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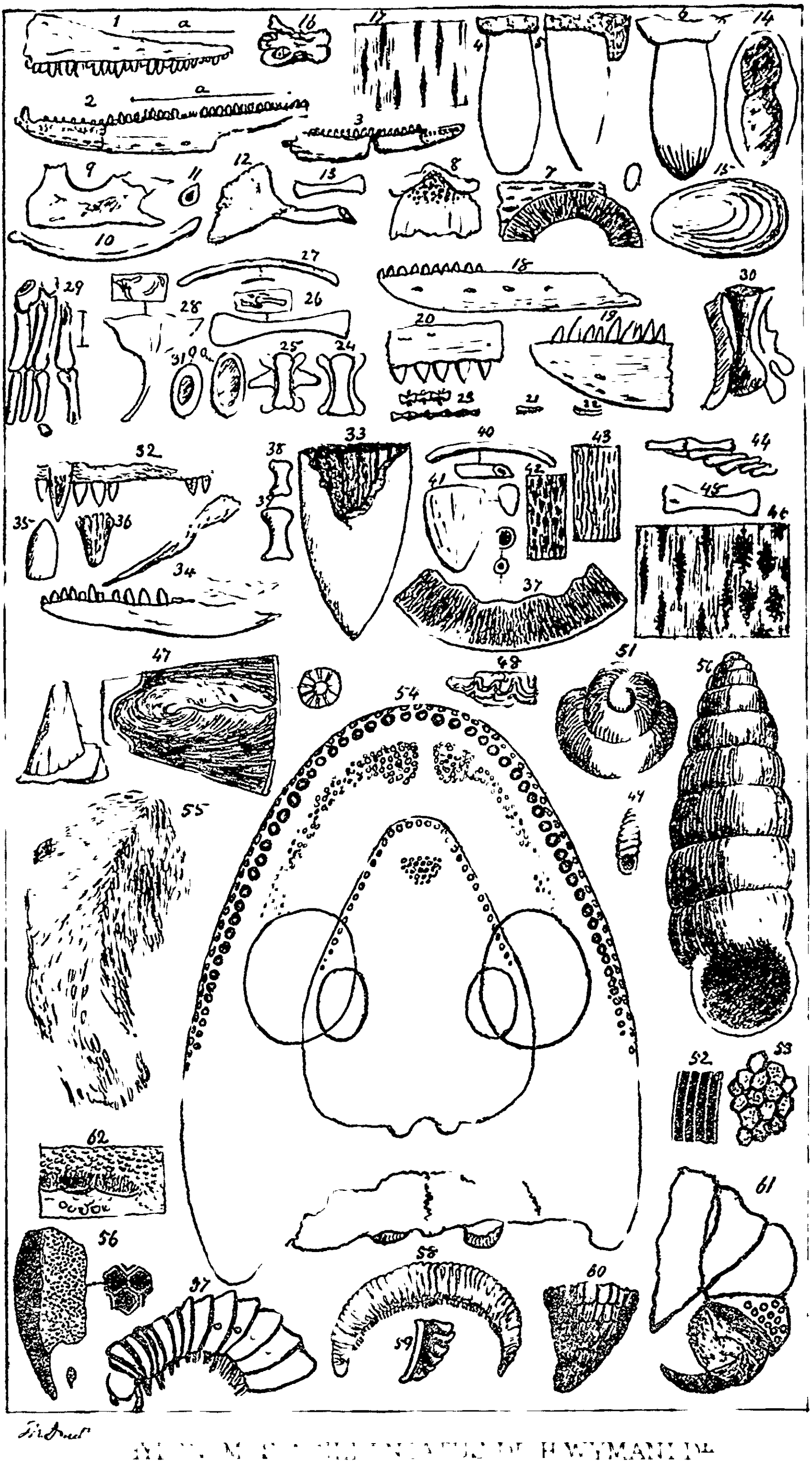

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THE

CANADIAN

NATURALIST AND GEOLOGIST.

VOL. VIII. AUGUST, 1863. No. 4.

ART. XIX—*Observations on the Geology of St. John County, New Brunswick.* By G. F. MATTHEW, Esq.

As some interest in the geology of this vicinity has been excited by the articles of Professor Dawson on the Upper Devonian Flora of eastern America, in the 'Canadian Naturalist' and 'Journal of the Geological Society,' a few remarks on the lithology, stratigraphy, and distribution of the older deposits of this neighbourhood may not be unacceptable.

In presenting them, however, I would claim a considerate criticism of the errors of one who is only an amateur of the science. I have confined my observations to a limited district, because it seemed to me that more permanent additions would thus be made to our knowledge of the geology of this part of the province than would be obtained by rambling over a larger field.

If I have given more prominence to details than may seem necessary, it is because I anticipate that the structure of the district which I propose to describe will explain that of the broken and hilly region east and northeast of St. John; and in a minor degree that to the westward.

The Devonian age of certain deposits in Gaspé, Nova Scotia, and Maine, had been recognized before the existence of strata of this age in New Brunswick was ascertained.

In various parts of the Bay of Fundy, red sandstones had been observed. Some were referred to the carboniferous period while others were found to be of still later origin. The deposits to which these remarks more particularly relate were all classed as Silurian.

In June, 1861, Dr. Dawson asserted the Devonian age of the sandstones of Perry in Eastern Maine, and, in consequence, those of St. Andrews, N. B., from certain fossil plants submitted to him for examination. Dr. Jackson had previously suggested this as the probable age of these rocks. The additional proofs accumulated by Prof. C. H. Hitchcock, have thrown much further light on their history, and their Devonian age is now clearly recognized.

Sandstones and conglomerates similar to these are known to occur at different points between Passamaquoddy Bay and the mouth of the river St. John, but their stratigraphy and position have not been determined.

On the eastern side of the harbour of St. John, and extending many miles along the coast, are extensive sedimentary deposits of great thickness, consisting almost entirely of fragmentary rocks, usually of coarse materials, varied by the addition of numerous beds of volcanic origin.

The lower members of this formation pass beneath the harbour and extend a few miles along the coast to the westward. It is in this direction that vegetable remains of the period when these rocks were formed, have been found in the greatest abundance and best state of preservation. The examination of these fossils has enabled Dr. Dawson to refer the strata in connection with them to the Chemung and Portage group of New York geologists.*

The sediments which underlie this formation are of equal or greater thickness; but few well-preserved fossils have been found in them, and these have not been studied; their age is therefore uncertain. The resemblance of some of these beds to the middle Devonian of New York has already been pointed out by the same observer.

To the eastward of St. John, Dr. Gesner (3rd Report, pp. 5-11) recognized two series of rocks, both of which he refers to the Silurian age, namely, an upper group of limestones, slates, and sandstones, containing remains of plants, mollusca, &c., and described

* The late Dr. Robb suggested this view of their age some years ago, although he had previously classed them as Lower Silurian (Johnston's Report on agricultural capabilities of N. B.). I am not aware that he published anything on the subject.

as shelving from the southern side of a ridge of syenite; and an older group, in which he includes the conglomerates, clay slates, sandstones, talcose slates and trap beds of Mispeck and Black River.

It will be one of my objects in the following remarks to show that the latter group is partly contemporaneous with, but for the most part less ancient than those to which Prof. Dawson's papers relate, and that Dr. Gesner's lower group is really to a great extent younger than his "upper series."

In the map and section accompanying these observations, I have endeavoured to show the distribution of the various groups of strata and the manner in which they have been tilted and folded.

Three principal folds in the strata are observable. The outer folds are anticlinal. Of these the northwestern skirts the south side of Kennebeckasis Bay, a lake-like expansion of the lower part of that river.

The southeastern runs parallel to the Bay of Fundy, and at a short distance from it. Its axis has a considerable inclination to the southwest, for the strata are found to bend over it (in ascending order) in that direction.

This peculiarity causes the deposit in the intermediate synclinal fold to expand to the westward and assume the appearance of a basin opening to the sea.

On examining the section it will be seen that of the two anticlinal folds there shown, the northern brings up beds of an age much greater than any which are seen in the southern, where the section crosses it.

Principal Dawson in his article on the Devonian Flora of Northeastern America,* published in the November number, 1862, of the Journal of the Geological Society, divides these pre-carboniferous beds into several groups, which with some modifications are given below. I have attached names to these groups (indicating the localities where the best and most typical exposures have been observed), which may serve the convenience of local observers,

* I was favoured with an opportunity to peruse the rough draft of a part of this article, and have in consequence to a great extent avoided details relative to the rocks in the city and its immediate vicinity. Had I seen it in print before the following remarks were written, I would have omitted more, and thus have made them more concise and less repetitious.

till the strata shall have been co-ordinated with deposits in regions better known.

PORTLAND SERIES (Nos. 7 and 8 of Dawson), thickness unknown. Granite and syenite, mica, schist and gneiss, limestones, clay slate, and sandstone. *Fossils*, fragments of plants in the upper beds.

COLDBROOK GROUP (No. 6 of Daw. in part), thickness 3,000 feet or more.

a. Greenish grey slate, stratification very obscure.

b. Bright red slaty conglomerate and dark red sandy shale.

c. Reddish conglomerate and grit, hard grey sandstone.

ST. JOHN GROUP (Nos. 5 and 6 in part of Daw.), thickness 3,000 feet or more; several zones of soft black and dark grey finely laminated shales alternating with zones of coarser grey slates containing numerous thin beds of fine grained sandstone. *Fossils*, lingula, a conchifer, annelides, coprolites.

BLOOMSBURY GROUP (No. 4 of Daw.), thickness 2500 feet.*

a. Basalt, amygdaloid, trap-ash, trap-ash slate; some beds of conglomerate. Thickness 2000 feet.

b. Fine grained red clay slate } Thickness 500 feet.
Reddish grey conglomerate }

LITTLE RIVER GROUP (Nos. 2 and 3 of Daw.), thickness 5200 feet.

a. "Dadoxylon sandstone," grey sandstone and grit with beds of dark grey shale, sometimes graphitic. Thickness 2800 ft.

Fossils. Numerous plants, several crustaceans, wings of insects. (C. F. Hartt.)

b. "Cordaite shales," grey, greenish, and red shales; reddish and grey sandstones, grits, and conglomerates, alternating with the shales. Thickness 2400 feet.

Fossils. Cordaites, Calamites, Stigmaria, Ferns, &c., for the most part identical with those of the preceding section.

(?) Granulite or granitic sandstone, micaceous slate, trap-ash.

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* Where groups appear on both sides of the synclinal fold the average thickness has been given. The measurements are to be regarded as merely approximate.

MISPECK GROUP (No. 1 of Daw.), thickness 1800 feet.

a. Coarse subangular conglomerate.

b. Fine-grained purple clay slate and grits surmounted by slate conglomerate.

(?) Red and green slate, basalt (stratified?).

Topography.—The indentations in the coast line of the Bay of Fundy at Port Simonds and St. John harbour, cut directly across all the groups of rocks mentioned above, except those of the Portland series, which are crossed by the outlet of the St. John river.

In the peninsula thus formed between Kennebeckasis Bay and the Bay of Fundy, two hilly ridges, one skirting the former and the other the latter Bay, with an intermediate valley, are the most prominent topographical features.

The valley in its upper part forms the basins of several lakes (Loch Lomond, &c.), and forks as it approaches the sea. One branch through which the Mispeck flows, ends at Port Simonds; the other extends to the harbour of St. John, and is drained by Little River. An intermediate ridge of land, which extends a short distance into the Bay between the two ports, consists principally of the highest group of Devonian rocks, (see Section).

The uneven and hilly tract on the northwestern side of the peninsula is underlaid by the Portland series and Coldbrook group, and its surface is diversified by numerous lakelets and ponds.

The shales of the St. John group, being much softer than the deposit on either side, have suffered more from denuding agencies. They lie at the bottom of that branch of the central valley which ends at the harbour. Advantage has been taken of this depression to supply the city with water from lakes in the vicinity of Loch Lomond.

The volcanic and sedimentary beds of the succeeding group stand out boldly above the general level of the country wherever they attain a considerable thickness, and usually bear a generous forest growth.

In passing from the wooded slopes underlaid by rocks of this group to the arenaceous beds which succeed them, a notable change is apparent in the vegetation. Barren wastes and bare ledges of sandstone take the place of thick woods wherever the influence of the subjacent rock is not modified by the presence of a foreign soil.

These open moorland tracts are known as "Barrens," and are covered with a profusion of heath-like plants.*

In the upper part of the Little River group, some improvement in the character of the soil is manifest, more especially where volcanic sediments prevail.

But the agricultural capabilities of the land underlaid by these beds, as well as those of the highest Devonian group, depends very much upon the presence or absence of diluvial accumulations. The soils of the peninsula are indeed not remarkable for fertility, except where sea or river alluvium has been formed, or carboniferous deposits prevail. Large tracts are entirely barren and unproductive.

Portland Series.—The intricate structure and extensive metamorphism of these older beds renders their examination difficult and perplexing. They are introduced here principally on account of their connection with later deposits. Their general appearance has been so well described by Dr. Dawson, that it is only necessary to mention some peculiarities which did not come beneath his notice. Beside the syenitic gneiss observed by him, there are masses of syenite and granite in which no traces of stratification are discernible; also beds of mica schist and gneiss conglomerate. The upper part of the series is mostly calcareous, consisting of limestone strata separated by deposits of pyritous slates. Several of these are graphitic and contain small fragments of plants.

Coldbrook Group.—To these calcareous beds succeeds a group of rocks which does not hold a prominent place at St. John, but is largely developed to the eastward of that place. They are well exposed in the valley of Coldbrook, and further east where the following succession may be seen:

1. Hard greenish grey slate, stratification very obscure.
2. Conglomerate with bright red slaty paste.
3. Grey conglomerate.
4. Coarse reddish grit and conglomerate with purple sandstone.

Apparent thickness of the whole, 5000 feet.

* Gaylussacia resinosa, Vaccinium Pennsylvanicum, V. Vitis-Idœa, Cassandra calyculata, Epigœa repens, Gaultheria procumbens, Kalmia angustifolia, Rhodora Canadensis, Corema Conradii, &c., are common on the ridges; while Sedum latifolium, Kalmia glauca, Andromeda polifolia, Myrica Gale, and a variety of other species occur in the hollows, which frequently expand into sphagnous bogs.

To the westward of St. John this group thins out rapidly. At the "falls" of the river it does not exceed 150 feet.

No organic remains have been detected in it.

St. John Group.—No division of these slates has been attempted, as there is a repetition of similar sediments; the strata are much plicated, and the only well preserved fossil—a lingula—which occurs in considerable number is common to the coarser beds throughout the group.

