compared them with specimens of the singular phosphatic tubes found not infrequently in the Trenton and Chazy formations, and described by Billings under the name *Serpulites splendens* and *S. dissolutus*. Specimens of these tubes, when sliced, show a structure not fragmental, but composed of very fine concentric laminæ, with indications, in some specimens, of minute sinuous tubuli. They are smooth internally, and without show indications of thickened ridges and of transverse lines of growth. One of my specimens has been coated externally with a thin layer of some Monticuliporid coral. If these are worm-shells, of which there seems little doubt, they suggest affinities with the phosphatic *Hyolithellus* and *Salterella*.

It may, perhaps, be useful to suggest provisional names for the arenaceous and phosphatic worm-tubes resembling those of *Sabellaria* and here described. Those from the Black-River formation may be named *Sabellarites trentonensis*; and the thick-walled phosphatic tubes, from the Quebec group, *S. phosphaticus*.

* Vol. xxii. p. 608. In the paper of 1866 these are referred to as from the Laurentian of Madoc, Ontario. Since then these beds have been recognized as being later than Laurentian, possibly Huronian, and designated the "Hastings group."

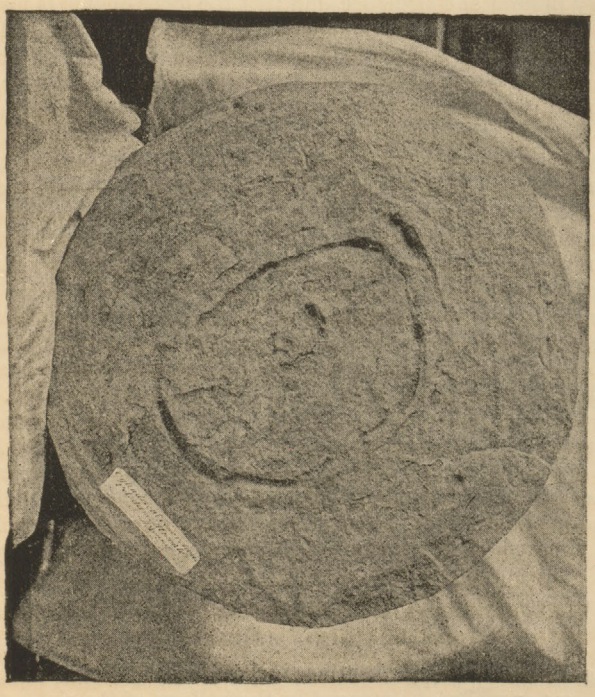
† Vol. xxxii. p. 286.

‡ *Op. cit.* p. 288.

§ V. Trunk-like Concretions in the Potsdam Sandstone. (Fig. 13.)

Many years ago specimens were obtained from the Potsdam Sandstone of Ontario, by the late Sir William Logan, which presented the aspect of large cylindrical trunks, a foot or more in diameter. They were casts in sandstone, without any external bark or organic matter, though showing obscure concentric lines on the ends. No opinion was, I believe, hazarded at that time respecting their origin; and more recently fine specimens have been collected by Dr. Selwyn on the bank of the Rideau Canal near Kingston; and Mr. A. Young, a student of McGill University, obtained others at Almonte, which he presented to the Peter-Redpath Museum. One of these is represented in fig. 13.

Fig. 13.—*Trunk-like Concretion.* Potsdam Sandstone; Almonte, Canada. $\frac{1}{6}$ nat. size. (From a Photograph.)



An incidental light seems to have been thrown upon their nature by the study of certain recent concretions, now forming in the alluvial clay of the St. Lawrence, by Rev. Prof. Kavanagh, of Montreal. These are small cylindrical bodies with a minute per-

foration in the centre, often containing a little vegetable matter. They were thus described * :—

"These little bodies are evidently clay concretions formed around vegetable fibres, and hardened by a small percentage of calcium carbonate, since when treated with hydrochloric acid they effervesce feebly and become disintegrated. They probably originate in the molecular aggregation of the calcareous matter in the clay around any foreign body included in it. They are about half-an-inch in diameter, and the largest may have been two inches in length; with rounded ends. When broken, they show a small central canal containing a little sand and strips of epidermal tissue, the remains of a root or stem. One shows three branches, apparently proceeding in a verticillate manner from a central stem. In the centre, the light reddish-brown colour of the clay has assumed a greenish hue, owing to deoxidation of the peroxide of iron by decay of the vegetable nucleus."