The great mass of the deposit consists of a grey clay slate often sandy, the layers of which present glistening surfaces owing to the abundance of minute spangles of mica. This rock frequently becomes very fine in lamination and texture, and dark in colour. Four thick bands of this kind occur, the uppermost of which has been denominated by Dr. Dawson papyraceous shale. They have as yet yielded no fossils.* The three bands of coarser shale which alternate with them include numerous layers of a fine compact grey sandstone, from a few inches to ten feet or more in thickness; a few are so highly calcarerous as to become almost limestones. The surfaces of the layers in the coarser bands are frequently covered with worm burrows, ripple marks, shrinkage cracks, scratches—apparently made by creatures gliding through the shallow waters in which they were deposited—and other evidences indicating that the slates are in great part of littoral origin.

Fragments and complete shells of a Lingula are scattered over the surfaces of the sandy layers, and thin seams composed entirely of these shells packed closely together are occasionally met with.

These shales maintain a comparatively uniform breadth between Loch Lomond and St. John, but to the westward of the city their thickness rapidly diminishes. No proof that they are unconformable to the deposits contiguous to their base and summit has been observed.

* Since writing the above, I visited, in company with my brother, Mr. C. R. Matthew, a locality on Coldbrook where he had previously met with loose pieces of fossiliferous slate. We found this rock in place near the base of the St. John group, and obtained from it, beside some obscure remains, a small orthoceratite, and numerous trilobites of two or three species, the latter so excessively distorted that not even the genera can be made out. These and the species discovered in the Dadoxylon sandstone by Mr. Payne, are, I believe, the only trilobites found *in situ* in the province.

REFERENCE.

No, 1. *New Red Sandstone*..

2. *Carboniferous*........

3. *Lower do.* ....

4. *Mispeck Group*......

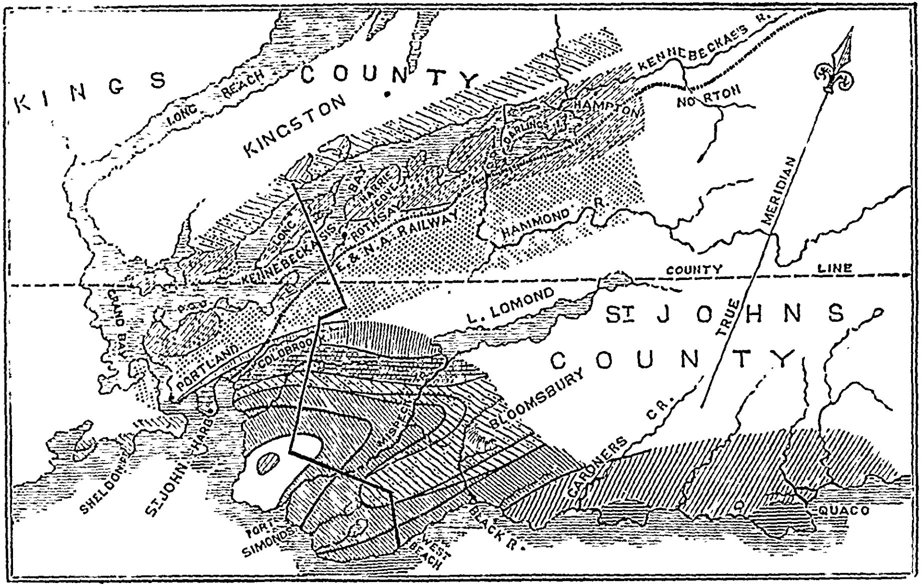
5. *Little River Group* ..

6. *Bloomsbury Group*....

7. *St. John's Group*.....

8. *Coldbrook Group*,.....

9. *Portland Group*......



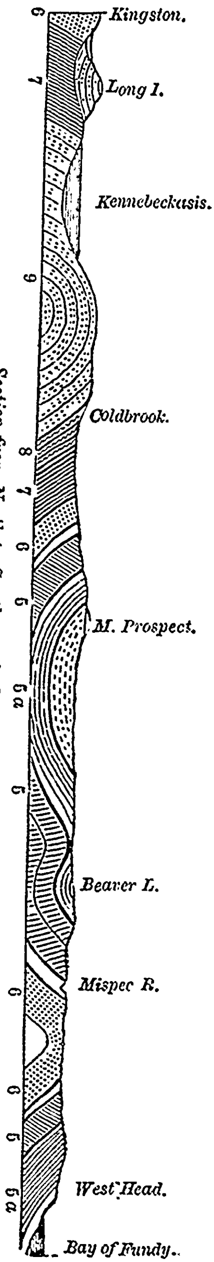
MAP OF THE VICINITY OF ST. JOHN, NEW BRUNSWICK.

Long Island in Kennebeckasis R. is principally composed of conglomerate and sandstone of lower carboniferous age, which rise in a bold and picturesque cliff from the water's edge at the eastern end. At the foot of this cliff and extending thence along the southeastern side of the island, strata of much greater age are exposed to view. They consist in ascending order of—1st. Granite and granitic gneiss; 2nd. Crystalline limestone and altered slate; 3. Thinly laminated grey shales with thin layers of fine sandstone much contorted. The whole dip to the northwest at an angle of 60° to 70°. In the shales, fragments of a lingula occur similar to that found in the St. John beds and probably identical with it. There are also numbers of worm burrows and other markings like those in the shales at St. John. The texture and position of this deposit as well as the obscure fossils which it holds, seem to show that it is identical with that which underlies the city. A small exposure of slates, evidently a continuation of those on Long Island, may be seen at Sand Point on the south side of the river, six miles southwest.

These limited exposures of slate seem to me to point out the occurrence of a belt of fine sediments on the northwest of the Portland series of rocks similar to that which is more clearly seen on the southeastern side of St. John, &c.; and further to indicate that the valley of the Kennebeckasis, now mostly filled with carboniferous deposits, was originally scooped out of the soft beds of the St. John group.

Bloomsbury Group—*a. Volcanic beds.* At the centre of the parish of Simonds, St. John County, rises a high hill called Bloomsbury mountain, the western termination of

Section from North to South, on the line marked on the Map.



a ridge of land extending in a northeast direction through the middle of the county. The hill and ridge are on the southern anticlinal fold already alluded to. In the rear of Quaco the ridge is composed in part of syenitic and granitic rocks, but between the hill and the harbour of St. John no rocks of greater age than the trap beds of this group appear.

The elevation consists of basaltic trap, and is flanked on each side by beds of amygdaloid, trap-ash, and other products of volcanic origin, which also cover the crest of the anticlinal fold for two or three miles west of the hill. The succession of strata is best displayed on the south side of the hill where they succeed each other in the following order:—Basaltic trap, unstratified, of great thickness; bedded basalt, amygdaloidal porphyry, bedded basalt, hornblendic trap-ash, micaceous quartzite, vesicular trap-ash slate; thickness of the stratified deposits about 3000 feet. There is also on this slope a volcanic conglomerate, viz., fragments of trap rocks imbedded in trap-ash slate. The quartzite resembles some of the finer beds at West Beach and Black River, and the porphyry is that alluded to in Gesner's 3rd Report, p. 15. The trap-ash slate is in many places full of irregular vesicles, the sides of which are coated with minute crystals of quartz, calcite, and specular iron.

The great increase in bulk of the stratified traps, &c., at this place, and the nucleus of basalt over which they are spread, seem to indicate that it is one of those vents from which during the Devonian period, lava, ashes, and fragments of rock were poured forth and carried many miles to the westward.

The outcrop of the lava beds can be traced trending away to the north and west, till they cross the harbour at the southern end of the city, and disappear in the post-pliocene gravels west of St. John.

On the north side Kennebeckasis valley is bordered by a range of abrupt hills from 250 to 600 feet high, consisting of altered clay slate and sandstone, with numerous beds of greenstone interstratified, the whole series being much disturbed and usually vertical. They may be the equivalents of the volcanic sediments described above; but their outcrop is so straight for a distance of thirty miles, that they may prove to be part of an older series brought up by a fault.

b. Sedimentary beds.

On each side of Bloomsbury mountain, and separated from it by the forks of Black River, there are subordinate ridges of a dark red slate, capped by heavy beds of reddish conglomerate having a thickness of 2000 feet.

This thickness decreases so rapidly to the westward, that at Courtney Bay on the east side of the harbour it does not exceed 150 feet.

These sediments constitute a passage from the volcanic beds to the sandstones of the group above. No fossils have yet been obtained from them, and as they are thickest where the former are most prominent, they have been grouped as above.

LITTLE RIVER GROUP—*a. Dadoxylon Sandstone.*—This deposit in its lithogolical characters and fossils is the most constant and unchanging of the strata which have been shown to be unquestionably of Devonian age, and has been a valuable guide in tracing out the relations of the rocks eastward of St. John. A fine exposure of the whole of this sandstone and the greater part of the upper division of the group may be seen north of Mount Prospect (about four miles east of the city) where they rise from beneath the post pliocene gravel of Little River valley. The first consists of hard grey sandstone, with beds of grit and layers of dark grey shale at intervals, the whole having a thickness of 2000 feet. The fossils are *Calamites transitionis*, and fragments yielding discigerous and other porous tissues. The lower layers can be traced four miles east (to Latimore Lake), where they sink beneath gravel beds in the valley of the Mispeck River.

On the south side of the valley the sandstones again reappear with a westerly dip. Further down the river the strata incline to northwest and westnorthwest as they approach Port Simonds.

At the bridge over the Mispeck on Black River road the sandstone contains fragments of carbonized wood, *Calamites transitionis*, and *C.* sp.? A bed of dark shale at the same place holds *Cordaites Robbii*, *C. angustifolia*, and a calamite (*C. cannaeformis ?*), numerous stems of ferns and leaflets and broken fronds of two species (one is probably *Neuropteris polymorpha*, Daw.) A few beds of grey pebble conglomerate occur in the sandstones of this valley, and the thickness of the deposit is much greater than at Little River; and further west (being about 3600 feet) an outcrop of grey sandstones, which I have, no doubt belong to this series, was traced for several miles along the southeastern side of Bloomsbury axis. They rest conformably on the lower division of the Bloomsbury group, being separated from it by a thin band of dark red slates, probably representing the upper division. Beds of dark shale, which are intercalated with the sandstones, hold stems and other fragments of plants.

The upturned edges of these rocks, so remarkable for the abundance and perfection of the flora which they contain, have thus been traced around a double curve from Manawagonis to Black River, a distance of more than thirty miles and therefore spread over an area of sixteen miles in breadth.

On a grey slate, just above the most prolific plant-bed at Duck Cove, distinct rain marks like those obtained from the red sandstones of Connecticut were observed.

It will be observed that from the base of the Bloomsbury group to the top of this sandstone there is a series of deposits similar to those of the Coldbrook group, viz., volcanic sediments, red slates and conglomerates, grey sandstones.

b. Cordaite shales.—At the locality north of Mount Prospect, there is an excellent exposure of this as well as the lower division of the Little River group. By increase in the bulk and frequency of the finer beds, the sandstones gradually pass into arenaceous shales of greenish, grey and red colours, which frequently alternate with reddish and grey sandstone and grit,* the latter predominating east of this place, while the shales are more prevalent in the western extension of the deposit. Near its upper limit it approximates in the increase of coarser sediments to the lower beds of the Mispeck group; from these, however, the older conglomerates are easily distinguished by the small size, great number, and roundness of the quartz pebbles. *Cordaites Robbii* has been found to characterize these shales throughout nearly their whole thickness of 2300 feet. They cover an extensive area in the valley of Mispeck River, owing principally to a secondary fold in the strata (see section).

A thick series of micaceous slates and imperfectly formed granites and granulites or granitic sandstones with beds of trap-ash, conglomerate grit and limestone occur on the Bay shore at West Beach and Black River; and with their contained minerals are described in 3rd Report on Geology of New Brunswick. At the

* In two-thirds of the thickness of these shales there are thirty-seven distinct alternations of these coarser beds with the shales, varying from two to forty feet in thickness. In the upper third the sandstones become redder, and some thick beds of a coarser conglomerate appear.

point where they are crossed by the section they present the following succession :

1st. Red clay slate, and grit, and coarse reddish micaceous slate, resting upon the Dadoxylon sandstone.

2nd. A thick mass of granulite and imperfectly formed granite, with beds of trap-ash.

3rd. Grey micaceous slate.

4th. Reddish sandstone and grit, overlaid by coarse conglomerate holding beds of hematite.

5th. Dark grey micaceous slate, and basalt (stratified ?).

A short distance to the eastward, the quasi-granite passes into schist abounding with volcanic ash beds, and overlaid by similar strata containing several large beds of iron one.

Further east in the same metamorphic belt are a number of thick belts of impure limestone much altered, and hard clay slate with copper pyrites. The highest beds exposed at Black River are red and green clay slates, beds of trap-ash and basalt, resembling the volcanic sediments of the Bloomsbury group. The position of these metamorphic beds will be discussed further on.

Mispeck Group.—Filling the centre of the basin of Devonian rocks intervening between Little River and Mispeck River, and having a breadth of about two miles, is a group of sediments in which no organic remains have been found, and which there is reason to suppose should be separated from the fossiliferous strata below, although resembling the latter in appearance and equally metamorphosed. West and north of Mount Prospect where the cordaite shales disappear beneath the stratified gravel which covers the top of that hill, the dip of the beds at the base of this group rapidly diminish s from 30° to 15°, and the strike at the same horizon varies 10°. The lowest member is a coarse reddish conglomerate having a red slaty paste filled with large subangular fragments of a grey altered rock, like the lower slate of the Coldbrook group. It also contains fragments of reddish sandstone and a few pieces of impure slaty limestone. The conglomerate is overlaid by thick beds of purple clay slate, which by the accession of coarser materials becomes a slaty sandstone and grit filled with white particles. The highest member on the line of section is a slaty conglomerate holding fragments of slate and sandstone. The strata of this group are much thicker on the north than on the south side of the basin. An isolated deposit of red slate resembling the finer beds of this group, rests against a mass of altered rock which seems to be a continuation of the Bloomsbury volcanic beds, at Taylor's Island, west of the harbour of St. John.

ASSOCIATED DEPOSITS.—These consist of sediments mostly arenaceous, referable to the carboniferous and new red sandstone formations.

Lower carboniferous.—The upper part of the valley of the Kennebeckasis river is filled with deposits of carboniferous age; in the lower part of the valley these rocks have been to a great extent removed by denuding agencies, and only detached masses remain. They seem divisible into two principal sections, viz.:

A lower—consisting of coarse red conglomerates, red sandstones, and red shales. Fossils—Algæ and stems of land plants.

An upper—comprising grey sandstones and grey and brown shales.

The lower beds were at first referred by Dr. Gesner to the new red sandstone, but subsequently on account of their resemblance to sandstones, gypsums, &c., of Minas Basin, to the lower carboniferous formation.

The discovery of certain plants in the shales of the upper division at Norton station and Darling's Island in King's County, enables me to confirm the latter view of their age. At the latter place gray shales intercalated with grey sandstones hold the following species:

Lepidodendron elegans, *L. corrugatum*, and a species resembling *L. Sternbergii*, also abundance of spore-cases of Lepidodendra. *Cyclopteris Acadica*, Daw. (or a species closely allied,) a carpolite (?).

The beds near Norton Station, which were cursorily examined by Mr. C. R. Matthew last summer, are described as a thick undulating series of grey and black shales and shaly sandstones. Many of the layers are ripple marked and dotted with small bilobate impressions, and contain small fragments of land plants. Broken specimens of *Lepidodendron corrugatum*, Daw., and *Lepidodendron elegans* were obtained here.

At Apohaqui, in beds belonging to the same series, a cordaite (or stem of a large fern) was found in the beds of bituminous shale, and seams of Albertite in sandstone were also observed. Further up the valley are thick deposits of bituminous shale and limestone, but their relation to the beds of Norton, &c., is not known.

The resemblance of these shales and sandstones to those of Horton Bluff and Gaspereaux river in Nova Scotia, is remarkable, both as regards fossils, and the condition under which the strata were deposited; and there is every probability that they are of cotemporaneous origin.

The conglomerates of the lower division are unconformable to the Portland series and St. John group, and have usually the following composition:

Paste—dark red clay or sand derived from granite, rarely a grey calcareous mud.

Pebbles—imperfectly rounded fragments, one foot or less in diameter, of

1st Granite or syenite.
2nd Metamorphic limestone.
3rd Mica slate.
4th Soft brown sandstone.

These rocks, except the last named, are derived from beds of the Portland series.

The pebbles in those beds which recline on the flanks of the hills on the north side of Kennebeckasis Bay, are however mostly from the traps, altered slates, &c., on which the conglomerates there rest.

In rear of the post-pliocene plateau at Red Head, on the east side of St. John harbour, is a small isolated deposit of conglomerate terminating in a cliff seventy feet high. It probably rests on the tilted edges of the lower beds of the Mispeck group, and is much less coherent than any of the Devonian conglomerates of the vicinity. The layers incline to the northwest at an angle of 30°. The paste of the conglomerate is a dark brownish red sandstone, enclosing fragments of 1st granite, 2nd grey metamorphic limestone, also pieces of trap, mica slate, and soft brown sandstone. The deposit is therefore in every respect similar to the conglomerates of the lower Kennebeckasis.

Carboniferous.—There is a limited deposit of this age extending along the coast from Emerson's Creek near Black river to Quaco, which is unconformable to the micaceous slates, &c., of Black river, and which contains a flora more like the ordinary forms of the coal measures, than is that of the Kennebeckasis beds. The genera Megaphyton (?), Sigillaria, Calamites, Cordaites, Asterophyllites, Sphenopteris, Neuropteris, are represented.

New-Red-Sandstone.—Bright red sandstones with some pebble beds, skirt the sea shore for a few miles near Gardner's Creek, and may be seen both on the east and the west side to rest upon the upturned edges of the carboniferous beds just referred to. They dip to the northwest, and hold fragments of coniferous wood.

Metamorphism.—In comparing the appearance of the beds of the Portland series to that of the Laurentian formation in Canada, Dr. Dawson indicates the apparent antiquity of the former and the extreme metamorphism which the older strata have undergone. In the upper part of the series, however, the change is not so complete, and small fragments of plants may still be detected in the shaly layers. In the St. John slates metamorphism has not proceeded so far, and the two highest Devonian groups present still less alteration in their shales, though the coarser sediments are often strongly cemented, the vegetable remains of the sandstones converted into anthracite, and the lustre of graphite given to the ferns, &c., which the finer beds contain.

As soon as we pass to the Lower Carboniferous deposits a wide distinction is this respect is at once apparent. The vegetable remains which they contain have the appearance of plants from unaltered coal-measures. The conglomerates also differ largely from those of the Devonian series in their incoherence, and many of the shales are scarcely harder than the dried mud of a pond.

Beside the regional metamorphism which characterizes all the Devonian and subjacent deposits, some of the beds have undergone a local change, which is most prominent in the volcanic sediments. By an alteration of this kind the stratification of the lower beds of the Coldbrook group has been almost obliterated.

In the Bloomsbury group it is very marked, because the deposits above and beneath have undergone much less change. Several of the finer beds of this group have been converted into quartzites and micaceous slate.

I have already alluded to a group of metamorphic strata at Black river and vicinity, which have been considered to be much older than the fossiliferous deposits in the vicinity of St. John. That they form a part of the Upper Devonian series seems clear, because,—

1st They overlie the Dadoxylon sandstone conformably (or nearly so).

2nd They underlie carboniferous deposits unconformably.

3rd They partake of the flexures of the Devonian series, which preceeded the formation of the Lower Carboniferous conglomerate.

Their unusual metamorphism is evidently caused by the abundance of volcanic debris with which the beds are charged. I have connected them with the cordaite shales, but it is quite possible that the upper part may be altered beds of the Mispeck group.

Dynamical Features.—The thinly laminated strata of the St. John group are in many places drawn up into sharp folds, having oblique axes directed to the west and southwest, and inclined to the horizon at various angles. The markings on the layers show that they have been inverted in some places where these plicatures cannot be traced. The real thickness of the group may therefore be much less than we might, from a cursory examination, be inclined to suppose.

The grander folds of the Upper Devonian and older beds have already been described. That these were induced at the close of that epoch is evident, because the materials of which the fragmental rocks at the base of the Lower Carboniferous strata on the Kennebeckasis are composed, have been derived from beds brought to the surface by the abrasion of one of these folds, and because at one locality these rocks rest on the upturned edges of the higher Upper Devonian strata. Physically therefore, the line of separation between the two ages is strongly marked in southern New Brunswick.

This fact stands out with greater distinctness when we consider that 2000 feet or more in vertical thickness of what had already become solid rock, were removed from the tops of the folds in the older beds, before the materials of which the Kennebeckasis conglomerate is formed, were exposed. And we cannot well avoid the conclusion that currents or other agencies of vast force or long continuance (perhaps both), held sway over this region at the opening of the carboniferous age. The wide hiatus between the two series also excites the suspicion that the conglomerate alluded to is not at the base of the carboniferous series. The gap which intervenes may be narrowed by the bituminous shales, &c.,

of Albert, which according to Dawson are beneath the carboniferous conglomerates of that county.

The Carboniferous strata both in the valley of the Kennebeckasis and on the coast have been crumpled up in the same manner as the Devonian of the intervening district, but at a later epoch. In the small deposit of New-Red-Sandstone at Gardner's Creek, these plications do not occur.

General Remarks.—In reviewing the general features of the deposits which I have attempted to describe, the rarity of deep water accumulations is worthy of note. Above the limestones of the Portland series the strata consist almost entirely of littoral or subærial deposits; the finer shales of the St. John group and some limestones at Black river being the only beds which indicate a deep water origin. Ripple-marks, and other evidences of a sea-margin have been observed at three different levels in the St John slates, and also at several places in beds of the Little River group and as already stated rain marks also occur.

The evidences of volcanic activity during the period marked by the Coldbrook beds, and the great accumulations of lava, ashes, and volcanic mud, which form the bulk of the Bloomsbury group, as well as the proof of renewed igneous action met with among the vast beds of gravel, sand, and clay subsequently formed, show that in some points the circumstances which attended the formation of Devonian deposits in eastern America differed widely from those which prevailed at the west.

The source of the detritus out of which the Devonian beds at St. John have been formed has not yet been ascertained; but that it is to be sought for in an easterly direction is obvious, since all the deposits (except perhaps the highest) increase in bulk and coarseness of material when traced in that direction. Its origin is probably closely connected with that of the volcanic beds, which as I have already shown are largely developed to the eastward.

An intimate relation between volcanic deposits and red sediments seems to exist in these beds, the latter appearing to be a consequence of the former. Thus red shales sandstones and conglomerates succeed the lowest member of the Coldbrook group; and a similar succession on a larger scale occurs in the Bloomsbury beds. If I am correct in referring the metamorphic strata of Black river to the cordaite shales or Mispeck group, a similar succession appears in the higher beds, not vertically, however, but horizontally.

A section of the Devonian rocks at Perry, Maine, is given by Prof. C. H. Hitchcock, in the Report of the Maine Scientific Survey, 1861, p. 252, which indicate three geological epochs. 1st Silurian; 2nd When beds of trap were spread over the upturned edges of the Silurian strata; 3rd The period when Devonian sandstones were deposited unconformably on the trap. This trap seems to hold the position of the Bloomsbury beds at St. John. But no evidences of unconformability between the latter deposits and the overlying plant beds have been observed. Prof. Hitchcock therefore surmises that the Perry sandstones may be equivalent to the higher beds at St. John (Cordaite shales and Mispeck group).

In confirmation of this view, I may remark that the Dadoxylon sandstone thins out both to the southwest and southeast, and notwithstanding its great thickness may be a comparatively local deposit. Moreover between the highest and the lowest beds of this sandstone, there is a decrease of fifteen to twenty degrees in the dip, showing that a subsidence of the area over which the deposit is spread took place while it was in process of formation. If this oscillation extended to the western part of the Bay of Fundy and no beds corresponding to this sandstone were formed there, a discordance between the dip of the trap and sandstones, such as is exhibited in the section at Perry, would result.

I have already alluded to a rapid and equally great decrease in the dip of the beds at the base of the Mispeck group. Uncon formability to the extent of thirty degrees may therefore occur where the highest and lowest of the Upper Devonian beds are in contact. This seems to be the case at Taylor's Island.

Note by Principal Dawson on some fossils referred to in the above paper.

Mr. Matthew has forwarded specimens of the Lower Carboniferous and New-Red-Sandstone plants referred to in the above paper. Among the former, I recognise most of the characteristic plants of the Lower Coal Formation of Horton in Nova Scotia, and have no doubt that the beds containing these fossils in New Brunswick, are strictly equivalent. The fossil wood from the New-Red-Sandstone, though not well preserved, appears to be coniferous, and to have one row of discs on the cell walls, in the manner of the mesozoic pines of the genus *Peuce* or *Pinite.*

The discovery of these plants by Mr. Matthew is of great importance in connection with the Devonian flora of the underlying beds; and it is extremely interesting thus to find, in so limited an area, a rich Devonian flora, two of the members of that of the Carboniferous system and indications of a mesozoic flora, in beds whose order of superposition is so distinct. It further affords an excellent illustration of the geological importance of the study of fossil plants, which first threw light on the age of these beds, and without which, in the absence of well-marked animal fossils, their position in the series of deposits would still have been uncertain.

Art. XX.—*On Ailanthine.* The silk yielded by the Saturnia or *Bombyx Cynthia*, with Remarks on the *Ailanthus glandulosa* or False Varnish Tree of China. By Robt. Paterson, M.D., F.R.C.P.E., Corresponding Member of the Botanical Society of Canada, &c., &c.

(*Read before the Botanical Society of Canada, January* 26, 1863.)

There are few individuals who have not watched the interesting changes which take place in the larvæ of the *Bombyx Mori*, or common silk-worm, from the point of its exit from the egg until it has reached its full butterfly existence; and many there are who have been sadly disappointed at the mortality which comes over a brood of silk-worms in a single night from some cause or causes unknown and consequently equally unremediable. Such epidemics are continually occurring in China as well as Europe, and constitute one of the greatest obstacles to the introduction of the culture of the silk-worm into this country. What occasions this sudden decimation of these insects has never been determined, but has long led to a wish, on the part of those interested, that a more hardy breed of silk-producing worms could be introduced into Europe, even although the produce was coarser, and of a worse colour, than the ordinary mulberry silk.

Recent information, through our missionaries in China, leads to the knowledge that there is a considerable number of worms used by the Chinese, in different districts, for the production of silk of various qualities and coarseness. These varieties of silk are used in China principally for the manufacture of dresses for the peasantry. Of late, however, some of these have reached this country, and have been considered durable and excellent. Could we but rear such silk in our country, as we hope shortly to be able to show that we can do, how much of the present overwhelming distress, which is visiting our manufacturing districts in consequence of the American war, might be avoided. Such material, if not used alone, might be readily mixed with cotton or wool; and thus many new and beautiful, if not very durable, fabrics might be produced.

In 1814 Dr. Roxburgh* published an interesting memoir on the silk-producing moths of the East Indies, and soon afterwards the Arrindy, or Palma Christi silk-worm was introduced into Europe. The Castor Oil Plant, in this climate and in the north of France is but a delicate shrub; in the south of Europe, however, where the temperature never reaches the freezing point, it becomes a tree of very striking aspect, with large and richly tinted foliage. In such districts, therefore, the Arrindy moth thrives well, having plenty of food, undergoing its changes rapidly, and yielding five and six crops annually of silk of excellent quality. What was required for our climate, however, was an insect which, while sufficiently hardy to stand our cold springs and autumns, would also be regardless of storms, rain, dew, &c. Such a worm was first sent to Europe by the Abbé Fantoni, a Piedmontise missionary in the province of Shan Tung. He sent some cocoons immediately after the first gathering in 1856, to some friends in Turin. The name of the tree, on the leaves of which they lived was to him a mystery, but he described it as being like the leaf of an acacia: so when the young brood hatched, various and many were the plants tried for their food, until the leaves of the *Ailanthus glandulosa* were presented to them; these they immediately ate greedily, and always preferred them afterwards to any other kind of food.

There can now be little doubt but that the Arrindy or Palma Christi moth, introduced into Europe from Dinagepore and Rungpore in Bengal in 1854, and the Ailanthus moth introduced into Europe from the province of Shan Tung in China, in 1858, are one and the same animal. The insects introduced in 1854 were delicate, and did not stand much lowering of the temperature, besides the tree on which they fed perishes at 32° or 33° Fah. The insects introduced in 1858 were hardy, stood rain and cold, and the tree which they preferred is a hardy one in our climate. Those introduced in 1858, from China, would not eat the Palma Christi, and very naturally it was believed that they were different insects; upon examination, however, they turn out to be the same. Their changes, the colour of their larva, the character of the

* Linnæan Transactions, Vol. 7.

cocoon, the kind of silk, and the characterizing marks of the moth itself pronounce them at once to be the same animal. But how have these animals acquired such different habits and tastes? This can only be explained upon the supposition that a long period of hardening in a temperate climate like the province of Shan Tung would produce in course of time a more hardy progeny, feeding habitually on a common plant of the country; while the more natural and more effeminate brood of Central India, preferred as food the leaves of a plant which will only flourish in warm latitudes. Unless specific distinctions exist it is clearly a bad plan to distinguish an insect from the peculiar plant it eats, for this may be a simple point of preference,—if it cannot get the one it will eat the other and thrive on it; besides a long period of hardening will often enable an animal to live and thrive on a vegetable very different from its native food. We need only example the ordinary *Bombyx Mori* or common silk worm, the finest varieties of which, after passing a year or two in our climate, will live, and thrive, and spin beautiful silk on the common lettuce. Of the tree on which the ailanthus worm feeds it may be necessary here to speak shortly; we shall have to describe the animal itself more fully afterwards.