On comparison of these recent concretions with the Potsdam cylinders, it becomes apparent that they resemble each other very closely in form and structure, and that the older cylinders may have been formed in a similar manner, though on a gigantic scale. In confirmation of this view, it may be mentioned that in the Pleistocene clays of Green's Creek, on the Ottawa, cylindrical concretions surround twigs of poplar, which have been imbedded in the clay, and that in the Permian Sandstones of Prince-Edward Island ferruginous matter has cemented the sand into cylindrical concretions around stems of Calamites. This view as to the origin of the Potsdam cylinders is further confirmed by the rounded ends of some of them, and by the conformity of the internal concentric structure to this rounding. One of the smaller specimens in the Peter-Redpath Museum shows this peculiarity very well.

In the case of the Potsdam concretions, the nucleus of the concretion must have been an erect stem of some kind, possibly a *Chorda*-like *Alga*. So far as appears, this central stem must have been very slender, but no distinct traces of it have yet been observed. Perhaps the most remarkable fact in the case is that these cylindrical bodies are sometimes several feet in length, and pass through more than one bed of the sandstone. Another peculiarity is the presence is some of them of irregularly rounded cavities, apparently indicating the presence of bodies either concretionary or organic which have been removed by solution or decay. These, however, are very rare.

§ VI. Combinations of Worm-tracks with Ripple-marks and Shrinkage-cracks. (Figs. 14 & 15.)

Fig. 14 shows a rippled surface in Potsdam Sandstone with marks of worms or molluscs, arranged in the hollows of the ripples. The marks are simple trails, of that curious circular or chain-like form sometimes observed, and seem to have been made by animals creeping in the furrows between the ridges of the ripple-marks.

* 'Canadian Record of Science,' vol. iii. No. 5, January 1889, pp. 292–294.

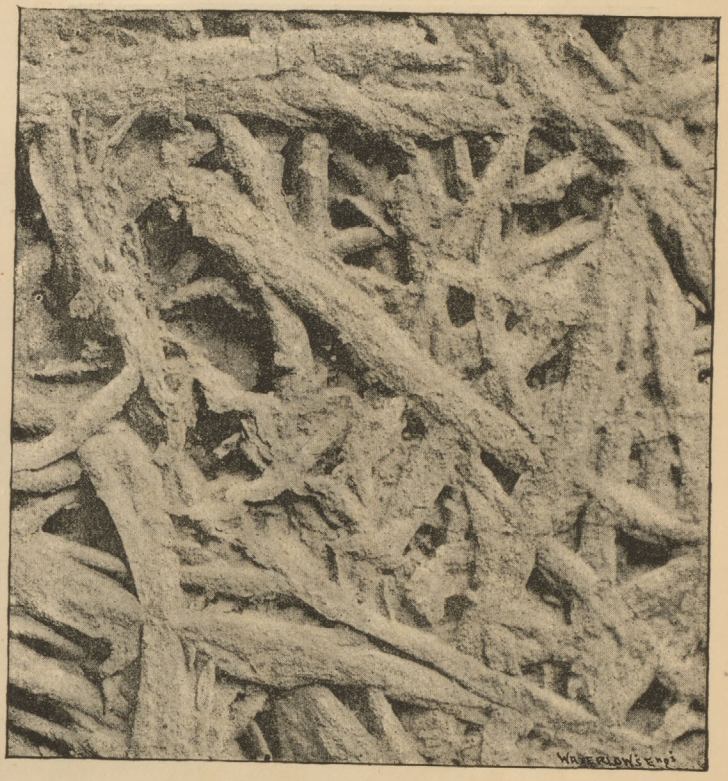
Photograph No. XI. (not figured) shows another combination, where numerous trails formed in soft sediment have been affected by shrinkage-cracks, produced by the drying of the mass, in such a manner as to present a very complicated appearance.

Fig. 14.—*Combination of Worm-trails and Ripple-marks.* Potsdam Sandstone; Canada. $\frac{1}{3}$ nat. size. (From a Photograph.)

Still another appearance which may be placed under this head is that in fig. 15, which represents part of the surface of a large slab of Calciferous Sandstone from St. Anne's. At first sight it seems to be covered with a network of shrinkage-cracks, but on closer inspection these are seen to be cylindrical worm-tracks or burrows planed off and flattened on one side, as if a slab covered with casts of worm-tracks had been rubbed or ground down till the originally rounded sides of all the more prominent were flattened. The only way in which it seems possible to account for such an appearance is to suppose that the tracks were partly filled with mud incapable of hardening into stone, and then completely filled and

covered with a bed of sand, hardened afterwards into rock. The effect would be that, on weathering, all the prominent parts filled with mud would disappear, leaving the slab in its present state.