It appears that the tree was originally introduced into this country by the abbé d'Incarville, in 1751, as the "Vernis de Japon" tree, or that which yielded the famous Japan or China varnish. This turned out, however, to be a mistake, as the true Japan varnish tree has since been introduced into Europe. Since this latter introduction the *Ailanthus glandulosa* has been known as the false varnish tree. It is a hardy plant in our climate, standing severe winters well, and producing an abundant crop of leaves especially from young shoots in early summer. It has no especial partiality for particular varieties of soil, thriving as well and producing as abundant a crop of leaves in the most barren soil as in the richest loam. It seems equally indifferent, too, as to the characteristics of the atmosphere in which it lives, healthy young trees being observable in the squares and smoky environs of London. The advantages of a plant such as this in the rearing of a hardy animal on its foliage need not be pointed out. Throughout France generally this tree flowers and seeds freely, and the seed sprouts and grows readily in Great Britain; but in addition to this method of propagation, another exists in the roots, which if cut into pieces like the potato spring forth and grow luxuriantly; no plant indeed can be more easily grown, or more easily increased when grown, than the *Ailanthus glandulosa.* But to enable this plant when grown to yield a proper supply of food for the ailanthus worm, it is necessary to cut it down and grow it ozier-like. In this way young shoots spring forth abundantly, and bear large and delicate leaves fitted for the young worm,and greedily devoured by the older ones. They have an additional advantage also that when the insects are placed upon them in the open air they are more easily protected by nets, &c., from the depredations of birds, insects, &c.

So much for the plant on which the animal feeds. Let us now turn to the insect inself :—I have already stated that the ailanthus silk worm was introduced into Europe in 1856.. Its cultivators have not been idle since that time as we find that M. Guerin Meneville endeavoured to introduce this worm into France. His first experiment did not succeed but the following year he reared a satisfactory crop of cocoons in the open air ; this, however, and all the efforts of the Societé d'Acclimatization of Paris were not sufficient to effect the general introduction of the animal into France. It became necessary for him to show that agriculturalists might derive a profit, and a good one, from the rearing of this insect.

Energetic, and thoroughly convinced ofthe success of such an experiment on a large scale, he induced personal friends to experiment on a larger scale at Toulon, in Provence, and at Chinon (Indre et Loire), the one being nearly in the south, the other in the centre of France.

At Chinon, for instance, 4,500 worms were placed upon flourishishing thickets of ailanthus, which had been cut down and grown as bushes with that intention. Their development progressed satisfactorily, and they yielded 3515 excellent cocoons, after suffering without injury, rains, heavy storms, and the attacks of birds and insects. The result of the experiment was a loss of about a fourth part, while the average loss of mulberry silk-worms is about one-half.

M. Meneville, after some careful experiments and calculations which were submitted to the imperial government, has thus stated his profit and loss account, on the rearing of ailanthine, or the silk of this worm, produced in districts south of Paris.

	Francs.
Twelve acres of ailanthus copse, share of expense of planting and annual expense of keeping up..................	2030
Average of receipts from two crops of ailanthine.........	9945

Which leaves a balance of 7915 frances for the twelve acres, or in round English numbers, £330 for twelve acres, or £27 10s. per acre. In India and China there are said to be six crops of silk annually; in the south of France two or three crops, but in the north of France and Great Britain two at most, and more securely one crop might be relied on. Let us take one good crop and see how our profit and loss account would stand in Great Britain The half of £27 10s. or £13 15s. would be the result, or about it; and be it remembered, for land, that after the planting of the ailanthus it requires no manure or tillage whatever, and the kind of soil being that on which nothing else would grow, provided always that it has as sheltered and sunny an exposure as possible. It always occurred to me that the climate of Canada would be especially favourable for the growth of ailanthine. The insect and the plant on which it feeds will stand any amount of cold; and when the Canadian summer would arrive, rapid growth would take place in the tree, followed by hatching of the worm; in this way food would be speedily produced for the young brood, and two if not three crops of silk taken from the trees during the season. The experiment is one worthy of trial.

In England and Scotland, for the last two years, some experimenters have been at work but as yet without any quantitative result. In the spring of 1862 I received, through the kindness of a friend, fifty eggs of the *Bombyx Cyrthia;* they hatched in about ten days after their arrival; they were fed with cut branches of ailanthus; kept in the ordinary temperature of the atmosphere, but under glass. Of the fifty worms (for the eggs all hatched) with all my inexperience, I had thirty-five large and fine cocoons being a result not far short of that in the central districts of France. With more experience and with growing plants prepared for the trial, I do not fear for the result of a quantitative trial in Scotland' at any future year.

It is my intention, in describing this insect, to follow the different changes which it undergoes from the egg onwards until we arrive at the characterizing moth itself, from which distinctive marks and pecularities are chiefly taken.

The Eggs. These are about the size of a large pin head, twice as large as those of the mulberry silk-worm with which we are all familiar. They are yellow coloured, equally large at both ends, flattened from above downwards, and with a depression in their centre. They soon change their colour to a greenish black, the colour becoming more marked the nearer the point of hatching is at hand. The caterpillars are hatched from ten to fifteen days after the eggs are laid according to temperature.

The Caterpillar. When the worm first escapes from the egg it is exceedingly minute; the colour of the segments of its body at this early stage is obviously yellow, but there are so great a number of black spots and dark coloured tubercles over it, as to give the impression that it is of a black colour; during the *second period*, that is to say after the first change of skin, the yellow colour becomes more marked, but the spots and tubercles are still black. During the *third period*, they become nearly pure white, arising from the presence of a white mealy secretion over their bodies, destined, obviously, to protect them from rain or dew, as water will not fix on it; the spots and points of the tubercles are still black or bluish black.

During the *fourth period* the body is at first white, but gradually changes to a pale green, the tubercles assuming the same colour, and soon the head, the feet, and the last segment become of a golden yellow; the flowery secretion still, to a certain extent, exists, and there are always black points upon the segments or rings of the body.

During the *fifth period* the emerald green colouring becomes more intense, the points, as to segments, assume a soft black colour, and the extremities of the tubercles a marine blue. The caterpillar grows rapidly during this stage, eats largely and greedily till it attains the length of from $2\frac{3}{4}$ to 3 inches long, it then ceases to eat, becomes torpid for a few days, and then, after fastening a few leaves together at the extremity of a leaf or branch it begins its cocoon. Such is the general character of the changes which this caterpillar undergoes; but to enable those who may follow out this inquiry to know when these changes may be expected and the size of the animals in them I will give a short table of my own experience, and that of my friend Dr. Gudwad, both in Scotland :—

Eggs hatched, 28 to 30th June	size $\frac{2}{8}$ of an inch.
First change, 7 to 9th July	size $\frac{1}{2}$ of an inch.
Second change, 13 to 15th July	size 1 inch.
Third change, 20 to 22nd July	size $1\frac{1}{4}$ inch.
Fourth change, 28 to 30th July	size $1\frac{1}{2}$ to 2 inches.

From this time till the period when it begins to spin it rapidly grows till it reaches from two and a half to three inches long, depending upon the abundance and quality of its food.

The experience of my friend Dr. Gudward is as follows :

Eggs hatched 19th Sept.
28th " 1st change began.
5th Octr. 2nd change began.
12th Octr. 3rd change began.
21st Octr. 4th change began.
3rd Nov. began cocoon.

The temperature ranged from 47° to 55°.

The Cocoon. I have already remarked that after a short period of torpidity when no more food is taken and during which the remains of the undigested food is passed by the worm in abundance, it begins its cocoon by fastening some threads of silk to the end of the branch or leaf stalk, and, after binding some leaflets together, it spins its cocoon in the hollow thus formed. The colour of the silk is of a yellowish brown colour, very like, indeed, to that of a decayed leaf. In weaving its cocoon this worm leaves at its lower extremity, an elastic opening for the exit of the moth. The threads at this opening are not cut across, but simply turned and laid one over another. The silk of this worm has not as yet been unwound in a continuous thread; this, doubtless, arises from the substance which glues the threads together requiring some other solvent than the warm water which so readily affects the solution of the gummy secretion of the mulberry silk. This however cannot long remain undiscovered in this country, as a chemical solvent for this secretion will doubtless ere long be found.* In China even there is reason to believe that this has been accomplished, as the last examples of ailanthine from that country are stated to leave no doubt of their having been unwound from the cocoon. Even the carded silk of this worm is abundantly used. In China it forms the most durable dresses of the peasantry,—dresses which are often handed down from father to son. In France this "flosille" or floss silk is abundantly used for weaving with thread and wool, and in the manufacture of fancy stuffs. At Roubaix, Nismes, and Lyons, it is imported from abroad in large quantities to the extent of 1,290,000 kilogrammes annually.

Mons. Geoffrey St. Hilaire, President of the Societé d'Acclimatization of Paris says:—"Here is the report of the weavers at

*It has been stated by some that the cause of the silk not winding off, results from the slanting opening at the bottom of the cocoon, admitting water, and thus sinking it and breaking the thread. This explanation is not satisfactory and is inconsistent with fact.

Alsace, who have made use of ailanthus silk. M. Schlumberger has found the cocoon very easy to card and spin; the thread obtained is less brilliant, strong and rough; it left no residue, not more than in combing the thread. It is a most excellent stuff for use in all manufactures where burre is employed. The cocoons are easily cleaned and they will take a good dye. This culture, made on a great scale, will furnish in abundance a finer and stronger floss than the mulberry silk-worm. The worm remains in the cocoon in the chrysalis condition for from twenty-six to thirty days, at which time the moth makes its appearance coming quickly and easily through the valvular opening at the extremity of the cocoon. At this time its wings are moist, soft, and folded up; and naturally upon emerging from the cocoon it seizes hold of the lower part of it, thus allowing its large wings to drop, become unfolded and stiffen. If this precaution is not taken when the moths are allowed to exit artificially, their wings never expand but remain crumpled up, the moth never regaining much activity with its wings in this state, and seldom connecting itself with the opposite sex. In rearing these moths therefore, it is of consequence to observe that upon their exit from the cocoon they have some substance on which they can climb up and allow their wings to hang down and become expanded.

The moths have been long familiar to us, in collections of Chinese Butterflies, brought to this country. It is large, the expansion of its wings being about five inches; the head and antennæ are greyish brown, the latter strongly pectinated; thorax and abdomen lighter grey, wings with a broad transverse light-coloured band near the middle, the space within which (forming nearly an equilateral triangle) is brownish grey, and that without ash colour, running into brownish grey at the margins of the wings, just within the margins there are two narrow brown streaks running parallel with them, somewhat interrupted before reaching a black spot near the apex of the superior wings; this spot is surmounted by a white crescent, and a zigzag white line runs from it to the tip. The basal portion of the superior wings is traversed by an ash-coloured bar commencing on the posterior edges next the shoulder, and after continuing in nearly a straight line for about half an inch is suddenly deflected and terminates on the anterior margin, between this bar and the transverse scapular line there is a pale longitudinal spot surrounded with black. The under wings likewise bear a similar spot but more crescent-shaped, and towards their base there is an ash-coloured arched bar bounded on the outer side with black. The under side differs principally in being paler and destitute of the angular and arched bars at the base of the upper and lower wings.* These moths, when in health and especially in sunshine, connect themselves and lay eggs in a few days. If they do not develope their wings or the temperature is low and without sunshine the males do not seek after the, females hence the eggs laid are often, under these circumstances, unproductive.

ART. XXI.—*The Air-Breathers of the Coal Period in Nova Scotia;* by J. W. DAWSON, LL.D., F.R.S., &c.

(*Continued from page* 175.)

VIII.—HYLONOMUS ACIEDENTATUS.

Plate VI, Figs. 1 to 16.

This species is founded on a single imperfect specimen obtained by me at the Joggins in 1859, and described in the Journal of the Geological Society, Vol. XVI. In this description, I mentioned, as probably belonging to this species, certain detached bones which I have since found reason to attribute to *Dendrerpeton Oweni.* These did not however materially interfere with the characters of species, which I shall give here from the fragments represented in Plate VI, Figs. 1 to 16, and which occur together in the matrix in such a manner as to render it certain that they belonged to the same individual.

In size, *H. aciedentatus* was about twice as large as the species last described. Its teeth are very different in form. Those on the maxillary and lower jaw are stout and short, placed in a close and even series on the inner side of a ridge or plate of bone. Viewed from the side they are of a spatulate form, and present a somewhat broad edge at top as in Fig. 4. Viewed in the opposite direction, they are seen to be very thick in a direction transverse to that of the jaw, and are wedge-shaped as in Fig. 5. There are about forty on each side of the mandible, and about thirty on each maxillary, as seen in Figs. 1, 2, and 3, of

* Sir H. Jardine's description of *Sturnia Cynthia*, and corresponding in every particular to ailanthus silk moth.

which the two first are magnified slightly, the last natural size.*

Since the publication of my previous paper, I have ascertained that the intermaxillary bones bore teeth of the form represented in Fig. 6. They are larger than the others, thick and coming to a blunt point, which is *seamed with longitudinal and slightly spiral ridges.* This singular tooth must have been a most efficient instrument for crushing and penetrating the coats of crustaceans and insects, or the bony armour of the smaller ganoid fishes. Remains exist at the extremity of the lower jaw, which show that a few teeth there also were larger than the others, but whether they differed in form cannot be determined. The pulp cavity of the teeth is less extensive in proportion than in *H. Lyelli*, and the structure in the cross section is simple, showing merely radiating ivory tubes, as in Fig. 7. The bone represented in Fig. 8, was found with these remains, and as it is too large for the last species, and different from anything known in *Dendrerpeton*, it probably belongs to the creature now under consideration. It is thin and smooth, except at the upper margin, where it has in the centre a group of small conical teeth. It evidently belongs to the palate, and somewhat resembles the palatal bone of *Menobranchus*, but is broader, and the latter has no teeth. Detached fragments of the skull show that its bones were thin and dense, and smooth on the surface as in *H. Lyelli*. That represented in Fig. 9 would seem to be a frontal bone seen from the inside.

The remains of *H. aciedentatus* are too scanty to warrant much certain inference as to its form. Its vertebræ would seem to have resembled those of *H. Lyelli*, but to have been elongated and more thoroughly ossified (Fig. 16). Its ribs are similar in form and proportion to those of the last named species (Figs. 10 and 11). A pelvic bone and some detached phalangial bones (Figs. 12 and 13) as well as very fragmentary limb bones, would indicate that its limbs were well developed. Its external scales are similar to those of the last species but larger, and a few fragments of skin show scales and appendages similar to those of *H. Lyelli*, but of greater dimensions (Figs. 15 and 62). The microscopic structure of its bone is also similar to that in the last species (Fig. 17). No doubt a more perfect specimen would show many points of difference between these species, not now appreciable;

* In Prof. Owen's paper, J.G.S., Vol. 18, this bone is figured, but incorrectly stated to be twice natural size, and referred to *H. Lyelli.*

but in the mean time the very different form of the teeth is a sufficient distinction. In *H. Lyelli* these are conical and pointed. In the present species they are of a peculiar wedge shape—their diameter transversely to the jaw being the greatest at the base, while at the top they are sharpened to an edge. The peculiar form of the intermaxillary teeth may also serve as a distinctive character, though those of *H. Lyelli* are not yet known. The form of the vertebræ would further seem to indicate different proportions of body. On the whole, while this species is in all probability generically related to the last, it is certainly specifically distinct. Its habits and food may have been similar, but its dental apparatus was stronger and more formidable.

EXPLANATION OF PLATE VI, FIGS. 1 TO 16, AND FIG. 62.

Hylonomus aciedentatus.

Fig. 1—Maxillary bone, magnified, (*a*) natural size.
" 2—Mandible magnified, (*a*) natural size.
" 3—Portion of mandible, natural size.
" 4 and 5—Tooth, seen from the side and front.
" 6—Tooth of intermaxillary.
" 7—Cross section of tooth, magnified.
" 8—Palatal bone with teeth.
" 9—Frontal bone.
" 10 and 11—Rib natural size and cross section enlarged.
" 12—Pelvic bone.
" 13—Phalangial bone.
" 14 and 15—Bony scales magnified.
" 16—Broken vertebra.
" 62—Portion of skin with horny scales.

IX.—Hylonomus Wymani.

Plate VI, Figs. 18 to 31.

This is the species of *Hylonomus* originally detected by Prof. Wyman in the specimens brought from the Joggins by Sir C. Lyell and myself. Remains of several additional individuals have since been found, but no skeleton approaching to completeness. I shall describe this the most diminutive of the reptiles of the Nova Scotia coal, with the aid of the fragments represented in Plate VI, Figs. 18 to 31, most of which are almost miscroscopic in size.

The skull seems to have been much of the same form as in *Hylonomus Lyelli*, but very thin and delicate, so that all the specimens hitherto found are crushed and fragmentary. The maxillary and mandibular bones are furnished with teeth which are bluntly conical in form, and in the latter bone seem to be confined to its front part, or to be very small posteriorly. They are thus much fewer in number than in the species last named. I have been able to make out only 22 in the lower jaw, and they are alternately large and small, as if replaced in this manner as worn out. Their structure is of the same simple character as in the other species of *Hylonomus*, and they have large pulp cavities.

The vertebræ of this species are singular and characteristic. The bodies are elongated and hour-glass shaped, with an internal cavity of the same form filled with calc spar (Fig. 30), and probably once occupied by cartilage. They have, in the dorsal region at least, strong articulating and lateral processes, and were furnished with numerous delicate ribs (Figs. 24, 25, 27). In one of my specimens as many as 38 of these little vertebræ may be seen lying together, and many of them attached to each other. This would indicate that the body was long and slender. It was furnished with limbs, similar to those of *H. Lyelli*, but very small and slender. The pelvis is of the same expanded form with that of the last species, and a pair of fore feet lying together on one slab, show the remains of four slender toes (Fig. 29). The bones of the limbs are very delicate and thin walled (Fig. 26). The bony scales are oval, and similar to those of the other species of the genus, but very small (Fig. 31.) I suppose it probable that the fragments of skin with imbricated scales represented in Plate V, Figs. 22, 23, and 24, may have belonged to this species, but I cannot certainly affirm that this was the case.

In length, *Hylonomus Wymani* could not have exceeded four or five inches, and its form was thin and slender. It may be questioned whether this little creature was not the young of one of the other species. The form of the vertebræ and teeth would, I think, prevent us from supposing that it stood in this relation to *H. Lyelli*. To *H. aciedentatus* it bears a stronger resemblance in these respects, though not sufficient to render specific identity probable; and the occurrence of so many specimens of the smaller species, without any of intermediate size, renders it likely that it did not attain to any greater dimensions.

Hylonomus Wymani probably fed on insects and larvæ, and searched for these among the vegetable debris of the coal swamps, which would afford to a little creature like this abundant shelter. It occasionally fell a prey to its larger reptilian contemporaries; for quantities of its tiny bones occur in coprolitic masses probably attributable to *Dendrerpeton.* It is interesting to find reptilian life represented at this early period, not only by large and formidable species, but by diminutive forms, comparable with the smallest lizards and newts of the modern world. The fact is parallel with that of the occurrence of several small mammalian species in the mesozoic beds. It will be still more significant in this respect if the species of *Hylonomus* should be found to be truly lacertian rather than batrachian.

EXPLANATION OF PLATE VI, FIGS. 18 TO 31.

Hylonomus Wymani.

Fig. 18—Lower jaw with teeth, magnified.
" 19—Anterior part of lower jaw more magnified.
" 20—Portion of maxillary bone with teeth, magnified.
" 21—Maxillary bone, natural size.
" 22—Lower jaw, natural size.
" 23—Vertebræ, natural size.
" 24 and 25—Vertebræ, magnified.
" 26—Humerus, natural size and magnified.
" 27—Rib, natural size and magnified.
" 28—Pelvic bone, natural size and magnified.
" 29—Foot; the line shows the natural size.
" 30—Broken vertebra magnified, showing internal cavity.
" 31—Bony scales, natural size and magnified.

X.—Hylerpeton Dawsoni.

Plate VI, Figs. 32 to 46.

In the more or less laminated material which fills the interior of the erect trees of the Joggins, it often happens that the more distinctly separable surfaces are stained with ferruginous or coaly matter, or with fine clay, so that the fossils which occur on these surfaces, and which would otherwise be more available than those in more compact material, are rendered so obscure as readily to escape observation. This was unfortunately the case with one of the most interesting specimens contained in the last of these trees which I had an opportunity to examine. It consisted of the detached bones of a reptile scattered over a surface so blurred and stained that they escaped my notice until most of them were lost; and I was able to secure only a jaw bone and fragments of the skull, with a few of the other bones. On these fragments Prof. Owen founded the genus *Hylerpeton* and the species named at the head of this article. His description is as follows:

"This specimen consists of the left ramus of a lower jaw (Fig. 32), which has been dislocated from the crushed head, of which the fore end of the left premaxillary is preserved, terminating near the middle of the series of the teeth of the more advanced mandible. A fragment of the left maxillary, which has been separated from the premaxillary, overlaps the hinder mandibular teeth. The fore part of the mandible is wanting. The teeth in the remaining part are larger and fewer, in proportion to the jawbone, than in *Hylonomus* or *Dendrerpeton*. They have thicker and more obtusely terminated crowns; they are close-set where the series is complete at the fore part of the jaw, and their base appears to have been anchylosed to shallow depressions on the alveolar surface. The shape of what is preserved of the upper jaw affords the only evidence, and not very decisively, that the present fossil is not part of a fish. It inclines the balance, however, to the reptilian side; and, accepting such indication of the class-relations of the fossil, it must be referred to a genus of *Reptilia* distinct from those it is associated with in the Nova Scotian coal, and for which genus I would suggest the term *Hylerpeton*.

"A small part of the external surface of the dentary bone shows a longitudinally wrinkled and striate or fibrous character. The outer bony wall, broken away from the hinder half of the dentary, shows a large cavity, now occupied by a fine greyish matrix, with a smooth surface, the bony wall of which cavity has been thin and compact. We have here the mark of incomplete ossification, like that in the skeleton of *Archegosaurus*. The crushed fore part of the right dentary bone, with remains of a few teeth, is below the left dentary, and exemplifies a similar structure. The teeth slightly diminish, though more in breadth than length, towards the fore part of the series: here there are nine teeth in an alveolar extent of 10 millimeters, or nearly 5 lines. The base of the teeth is longitudinally fissured, but the fissures do not extend upon the exserted crown. In their general characters, the teeth manifest at least as close a resemblance to those of *Ganocephala* as of *Lacertia* or any higher group of *Reptilia*; whilst their mode of implantation, with the structure and sculpturing of the bone, weigh in favour of its relations to the lower and earlier order of the cold-blooded Vertebrates."

I can add to the above description only a few facts obtained from careful examination of other fragments imbedded in the matrix. One of these is a portion of a maxillary bone (Fig. 32). It has teeth similar to those of the lower jaw in form (Figs. 34 and 35), but the last but one is twice the size of the others, and seems to have been implanted in a deep socket. All of the teeth have large pulp cavities, and the inner surface of the ivory is marked with slight furrows which are represented by ridges on the outer surface of the stony matter filling the pulp cavities (Fig. 36). The ivory of the teeth, however, which is very much coarser than that of the species of *Hylonomus*, presents in the cross section a simple structure of radiating tubes (Fig. 37). The surface of the cranial bones, of which some fragments remain, is marked in the same striate manner alluded to above by Prof. Owen (Figs. 42, 43). The microscopic structure of the bone is much coarser than that of *Hylonomus* or *Dendrerpeton*, the cells being larger and in some portions less elongated (Fig. 46). That the creature had stout ribs is shown by the fragments represented in Fig. 40; but the vertebræ are represented only by a few bodies of small relative size and perhaps caudal (Figs. 38 and 39). On the same surface was found the foot represented in Fig. 44. It is of small size relatively to the head, and was probably for swiming rather than walking. A few ovate bony scales were found with the bones, and probably belonged to this species (Fig. 41).

On the whole it seems certain that *Hylerpeton* must have been generically distinct from the other reptiles found with it, and it is probable that it was of more aquatic habits, swimming rather than walking; and feeding principally on fish. More perfect specimens would however be required in order to warrant any decided statement on these subjects. It is possible, as suggested by Prof. Owen, that the affinities of the animal may be with *Archegosaurus* rather than with any of the other coal reptiles; but I confess that my present impression is that it tends rather toward the genus *Hylonomus*. It may possibly be a link of connection between the *Microsauria* and the *Archegosauria*.

EXPLANATION OF PLATE VI, FIGS. 32 TO 46.

Hylerpeton Dawsoni.

Fig. 32—Portion of maxillary bone with teeth.
" 33—Lower jaw and portions of skull.
" 34 and 35—Teeth magnified.
" 36—Cast of pulp cavity of a tooth.
" 37—Cross section of tooth magnified.
" 38 and 39—Bodies of Vertebræ.
" 40—Fragments of ribs.
" 41—Bony scale natural size and magnified.
" 42 and 43—Surface of bone magnified.
" 44—Foot.
" 45—Bone of same magnified.
" 46—Section of bone highly magnified.

XI.—Additional Reptilian Remains.

Plate VI, Figs. 47, 48, and 54 to 56.

Beside the species above described, Mr. O. C. Marsh, in 1861,* added a new animal to the Joggins reptilian fauna; the *Eosaurus Acadianus.* The species is founded on two large biconcave vertebræ, in many respects resembling those of *Ichthyosaurus*, and indicating a reptile of greater size than any hitherto discovered in the coal, probably of aquatic habits, and possibly allied to the great *Enaliosaurs* or sea lizards of the mesozoic rocks. The specimen was found in a bed of shale belonging to group XXVI of my Joggins section, in the upper part of the middle coal measures, and about 800 feet above the bed which has afforded the remains described in previous sections. The beds belong to one of those intervals of shallow water deposition of sediment, which separate the groups of coal beds; and on one of them I found some years ago the footprints of *Dendrerpeton.*

The vertebræ of *Eosaurus* have been fully and ably described by Mr. Marsh in Silliman's Journal. Agassiz and Wyman regard their affinities as enaliosaurian. Huxley suggests the possibility, founded on his recent discovery of *Anthracosaurus Russelli,* that there may have been *Labyrinthodont* batrachians in the coal period with such vertebræ. However this may be, if the vertebræ were caudal as supposed by Mr. Marsh, since they are about 2¼

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* The remains were discovered in 1855 though not published till 1861.

inches in diameter, they would indicate a gigantic aquatic reptile, furnished with a powerful swimming tail, and no doubt with apparatus for the capture and destruction of its prey, comparable with that of *Ichthyosaurus.*

In a bed of hard calcareous sandstone, some distance below that which afforded the animal just noticed, there occur great numbers of teeth and scales, referable in part to large sauroid fishes, but perhaps also in part to reptiles. One of these is a remarkable tooth obtained by Sir W. E. Logan in 1843, and represented in Fig. 47. It resembles externally the teeth of *Baphetes*, but its structure is almost precisely that of the teeth of the *Lepidosteus*, or bony pike of the St. Lawrence. Another tooth from the same bed, and with a similarly fluted surface, has a more complex labyrinthic structure, as seen in Fig. 48, which however represents only a small fragment. With these occur large round thin scales like those of *Rhizodus*, but also wrinkled bony plates resembling that which I have attributed to *Baphetes*. From the hardness of the rock it is difficult to extract perfect specimens of these remains, and no bones other than teeth and dermal scales have been found.

Under this head may be noticed the coprolitic matter which not infrequently occurs with the remains of reptiles, in the erect trees of the Joggins, and to which reference has already been made in previous sections. This fossil excrement is of a brown or fawn colour, and consists in great part of carbonate of lime, indicating probably that shells of snails or other mullusks formed a considerable part of the food of the smaller reptiles of the coal swamps. Some portions of it are filled with small bones apparently of *Hylonomus Wymani*. Other examples contain abundance of fragments of chitinous matter referable in part to *Xylobius Sigillariæ*, the millipede of the coal; and in other instances to insects. Of the latter kind of remains the most interesting is an *Eye*, represented in Fig. 56. It must have belonged to an insect of considerable size, and with highly complex eyes, probably a neuropterous insect. As many as 250 facets are distinguishable in the fragment preserved, and the whole number in each eye may have amounted to 2000. In size and form the facets resemble those of the eye of a common Canadian dragon fly of the genus *Aeschna*, but are a little smaller. In this and other coprolites, though abundance of minute chitinous fragments remain, no others are sufficiently perfect to be recognized. In one coprolitic mass a quantity of thick crust or shell occurs, which under the microscope presents a minutely tubular and laminated appearance, resembling that of the shell of a crustacean rather than any other kind of structure with which I am acquainted. There may have been land-crabs in the coal period; but it is perhaps more likely that some one of the larger individuals of *Dendrerpeton* had been feeding on crustaceans in some pond or creek, before it fell into the pit in which it was entombed. It is however interesting to observe that no remains whatever of fishes have occurred in any of this coprolite or in the erect trees containing reptile bones, though such remains are very abundant in some of the associated beds. This fact confirms the inference deducible from other considerations, that the ground in which these open pits presented themselves, was not that of a very low swamp, liable to inundation, or very near to the sea or other bodies of water.