Fig. 15.—*Worm-burrows seen in section, owing to the manner of preservation and weathering.* Calciferous Sandstone; St. Anne's. (From a Photograph.)



All of these tracks or burrows are of the plain cylindrical forms to which the terms *Planolites*, Nicholson *, and *Arenicolites*, Salter †, have been applied, and which differ from *Scolithus* only in their more tortuous character, and in their usually being casts of mere trails on the surfaces of beds, rather than burrows or tubes penetrating them. I cannot doubt the origin of these markings, if for no other reason, on account of their covering such great surfaces of strata in a uniform manner.

* 'Proceed. Roy. Soc.' vol. xxi. 1873, p. 289; 'Manual Palæont.' edit. 2 vol. i. p. 320.

† 'Quart. Journ. Geol. Soc.' vol. xiii. 1857, p. 204.

§ VII. Branching Tracks. (Fig. 9, page 605.)

It is very puzzling to the Ichnologist to find so many impressions which he would regard as of animal origin branching in a manner to simulate plants. The distinction, however, between branching plants and branching tracks is usually sufficiently obvious to an experienced eye. The latter are generally of the nature of more or less cylindrical bodies, diverging or radiating from a common centre; while the former display either alternate ramification or bifurcation. As examples I may refer to Photograph No. xiii. (not figured) of *Buthotrephis gracilis*, and *B. Grantii*, figs. 16 and 17, true Fucoids, in

Fig. 16.—*Buthotrephis Grantii*. A true Fucoid, from the Silurian of Canada.

comparison with fig. 9 (above referred to), of radiating Annelid marks, or Photograph No. xv. (not figured), which represents a *Licrophycus*, probably a burrow with diverging tracks. Simple and branching trails of these kinds cover large surfaces of the Cal-

ciferous formation at St. Anne's, and are similar to markings of this kind which I have described from the Lower Carboniferous of Nova Scotia *.

Fig. 17.—*Buthotrephis Grantii.* A true Fucoid: carbonaceous. Niagara Formation. ½ nat. size. (From a Photograph.)

§ VIII. Rill-marks, as distinguished from Animal- or Plant-impressions. (Figs. 18 & 19.)

In my 'Acadian Geology' I have described the remarkable appearances simulating Algæ, or even gigantic trees, produced in the sloping banks of fine mud in the tidal channels of the Bay of Fundy. These are formed by minute rills, oozing from the wet sand or mud, and trickling in fine streams along the slimy surfaces, and uniting into larger and larger streams so as at length to produce the likeness of impressions of flattened trees, with large trunks and branches, dividing into twigs of extreme tenuity. Similar surfaces are often found in the Coal-formation, and sometimes on quite as large a scale as in modern tidal estuaries. Their forms and arrangement differ according to the slope and character of the sediment, and the amount of water it contains; but all show very delicate and often regular branching impressions. Figs. 18 and 19 represent two types of these in my collection from the Carboniferous of Nova Scotia, and

* 'Acadian Geology,' p. 256.

taken from surfaces unquestionably sculptured by water. A curious complication of such markings sometimes occurs when shrinkage-cracks, overflowed by a succeeding tide, have their edges sculptured by minute rill-marks. *Dictuolites Beckii*, of Hall*, is a remarkable example of this.

Fig. 18.—*Rill-mark.* Carboniferous; Nova Scotia. ½ nat. size. (From a Photograph.)

It would be invidious to refer to the numerous species of imaginary fossil plants that have been founded on such markings as those referred to above and shown by figs. 18 and 19. I may merely mention the genera *Dendrophycus*, *Delesserites*, *Vexillum*, *Aristo-*

* 'Palæontology of New York,' vol. ii. 1852, p. 6, pl. 2. fig. 1.

phycus, *Chloëphycus* *, *Tricophycus* of authors as examples of genera which contain, or consist of, examples of Rill-marks.