I may notice here certain very remarkable impressions, the origin of which I am at a loss to conjecture, but which may have had some relation to reptiles of the coal period. They occurred on the surface of a layer of grey sandstone about 60 feet above the bed containing the erect reptiliferous trees. This bed is one of a series of flaggy layers on which occur, with vegetable fragments, tracks, possibly of *Hylonomus*, and rain-marks. The impressions now referred to were thus described by me in 1861:

"They consist of rows of tranverse depressions, about an inch in length and one-fourth of an inch in breadth. Each trail consists of two of these rows running parallel to each other, and about six inches apart. Their direction curves abruptly, and they sometimes cross each other. From their position they were probably produced by a land or fresh-water animal—possibly a large Crustacean or gigantic Annelide or Myriapod. In size and general appearance they slightly resemble the curious *Climactichnites* of Sir W. E. Logan, from the Potsdam sandstone of Canada." To this I have only to add that the space between the rows of of marks is slightly depressed and smoothed, as if with a heavy body, like that of a serpent, trailed along.

I have given in Fig. 54, as a supplement to the history of *Dendrerpeton* and *Hylonomus*, a diagram of the form of the skull and the character of the dentition, restored from actual specimens This will serve further to illustrate the descriptions in previous sections.

In Fig. 65 I have represented a group of scales from the throat of *Dendrerpeton*, as they lie beside the skull from which the greater part of the details in Fig. 54 are taken. It will be seen that these are elongated, oval, and very closely imbricated in rows diverging in a pinnate manner from a mesial line. They would give much protection, while not deficient in flexibility. It is probable however that *Dendrerpeton* could breathe by other means than the gulping of air by the contraction of the throat; and would therefore be less dependent on the action of the gular muscles than the modern batrachians.

EXPLANATION OF PLATE VI, FIGS. 47, 48 AND 54 TO 56.

Additional Reptilian Remains.

Fig. 47—Tooth of unknown reptile or fish, natural size, section natural size, and portion of section magnified, showing infolding of the enamel and arrangement of the dentine.

" 48—Small segment of another tooth similar to the last in form and size, but more complex in the folding of the enamel.

" 54—Outer figure—Diagram of skull of *Dendrerpeton*, showing its size and general form, the appearance of the occipital condyles, and the arrangement of the double row of maxillary teeth and of the vomerine teeth.

" 54—Inner figure—Diagram of skull of *Hylonomus*, showing the arrangement of the single row of maxillary teeth and the patch of palatal teeth.

" 55—Bony scales of the throat of *Dendrerpeton Acadianum*, natural size.

XII. INVERTEBRATE AIR-BREATHERS.

Plate VI., Figs. 49 to 53, and 56 to 61.

In addition to the insect whose eye has already been noticed, but two species of land Invertebrates have been recognized in the coal of Nova Scotia. One of these is a snail, *Pupa vetusta*, the other a gally-worm or millepede, *Xylobius sigillariæ*. They are represented in the figures referred to at the head of this section, and have been fully described in the Journal of the Geological Society of London.

The first is the oldest known representative of the land snails, and so closely resembles the modern "chrysalis shells" of the genus *Pupa*, that I have not thought it desirable to refer it to a different genus, though the name *Dendropupa* has been proposed by Prof. Owen. Mr. J. S. Jeffreys and other eminent conchologists, who have seen the shell, concur in the opinion that it is a true *Pupa*; so that this genus, like Lingula and Nautilus, extends from the palæozoic to the modern times.

It may be described as a cylindrical shell, tapering to the apex, with a shining surface, marked with longitudinal rounded ridges. The whorls are eight or nine, rounded, and the width of each whorl is about half the diameter of the shell. The aperture is rather longer than broad; but is usually somewhat distorted by pressure. The margin of the lip is somewhat regularly rounded and is reflected outward. There are no teeth, but a slight indication of a ridge or ridges on the pillar lip, which may however be accidental. Length $\frac{3}{10}$ths of an inch or a little more. It was first recognized by Dr. Gould of Boston, in specimens obtained by Sir C. Lyell and the writer at the Joggins.

This little shell is remarkable, not merely for its great antiquity, but also because it is separated by so wide an interval of time from any other known species of its race, there being no other Pulmonate known until we reach the Purbeck beds, and no true land snail until we reach the Tertiary. It is also worthy of remark, that while hundreds of specimens have been found, not only in the erect reptiliferous trunks but in a bed 1217 feet lower, and separated by twenty-one coal beds, not any other species is found with it. It is very rare in modern times thus to find one species of snail in great abundance without any others. More especially is this so when we can examine, as in this case, not only the decayed trunks in which the creature sheltered itself, but also the beds of mud into which its dead shells were washed. These facts present a striking instance either of that "imperfection of the geological record", of which we hear so much, or of the solitary existence of a single species as a prophetic representative of future things, to be realized long after it had ceased to exist.

The lower bed, holding shells of *Pupa vetusta*, just mentioned, is a grey and greyish-blue under-clay, full of stigmarian rootlets, though without any coal or erect trees at its surface. It is 7 feet thick, with sandstone above and below. The shells occur very abundantly in a thickness of about two inches. They have been imbedded entire; but most of them have been crushed and flattened by pressure. They occur in all stages of growth; the young being, as is always the case in such shells, very different in general form from the adults. This bed is evidently a layer of mud deposited in a pond or creek, which afterward became silted up and carried sigillaroid trees. In modern swamps multitudes of shells occur in such places; and it is remarkable that in this case a single land shell should alone be found, without any trace of aquatic mollusks. The shells which occur in this bed are filled with the surrounding sediment. Those which occur in the erect *Sigillariæ*, on the other hand, except when they are crushed and flattened, are filled with a deposit of brown calc-spar. I infer from this that the latter when buried contained the animals, and consequently that these lived or sheltered themselves in the hollow trees, as is the habit of many modern land snails.

The gally-worm of the coal period, *Xylobius Sigillariæ*, must have existed in great numbers, as many layers in the erect trees are full of them. It probably lived in these decaying trunks just as its modern congeners do in similar places. As an air-breathing animal, and subsisting on vegetable food, it cannot have lived in water, or even in very wet places; and this is one of the evidences which in this case point to a greater dryness of the coal swamps than has hitherto been supposed probable; it also shows the resemblance of the conditions of the areas of coal accumulation to those of modern forests.

With regard to the affinities of *Xylobius*, its form and structure render certain its alliance with the Myriapods, and with the chilognathous division of them, or the gally-worms; but it is less certain to which of the families of the recent gally-worms it belongs, if to any of them. I have however little doubt that if it existed as a recent animal, it would go into the tribe *Bizonia* of Newport, and probably into the family of *Iulidæ*, to the typical genus of which it bears a strong resemblance in such points as can be made out. The oldest Myriapod previously known is, I believe, the *Geophilus proavus*, Münster, of the Jurassic period*.

EXPLANATION OF PL. VI, FIGS. 47 TO 53, AND 56 TO 61.

Invertebrate Air-Breathers.

Fig. 49.—*Pupa Vetusta*, natural size.
" 50.— " " magnified.

* Pictet, Palæontologie, Vol. 11, p. 405.

Fig. 51.—*Pupa Vetusta*, apex magnified.
" 52.— " " sculpture of surface magnified.
" 53.— " " cellular structure of shell highly magnified.
" 56.—*Eye of an Insect*, natural size and magnified, and three ocelli highly magnified.
" 57.—*Xylobius Sigillariæ*, Anterior segments magnified.
" 58.— " " natural size.
" 59.— " " part of one of the posterior segments magnified.
" 60.— " " caudal extremity magnified.
" 61.— " " head magnified, showing the eyes.

XIII.—Characters of the Animals described in this Paper.

To facilitate comparisons, I propose in this section to give an abstract of the leading structural points which may serve to distinguish the animals described in this paper from each other, and from such new species as may be discovered either in Nova Scotia or elsewhere. The characters given must necessarily be incomplete, and I shall confine myself to points distinctly ascertained and likely to be met with in any additional specimens which may be discovered.

Province.—VERTEBRATA.

Class.—Reptilia.

Order.—Microsauria.

Genus.—Hylonomus.

Reptiles or batrachians; with simple teeth in one series; biconcave vertebræ with arches anchylosed to them; ribs long and bent; limbs developed for walking; cranial bones smooth or nearly so; body protected below with oval or ovate bony scales, and above with horny scales and other appendages.

1. *Hylonomus Lyelli*, Dawson.—Teeth elongated, conical, thirty-six in each side of the jaw; larger toward the anterior part of the lower jaw; length of lower jaw .7 inch; limbs well developed, especially the posterior pair; bony scales oval; body above with imbricated horny scales, and rows of angular and bristly points.

2. *Hylonomus aciedentatus*, Dawson.—Teeth of maxillary and mandible thick wedge form, or nearly round at base and flattened to an edge at top. Teeth of intermaxillaries cylindric, bluntly

pointed, and with spiral furrows at the point. Number of teeth about forty on each side of jaw; length of lower jaw about 1 inch. Size more than twice that of *H. Lyelli.* Dermal covering so far as known, similar, but the parts large in proportion.

3. *Hylonomus Wymani*, Dawson.—Teeth obtusely conical, about twenty in each side of the jaw; length of lower jaw about .25 inch. Vertebræ elongated; size much smaller than that of *H. Lyelli.* Bony scales small and rounded, body above probably clothed in imbricated horny scales.

Order.—LABYRINTHODONTIA.

Genus.—BAPHETES.

Baphetes planiceps, Owen.—Teeth conical, hooked, striated longitudinally, and with inflected and convoluted cement; in two series; the inner of larger size. Cranial bones much corrugated. Head broad; breadth in front of orbits 6 inches; length from this line to front of snout 3½ inches. Probably a dermal covering of corrugated bony scales.

Genus.—DENDRERPETON.

Batrachians with a double series of teeth; the outer simple and flattened conic, the inner conical with inflected folds of cement. Teeth also on the vomer. Bones of skull corrugated; body protected below with long ovate or rhomboid bony scales, and above with imbricated horny scales. Form elongated, fore limbs largest, tail natatory, vertebræ biconcave, neural arches and bodies ossified.

1. *Dendrerpeton Acadianum*, Owen.—Inner teeth straight, conical; outer teeth short and obtuse. Length of head 2.75 inches, breadth at orbits about 2 inches, distance of orbits .7 inch. Length one to two feet.

2. *D. Oweni*, Dawson.—Teeth slender and hooked, and cement of inner teeth more perfectly inflected. Length of skull 1.2 inch, distance of orbits about .5 inch; length one foot or less.

Order.—ARCHEGOSAURIA ?

Genus.—HYLERPETON.

Hylerpeton Dawsoni.—Owen.—Teeth simple, bluntly conical, with large pulp cavity; about 13 in one side of the jaw. Two of the anterior teeth of the upper jaw twice as large as the others, and deeply sunk in the jaw. Length of lower jaw 1.3 inch Bones of skull puncto-striate. Limbs unknown, probably natatory.

SEDIS INCERTÆ.

Genus.—EOSAURUS.

Eosaurus Acadianus, Marsh.—Known by two biconcave vertebræ 2.4 inches in diameter and much resembling the caudal vertebræ of *Ichthyosaurus*—see paper by Mr. Marsh, Silliman's Journal, vol. XXXIV.

Province.—ARTICULATA.

Sub Class.—MYRIAPODA,

Order.—CHILOGNATHA.

Genus.—XYLOBIUS.

Xylobius Sigillariæ.—Dawson.—Body crustaceous, elongate, one to two inches in length, articulate; when recent, cylindrical or nearly so, rolling spirally. Feet small, numerous; segments 30 or more; anterior segments smooth, posterior with transverse wrinkles, giving a furrowed appearance. In some specimens traces of a series of lateral pores or stigmata. Labrum? quadrilateral, divided by notches or joints into three portions. Mandibles two-jointed, last joint ovate and pointed. Eyes ten or more on each side.

Province.—MOLLUSCA.

Class.—GASTEROPODA.

Order.—PULMONATA.

Genus.—PUPA.

Pupa Vetusta.—Dawson.—Cylindrical, tapering toward the apex; surface shining, minutely marked with longitudinal ridges; whorls 8 or 9, rounded, width of each equal to half the diameter of the shell; aperture rather longer than broad; outer lip regularly rounded and somewhat reflected; pillar lip straightened above, rounded below. Edentulous or with faint ridges on columella? Length .3 inch or a little more.

XIV.—Concluding Remarks.

Having finished the work which I proposed to myself, in illustration of the air-breathers of the coal period in Nova Scotia, it now remains to mention a few general thoughts which have arisen in connection with the animals which have been described.

I have endeavored, in the frontispiece, to present to the eye the forms and attitudes of these creatures. In doing so as little latitude as possible has been allowed to the imagination, and the structural points indicated by the bones and skin actually found, have been adhered to as closely as practicable. On the left hand *Baphetes planiceps* is seen emerging with a ganoid fish in its jaws. Next *Dendrerpeton Acadianum* is represented slowly walking up the inclined shore, and leaving its hand-like footprints thereon. A little farther up *Hylonomus Lyelli* is leaping in pursuit of an insect, and *Hylonomus Wymani* stands a little more in the foreground, while *Hylerpeton Dawsoni* is disporting itself in the water in front. I am quite aware that the form and action given to *Hylonomus* are at variance with the views of its nature which would ally it with *Archegosaurus;* but, as stated above, I cannot refuse my belief to the testimony of the bones themselves, which prove a development of the hind limbs not likely to have been associated with an elongated body and natatorial tail, and pointing to saltatory motion on land, and perhaps frog-like swimming in the water. In the middle ground of the picture I have placed a bank of soil, showing a section of a hollow trunk similar in situation to those in which the reptile bones of the Joggins occur, and on this bank and in the distance, I have endeavored to give some of the characteristic forms of the vegetation of the period: Ferns, *Cordaites*, *Sigillaria*, *Lepidendron*, *Lepidophloios*, and *Calamites*.

It has recently been a favorite view with some writers on this subject, that coal beds may have been formed in shallow salt water, and that *Sigillariæ* may have grown in such places, like mangroves. It will be seen from the frontispiece, that I do not believe in this theory of the formation of coal, but on the contrary adhere to the opinion which I have formerly maintained, that the coal beds and under-clays are of the nature of peaty soils. In no part of the world are the coal measures better developed or more fully exposed than in the coast sections of Nova Scotia and Cape Breton, and in these, throughout their whole thickness, no indication has been found of any of the marine fossils of the lower carboniferous limestone. Abundant remains of fishes occur, but these may have frequented estuaries, streams and ponds, and the greater part of them are small ganoids which, like the modern *Lepidosteus* and *Amia*, may have been specially fitted by their semi-reptilian respiration, for the impure waters of swampy regions. Bivalve mollusks also abound; but these are all of the kinds to which I have given the generic name *Naiadites*, and Mr. Salter those of *Anthracomya* and *Anthracoptera*. These shells are all distinct from any known in the marine limestones. Their thin edentulous valves, their structure consisting of a wrinkled epidermis, a thin layer of prismatic shell and an inner layer of sub-nacreous shell composed of obscure polygonal cells, all remind us of the Anodons and Unios.* A slight notch in front, noticed by Salter, as possibly byssal, concurs with their mode of occurrence in rendering it probable that, like mussels in modern estuaries, they attached themselves to floating or sunken timber. They are thus removed, both in structure and habit, from truly marine species; and if not actually of the family *Unionidæ*, must have been fresh-water or brackish-water mussels closely allied to this family. The crustaceans (*Eurypterus*, *Diplostylus*, *Cyprids*,) and the worm shell (*Spirorbis*)† found with them, are not necessarily marine, though some of them belonged probably to brackish water, and they have not yet been found in those carboniferous beds deposited in the open sea. There is thus in the whole thickness of the middle coal measures of Nova Scotia, a remarkable absence at least of open sea animals; and if, as is quite probable, the sea inundated at intervals the areas of coal accumulation, the waters must have been shallow and to a great extent land-locked, so that brackish-water rather than marine animals inhabited them.

On the other hand, there are in these coal measures, abundant evidences of land surfaces; and sub-aeriel decay of vegetable mat-

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* The microscopic structure of these shells is well preserved, and presents some differences of detail which I hope at a future time to illustrate.

† The idea of some Palæobotanists, that these so-called Spirorbes are fossil parasitic plants, is obviously a mistake. They are calcareous shells, and present under the microscope a prismatic cellular structure, with numerous minute tubuli, in the manner of the shells of modern *Serpulæ* and *Spirorbes*. In Nova Scotia I have seen *Estheriæ* only in the lower coal formation.

ter in large quantity is proved by the occurrence of the mineral charcoal of the coal itself, as I have elsewhere shown.* The erect trees which occur at so many levels, also imply sub-aerial decay. A tree imbedded in sediment and remaining under water, could not decay so as to become hollow and deposit the remains of its wood in the state of mineral charcoal within the hollow bark. Yet this is the case with the greater part of the erect sigillariæ which occur at more than 20 levels in the Joggins section. Nor could such hollow trunks become repositories for millipedes, snails and reptiles, if under water. On the other hand, if, as seems necessary to explain the character of the reptiliferous erect trees, these remained dry or nearly so in the interior, this would imply not merely a soil out of water, but comparatively well drained; as would indeed always be the case, when a flat resting on a sandy subsoil was raised several feet above the level of the water. Farther, though the peculiar character of the roots of *Sigillariæ* and *Calamites* may lend some countenance to the supposition that they could grow under water or in water-soaked soils, this will not apply to coniferous trees, to ferns, and other plants, which are found under circumstances which show that they grew with the *Sigillariæ*.

In the coal measures of Nova Scotia, therefore, while marine conditions are absent, there are ample evidences of fresh-water or brackish-water conditions, and of land surfaces, suitable for the air-breathing animals of the period. Nor do I believe that the coal measures of Nova Scotia were exceptional in this respect. It is true that in Great Britain evidences of marine life do occur in the coal measures; but not, so far as I am aware, in circumstances which justify the inference that the coal is of marine origin. Alternations of marine and land remains, and even mixtures of these, are frequent in modern submarine forests. When we find, as at Fort Lawrence in Nova Scotia, a modern forest rooted in upland soil forty feet below high-water mark,† and covered with mud containing living Tellinas and Myas, we are not justified in inferring that this forest grew in the sea. We rather infer that subsidence has occurred. In modern salt marshes it is not unusual to find every little runnel or pool full of marine shellfish, while in the higher parts of the marsh land plants are growing;

* Journal of Geological Survey, vol. XV.

† Journal of Geological Society, vol. XI

and in such places the deposit formed must contain a mixture of land plants and marine animals with salt grasses and herbage—the whole *in situ.**

These considerations serve, I think, to explain all the apparently anomalous associations of coal plants with marine fossils; and I do not know any other arguments of apparent weight that can be adduced in favor of the marine origin of coal, except such as are based on misconceptions of the structure and mode of growth of sigillaroid trees and of the stratigraphical relations of the coal itself.† It is to be observed, however, that while I must maintain the essentially terrestrial character of the ordinary coal and of its plants, I have elsewhere admitted that cannel coals and earthy bitumen present evidences of sub-aquatic deposition; and have also abundantly illustrated the facts that the coal plants grew on swampy flats, liable not only to river inundations, but also to subsidence and submergence.‡ In the oscillation of these conditions it is evident that *Sigillariæ* and their contemporaries must often have been placed in conditions unfavorable or fatal to them, and when their remains are preserved to us in these conditions, we may form very incorrect inferences as to their mode of life.

* In the marshes at the mouth of Scarborough River, in Maine, channels not more than a foot wide, and far from the sea, are full of Mussels and Myæ; and in little pools communicating with these channels there are often many young *Limuli*, which seem to prefer such places, and the cast off shells and other remains of which many become imbedded in mud and mixed with land plants, just as in the shales of the coal measures.

† It is unfortunate that few writers on this subject have combined with the knowledge of the geological features of the coal, a sufficient acquaintance with the phenomena of modern marshes and swamps, and with the conditions necessary for the growth of plants such as those of the coal. It would be easy to show, were this a proper place to do so, that the "swells," "rock-faults," splitting of beds, and other appearances of coal seams, quite accord with the theory of swamp accumulation; that the plants associated with *Sigillariæ* could not have lived with their roots immersed in salt water; that the chemical character of the underclays implies drainage and other conditions impossible under the sea; that the composition and minute structure of the coal are incompatible with the supposition that it is a deposit from water, and especially from salt water; and that it would be more natural to invoke wind-driftage as a mode of accumulation for some of the sandstones, than water-driftage for the formation of the coal.

‡ Journal of Geol. Socy., vols. X and XV and "Acadian Geology."

Farther, it is be observed that the conditions of submergence and silting up which were favorable to the preservation of specimens of *Sigillariæ* as fossils, must have been precisely those which were destructive to them as living plants; and on the contrary that the conditions in which these forests may have flourished for centuries, must have been those in which there was little chance of their remains being preserved to us, in any other condition at least than that of coal, which reveals only to careful microscopic examination the circumstances, whether aerial or aquatic, under which it was formed.

It is also to be observed that, in conditions such as those of the coal-formation, it would be likely that some plants would be specially adapted to occupy newly emerged flats and places liable to inundation and silting up. I believe that many of the *Sigillariæ*, and still more eminently the *Calamites*, were suitable to such stations. There is direct evidence that the nuts of *Sigillariæ* (Trigonocarpa) were drifted extensively by water over submerged flats of mud. Many *Cardiocarpa* were winged seeds which may have drifted in the air. The Calamites may, like modern *Equiseta*, have produced spores with elaters capable of floating them in the wind. One of the thinner coals at the Joggins is filled with spores or spore-cases that seem to have carried hairs on their surfaces, and may have been suited to such a mode of dissemination. I have elsewhere proved that at least some species of *Calamites*, were by their mode of growth admirably fitted for growing amid accumulating sediment and for promoting its accumulation.

These and other facts to be ascertained only by a careful and minute study of the coal formation and its fossils, are essential to a right understanding of the complicated conditions involved in the growth of these great deposits; and notwithstanding the immense mass of facts which has been collected, there is still no department of geology more encumbered with crude hypotheses and hasty generalizations, than that which relates to the history of the carboniferous period.

The reptiles of the coal formation are probably the oldest known to us, and possibly, though this we cannot affirm, the highest products of creation in this period. Supposing, for the moment, that they are the highest animals of their time, and what is still less likely, that those which we know are a fair average of the rest, we have the curious fact that they are all carnivorous, and the greater part of them fitted to find food in the water as well as on he land. The plant feeders of the period, on the land at least, are all invertebrates, as snails, millepedes, and perhaps insects. The air-breathing vertebrates are not intended to consume the exuberant vegetable growth, but to check the increase of its animal enemies. Plant life would thus seem to have had in every way the advantage. The millepedes probably fed only on roots and decaying substances—the snails on the more juicy and succulent plants growing in the shadow of the woods. While, moreover, the vegetation of the coal swamps was most abundant, it was not, on the whole, of a character to lead us to suppose that it supported many animals. Our knowledge of the flora of the coal swamps is sufficiently complete to exclude from them any abundance of the higher phænogamous plants. We know little, it is true, of the flora of the uplands of the period; but when we speak of the coal formation land, it is to the flats only that we refer. The foliage of the plants on these flats, with the exception of that of the ferns, was harsh and meagre, and there seem to have been no grasses or other nutritious herbaceous plants. These are wants of themselves likely to exclude many of the higher forms of herbivorous life. On the other hand there was a profusion of large nut-like seeds, which in a modern forest would probably have afforded subsistence to squirrels and similar animals. The pith and thick soft bark of many of the trees must at certain seasons have contained much nutritive matter, while there was certainly sufficient material for all those insects whose larvæ feed on living and dead timber, as well as for the creatures that in turn prey on them. It is remarkable that, perhaps with the exception of a very few European insects, no animals fitted to avail themselves of these vast stores of food have been discovered in the coal. The question: "What may have fed on all this vegetation?" was never absent from my mind in all my explorations of the Nova Scotia coal sections; but no trace of any creature other than those already mentioned has ever rewarded my search. In Nova Scotia it would seem that a single snail and a single gally-worm were the sole links of connection between the plant creation and air-breathing vertebrates. Is this due to the paucity of the fauna, or the imperfection of the record? The fact that a few erect stumps have revealed nearly all the air-breathers yet found, argues strongly for the latter cause; but there are some facts bearing on the other side.

Our gally-worm, if, like its modern relatives, hiding in crevices of wood in forests, was one of the least likely animals to be found in aqueous deposits. The erect trees gave it its almost sole chance of preservation. *Pupa vetusta* is a small species, and its shell very thin and fragile, while it probably lived among thick vegetation. Further it occurs in great abundance in the sigillaria stumps, and also in a bed separated from these by a thickness of 1217 feet, including 21 coal seams, having an aggregate thickness of about 20 feet, 3 beds of bituminous limestone of animal origin, and perhaps 20 beds holding *Stigmaria* in situ, or erect *Sigillariæ* and *Calamites*. The lapse of time implied by this succession of beds, many of them neccessarily of very slow deposition, must be very great, though it would be mere guess work to attempt to resolve it into years. Yet long though this interval must have been, *Pupa vetusta* lasted without one iota of change through it all; and more remarkable still, was not accompanied by any other mollusk of its family. Where so many specimens occur, and in situations so diverse, without any additional species, the inference is strong that no other of similar habits existed. If in any of those sub-tropical islands, whose climate and productions somewhat resemble those of the coal period, after searching in and about decaying trees, and also on the bars upon which rivers and lakes drifted their burdens of shells, we should find only a single species, but this in very great numbers, we would surely conclude that other species, if present, were very rare.

Again, footprints referrible to *Dendrerpeton* occur in the lower coal measures below the marine limestones, in the middle coal measures, and in the upper coal formation, separated by a thickness of beds which may be estimated at 15,000 feet, and certainly representing a vast lapse of time. Did we know the creature by these impressions alone, we might infer its continued existence for all this great length of time; but when we also find its bones in the principal repositories of reptile remains, and in company with the other creatures found with it, we satisfy ourselves that of them all it was the most likely to have left its trail in the mud flats. We thus have reason to conclude that it existed alone during this period, in so far as its especial kind of habitat was concerned; though there lived with it other reptiles, some of which, haunting principally the woods, and others the water, were less likely to leave impressions of their footprints. These may be but slight indications of truth, but they convey strong impressions of the persistence of species, and also of the paucity of species belonging to these tribes at the time.

Every fact of this kind is at present regarded in its bearings on the probable origin of species, and on the questions of independent creation or of derivation by natural selection, or by some other secondary law. Naturalists have set themselves to discover the philosopher's stone which can transmute the viler into the more exalted species. They will probably fail as others have failed before, but may at least hope to elicit some law of succession or occurrence of living creatures, and to settle more clearly than heretofore what should be regarded as natural species, as distinct from mere races and varieties. It may perhaps be found, after all, that the question whether the creative force manifested itself in calling certain species into existence from nothing, from dead matter, or from previously organized matter, whether by an instant and miraculous act, by more sudden natural change, or by slow and gradual processes, is insoluble by us; or that all or many of these modes may have been concerned in making living beings what they are; but of this every sound thinker must be convinced, that if not originating in distinct creative acts, species as we have them must be due to causes vastly more recondite and complex than the present advocates of derivation suppose. Nor can even the transmutationist altogether get rid of the miracle of creation; though he may push it back to as great a distance as possible. Some creative force must always precede law, and this even when the theorist goes so far as to derive all things from a concourse of atoms; or, more venturous still, dispenses even with atoms, and resolves all that he knows into an aggregate of conflicting yet mutually convertible forces. It is scarcely to be supposed that any member even of this last school, will choose to plunge into the two-fold absurdity of supposing that forces are themselves produced by nothing but the law of their own action, and produce all things by their action on nothing but themselves.

If we could affirm that the air-breathers of the coal period were really the first species of their several families, they might acquire additional interest by their bearing on this question of origin of species. We cannot affirm this; but it may be a harmless and not uninstructive play of fancy to suppose for a moment that they actually are so, and to inquire on this supposition as to the mode of their introduction. Looking at them from this point of view, we shall first be struck with the fact that they belong to all of the three great leading types of animals which include our modern air-breathers—the Vertebrates, the Articulates, and the

Mollusks. This at once excludes the supposition that they can all have been derived from each other, within the limits of the coal period. No transmutationist can have the hardihood to assert the convertibility, by any direct method, of a snail into a millipede, or of a millipede into a reptile. The plan of structure in these creatures is not only different but contrasted in its most essential features. It would be far more natural to suppose that these animals sprang from aquatic species of their respective types. We should then seek for the ancestors of the snail in aquatic gasteropods, for those of the millipede in worms or crustaceans, and for those of the reptiles in the fishes of the period. It would be easy to build up an imaginary series of stages, on the principle of natural selection, whereby these results might be effected; but the hypothesis would be destitute of any support from fact, and would be beset by more difficulties than it removes. Why should the result of the transformation of water snails breathing by gills be a *Pupa*? Would it not much more likely be an *Auricula* or a *Limnea*? It will not solve this difficulty to say that the intermediate forms became extinct and so are lost. On the contrary they exist to this day, though they were not, in so far as we know, introduced so early. But negative evidence must not be relied on; the record is very imperfect, and such creatures may have existed though unknown to us. It may be answered that they could not have existed in any considerable numbers, else some of their shells would have appeared in the coal formation beds, so rich in crustaceans and bivalve mollusks. Further, the little Pupa remained unchanged during a very long time, and shows no tendency to resolve itself into anything higher or to descend to anything lower. Here, if anywhere, in what appears to be the first introduction of air-breathing invertebrates, we should be able to find the evidences of transition from the gills of the prosobranchiate and the crustacean to the air sac of the pulmonate and the tracheæ of the millipede. It is also to be observed that many other structural changes are involved, the aggregate of which makes a pulmonate or a millipede different in every particular from its nearest allies among gill-bearing gasteropods or crustaceans.