I may add that I have discussed other forms of such impressions in my papers on Footprints of *Limulus*, and on the genus *Rusichnites*, in the 'Canadian Naturalist,' and in that on "Impressions of Aquatic Animals in the Carboniferous Rocks"†. In my work, 'The Geological History of Plants', I have also endeavoured to state the criteria for

Fig. 19.—*Rill-mark*. Carboniferous; Nova Scotia. ½ nat. size. (From a Photograph.)

separating such markings from true Algæ, and have referred to instances in which, while, on the one hand, mere markings have been elevated into marine plants, on the other, true land plants, imperfectly preserved, have been degraded into Algæ. I may also state that in America the Clinton formation, intervening between the Medina Sandstone and the Niagara Limestone, and containing many thin-bedded arenaceous and argillaceous deposits, is remarkably rich in such impressions. Many of these have been figured by Prof. Hall ‡ and referred to worms, crustacea, and gastropods. In the vicinity of Hamilton, Ontario, large collections have been made by Lt.-Col. Grant, who has enriched the Peter-Redpath Museum of

* Miller now admits that this is not an *Alga*.

† Amer. Journ. Sci. ser. 3, vol. v. 1873, pp. 17, &c.

‡ 'Palæontology of New York', vol. ii. 1852.

McGill University with a very large and instructive series of slabs including a vast variety of forms, a few only of which have been noticed in this paper.

[I desire also to remark that the facts above detailed, together with the discoveries of Annelid-jaws by Hinde and others, show that the Marine Worms must have culminated, in regard to size, abundance, and range of organization, at a very early geological period.—*September* 9th, 1890.]

I need not refer to the well-known and important observations of Nathorst, Williamson, Owen, Miller and James of Cincinnati, Zeiller, Salter, and others on this subject, or of the able defence of the Algoid nature of some of them by Delgado, Saporta, and Crié. My object has been merely to give some clear and instructive examples which may tend to settle some of the points which have been in dispute.

The whole of the specimens referred to in the above paper are, with many others, in the Peter-Redpath Museum of McGill University. A number of them are large slabs, of which only a portion or a reduction could be given in the photographs.

§ IX. Notes.—I append, as an interesting impression, Photograph xx. (not figured), which shows part of a rain-marked surface from the Devonian of Gaspé, which has subsequently curled up and cracked in drying, in the manner which may often be seen in modern pools, when dried up.

I should perhaps add that, after many unsuccessful attempts, I have been able to find vegetable structure on only one specimen of any of the so-called Algæ of the Lower Palæozoic rocks. This is a flattened cylinder referable to the genus *Palæophycus*, from the Trenton Limestone. Its structure is somewhat imperfect, but shows long sinuous tubes like those in the stems of some Laminariæ. All the other Algæ of these older formations that I have met with are either reduced to carbonaceous films destitute of structure or are mere impressions without organic matter.

[Since the above paper was written Mr. G. F. Matthew has given (Amer. Journ. Science, ser. 3, vol. xxxix. 1890, p. 145) a notice of some worm-burrows, from the Lower Cambrian of New Brunswick, which he regards as similar to those described by Torell from the Eophyton- and Fucoid-sandstones of Sweden, and certain remarkable markings from the still older Animikie formation of Lake Superior. These last are of two kinds, curved divergent marks (*Taonichnites*), and straight striæ, crossing at acute angles (*Ctenichnites*). The specimens, from the Cambrian of Canada, referred to *Eophyton* seem, so far as known, to be of the nature of the straight markings which I have elsewhere named *Rhabdichnites*.—J. W. D., *September* 9th, 1890.]

[Note.—Lesley ('Dictionary of Fossils,' p. 1195) refers to a specimen, found by Walcott, showing the shell of a large Mollusk at the end of a track resembling *Rusichnites*. Billings and Nathorst have shown that some transversely-wrinkled tracks may have been produced by the foot of Gastropods.—J. W. D., *October* 2nd, 1890.]

Discussion.

Prof. Hughes would like to see a combination of geologists and zoologists discussing each one of the various marks. He had paid most attention to *Cruziana*, and was glad to find that the Author agreed with him that it was impossible to refer it to any surface-track, and difficult to explain it on the hypothesis of its representing the form of any soft-bodied animal such as *Nereis*.

Dr. Hinde observed that for many years the origin of these marks had been discussed. He thought that most of them were the tracks and filled-up burrows of marine organisms. The fact that no carbonaceous matter had been found with these forms in the different countries where they occurred was opposed to the theory of their plant-origin. On the other hand, he had obtained undoubted Annelid remains from some of the very beds containing these markings.