It may be said however that the links of connection between the coal reptiles and the fishes are better established. All the known coal reptiles have leanings to the fishes in certain characters; and in some, as in *Archegosaurus*, these are very close. Still the interval to be bridged over is wide and the differences are by no means those which we should expect. Were the problem given to convert a ganoid fish into an *Archegosaurus* or *Dendrerpeton*, we should be disposed to retain unchanged such characters as would be suited to the new habits of the creature, and to change only those directly related to the objects in view. We should probably give little attention to differences in the arrangement of skull bones, in the parts of the vertebræ, in the external clothing, in the microscopic structure of the bone, and other peculiarities for serving similar purposes by organs on a different plan, which are so conspicuous so soon as we pass from the fish to the batrachian. It is not in short an improvement of the organs of the fish that we witness so much as the introduction of new organs. The foot of the batrachian, bears perhaps as close a relation to the fin of the fish as the screw of one steamship to the paddle wheel of another, or as the latter to a carriage wheel; and can be just as rationally supposed to be not a new instrument but the old one changed.

Again, our reptiles of the coal do not constitute a continuous series, nor is it possible that they can all, except at widely different times, have originated from the same source. To suppose that *Hylonomus* grew out of *Dendrerpeton* or *Baphetes*, and *Eosaurus* out of either, startles us almost as much as to suppose that *Baphetes* grew out of *Rhizodus*, or *Hylonomus* out of *Palæoniscus*. It either happened, for some unknown reason, that many kinds of fishes put on the reptilian guise in the same period, or else the vast lapse of ages required for the production of a reptile from a fish, must be indefinitely increased for the production of many dissimilar reptiles from each other; or on the other hand we must suppose that the limit between the fish and reptile being once overpassed, a facility for comparatively rapid changes became the property of the latter. Either supposition would, I think, contradict such facts bearing on the subject as are known to us.

We commenced with supposing that the reptiles of the coal might possibly be the first of their family, but it is evident from the above considerations, that on the doctrine of natural selection, the number and variety of reptiles in this period would imply that their predecessors in this form must have existed from a time earlier than any in which even fishes are known to exist; so that if we adopt any hypothesis of derivation, it would probably be necessary to have recourse to that which supposes at particular periods a sudden and as yet unaccountable transmutation of one form into another; a view which in its remoteness from anything included under ordinary natural laws, does not materially differ from that currently received idea of creative intervention, with which, in so far as our coal reptiles can inform us, we are for the present satisfied.

There is one other point which strikes the naturalist in considering these animals, and which has a certain bearing on such hypothesis. It is the combination of various grades of reptilian types in these ancient creatures. It has been well remarked by Hugh Miller, and more fully by Agassiz, that this is characteristic of the first appearance of new groups of animals. Now selection, as it acts in the hands of the breeder, tends to specialization; and natural selection, if there is such a thing, is supposed to tend in the same direction. But when some distinctly new form is to be introduced, an opposite tendency seems to prevail, a sort of aggregation in one species of characters afterward to be separated and manifested in distinct groups of creatures. The introduction of such new types also tends to degrade and deprive of their higher properties previously existing groups of lower rank. It is easy to perceive in all this, law and order in that higher sense in which these terms express the will and plan of the Supreme Mind, but not in that lower sense in which they represent the insensate operation of blind natural forces.

Humble though the subjects of this paper are, we see in them the work of Supreme Intelligence, introducing new types upon the scene and foreshadowing in them those higher forms afterward to be created. It is this, their Divine origin, and the light which they throw on the plan and order of the creative work, of which we ourselves form a part, that gives them all their interest to us. They are the handiwork of our Father and our God, traces of his presence in primeval ages of the earth, evidences of the unity of his plan and pledges of its progressive nature; adding their feeble voices to the testimony of revelation in respect to the history of creation in its earlier stages, and to the carrying on of that plan which still involves the extinction of many things from the present world, and the elevation of others into new and glorious manifestations. Their place in the system of nature and in the order of the world's progress, their uses in their own time and their relations to other beings as parts of the great cosmos, are the points that chiefly interest us: and if any one desires to understand more in detail, how they were created, we wish him all success in his inquiries, but warn him not to suppose that this great mystery is to be solved by a reference merely to material agencies apart from that Spiritual Power who is the essence of forces, the origin of laws.

ART. XXII.—*On the Origin of Eruptive and Primary Rocks.* By THOMAS MACFARLANE. *Part I.*

(Presented to the Natural History Society.)

On a former occasion,* I had the honor of presenting to this Society a series of papers describing the primitive formations as they occur in Norway, and comparing them with their Canadian equivalents. I then confined myself to a simple statement of the facts known regarding these formations, referring to their constituent rocks, to their structure, and to the order of their succession, but abstaining altogether from any attempt to propound a theory which might explain the various phenomena described. I subsequently † however gave a translation of a chapter from Naumann's classical *Lehrbuch der Geognosie*, wherein the various views entertained by geologists as to the origin of these formations, are plainly and impartially stated. It there appears, that although there exists an extraordinary diversity of opinion among geologists on this subject, there are two distinct and opposing theories, under one or other of which those different views may be classified. The first of these theories, and the one adopted by the majority of geologists, supposes the primitive or primary rocks to have resulted from the alteration or metamorphism of sedimentary strata. The second theory supposes them, in part at least, to represent the first solidified crust of our planet.

Although these opposing theories might with justice be respectively termed, so far as they refer to the origin of the primary rocks, the aqueous or metamorphic theory, and the igneous theory, still they must not be considered as bearing the slightest relation to the old theories adopted, and so pertinaciously

* Canadian Naturalist, Vol. VII, p. 1.

† Canadian Naturalist, Vol. VII, p. 254.

argued by the neptunists and plutonists. The question in dispute then, referred to the origin of the undoubtedly intrusive and unstratified rocks,—granite, porphyry, basalt, &c. So far however as concerns the primitive stratified rocks, Werner and Hutton both regarded them as of sedimentary origin, although they differed as to the state in which they were deposited; and Hutton alone considered it necessary to explain their crystalline condition by the metamorphic action of heat. Indeed, instead of there being any analogy between the old controversy and the present question, it happens that Hutton, the founder of the plutonic school of former days, was the originator of the theory at present prevailing of the aqueous origin of the primary stratified rocks.

On the other hand, it is scarcely possible to say who was the author of the igneous theory, although the writings in which it was propounded are of comparatively recent date. Probably among its earliest supporters was Sir H. T. De la Beche, who thus expresses himself on the subject:—"If we consider our "planet as a cooling mass of matter, the present condition of "its surface being chiefly due to such a loss of its original heat "by long continued radiation into the surrounding space, that "from having been wholly gaseous, then fluid and gaseous, and "subsequently solid, fluid and gaseous, the surface at last became "so reduced in temperature, and so little affected by the remain-"ing internal heat, as to have its temperature chiefly regulated "by the sun, there must have been a time when solid rock was "first formed, and also a time when heated fluids rested upon it. "The latter would be conditions highly favorable to the pro-"duction of crystalline substances, and the state of the earth's "surface would then be so totally different from that which now "exists, that mineral matter even abraded from any part of the "earth's crust which may have been solid, would be placed under "very different conditions at different periods. We could scarcely "expect that there would not be a mass of crystalline rocks "produced at first, which, however they may vary in minor "points, should still preserve a general character and aspect, the "result of the first changes of fluid into solid matter, crystalline "and sub-crystalline substances prevailing, intermingled with "detrital portions of the same substances, abraded by the move-"ments of the heated and first formed aqueous fluids." *

* Report on the Geology of Cornwall, &c., p. 32.

Although this language is somewhat indefinite, still the idea embodied in the igneous theory is shadowed forth in it, and on the whole this quotation may be considered as the text of the present essay. It is I believe possible to maintain, with every appearance of reason, that the Primitive Gneiss formation constitutes the first solidified crust of the originally fused globe, and that the crystalline and sub-crystalline rocks of the Primitive Slate formation are the products of a peculiar transition period, during which aqueous fluids gradually accumulated on the surface, and the latter attained a temperature approaching somewhat to that of the present day.

In attempting to show that this proposition is supported by geological evidence, I shall confine myself principally to arranging and elaborating the facts and arguments in support of it, which I have found scattered through a considerable number of geological papers and manuals. I shall also, in order to state the case with full force, be obliged to insert prefatorily much of what may be considered as mere elementary facts in physical geography and geology. I shall first refer to the evidences which we possess regarding the internal heat of our planet and its density, deducing from them certain conclusions as to the present condition of the interior of the earth. In doing so, I shall allude to the nature of certain volcanic products; and then continuing the considerations of the constitution and mode of occurrence of igneous rocks, I shall search back through the various eruptive formations for evidences of the nature of the igneous action which has taken place in former periods of the earth's history, and ultimately arrive at the consideration of the theory of the earth's original state of igneous fluidity. This theory, universally admitted by geologists, will then afford us a firm starting point for some speculations as to the process of the first solidification of the earth's crust, and the origin of gneissoid rocks. Pursuing the subject further, I shall endeavour to shew that the peculiar rocks of the Primitive Slate formation are also products of the action of the first condensed fluids on the heated crust of the earth. There are few theories whereon such a unanimity of opinion exists among geologists, as that of the originally fused condition of our planet, and few formations regarding the origin of which more uncertainty prevails than that of the primitive formations. If therefore it can be shewn to be probable that these primitive formations have merely resulted from an originally fused globe in the process of cooling, much will have been done toward filling up a great gap in the history of the earth's development.

I. The Temperature and Density of the Interior of our Planet.

It will no doubt seem to many that the matters to be treated of in this chapter, are far beyond the limits of the subject of the present paper. Since, however, the originally fused condition of our planet, and the constitution of its mass, are at the foundation of the igneous view of the origin of the primitive gneiss formation, it would seem necessary to refer to the reasonings upon which the idea of a fused globe, and the various theories propounded regarding the structure of the interior of our planet, are based. Many of these reasonings are founded on phenomena observable at the present day, which point to the existence of intense heat and extraordinary density in the centre of the earth. Hence this proposed recapitulation of the evidences of internal heat and density may not be out of place.

Whatever may have been the temperature of the earth's surface in the former periods, it is abundantly evident that it is now altogether regulated by the sun. Since the influence of the sun's rays penetrates to some extent beneath the surface, and affects the degree of temperature there existing, it will be necessary to define the extent to which this takes place, before proceeding to advert to the influence of the subterranean heat on the temperature of the earth's crust. It is obvious that the influence of the sun's rays is exerted very irregularly, and that variations in the degree to which the surface of the earth is affected by it occur throughout the day, and annually. The diurnal variations are of course not so great as those of the year, and the latter vary of course with the situation of the point of observation. These diurnal and annual variations are less and less felt, the deeper, to a certain point, we penetrate beneath the surface. Towards this point the extremes of temperature gradually approach nearer to each other, the differences are gradually equalized, and finally they disappear completely. The depth at which this point of constant temperature exists varies with latitude and climate, and with the capacity for conducting heat which the surface possesses. In African deserts, where the sand has been found to possess sometimes a temperature of 40° to 48°

R,* the point of constant temperature is near the surface, because the annual variations are comparatively small. The average temperature of the warmest month in Singapore is 22.40° R., of the coldest month 20.6° R.† The yearly variation therefore, does not exceed 1.8° R., and consequently the point where the extremes equalize themselves must be very near the surface. In higher latitudes however, where the variations are greater, (London 11.80° R., Paris 13.50° R., New York 21.70° R.,) the point of invariable temperature lies deeper. In the temperate zone, the daily variations disappear at a depth of from three to five feet, and the annual variations at a depth of from 60 to 80 feet beneath the surface. The celebrated thermometer placed 86 feet beneath the surface in the vault of the national observatory at Paris in 1783, shews constantly a temperature of 9.60° R.‡ Since the average temperature of Paris is 8.60° R., it would therefore appear that even at this depth of 86 feet the influence of the central heat begins to make itself felt.

As early as the year 1678, the Jesuit Athanasius Kircher was informed by Hungarian miners that a higher temperature existed in the depths of mines, than on the surface of the earth, and Von Trebra, in 1785, mentions the same fact.§ Not only was practical experience of the existence of a subterranean source of heat first obtained by miners, but the first experiments made with the view of ascertaining the temperature of the earth's crust at greater depth, were instituted in mines. The results of these experiments constituted for a long time the only proofs of the increase of the temperature with the depth. It cannot be denied however that the observations made in the shafts and underground working of mines are subject to various disturbing influences, so that it would appear that at least the earliest of these observations are less to be relied upon than those from other sources. But since they shew a general coincidence they furnish, when taken in connection with other observations, a complete confirmation of the fact of the increase of temperature with the depth. The results of the experiments instituted in mines, differ in value according as they have reference to the tempera-

* Pouillet; Muller, Lehrbuch der Physik and Meteorologie, Vol II, p. 724.

† Ibid II, 716.

‡ Quenstedt, Epochen der Natur, p. 13.

§ Ibid p. 12.

ture of the air, water or rock there occurring. Those obtained from observations made on the rock plainly deserve most confidence.* Not only in European mines, but in those of South America, Mexico, the United States, and the East Indies, observations have proved that the temperature increases with the depth, and shewn that it remains invariable at one and the same depth, provided no disturbing causes are at work. In 1740, Gensanne instituted experiments at Giromagny in the Vosges which gave the following results :— At a depth of

339	feet the	temperature	was........	12.5°.	Centigrade.
634	"	"	"	13.1°	"
948	"	"	"	19.0°	"
1333	"	"	"	22.7°	"

Saussure obtained the following results at Bex in the Canton Waadt, in a shaft in which no one had been for three months previously.

Depth.	Temperature.	
322...........................	14.4°	Centigrade.
564...........................	15.6°	"
677...........................	17.4°	"

Similar observations were afterwards made in the mines of Freiberg by d'Aubuisson, Von Humboldt, and Von Trebra; in the mines of Cornwall by Forbes, Fox, and Barkam, and in the Anzasca valley by Fontanetti. The most comprehensive and exact observations were however those made at the instance of the government mining officials of Saxony and Prussia, in the mines of those countries. The observations in the Prussian mines led to the following results.†

1. That a decided increase of temperature takes places with increase of depth.
2. That the temperature at every greater depth is invariable, since the annual oscillations were at the most only 1°.
3. That the depth corresponding to an increase of temperature of 1°, differs extremely in different localities, varies from 48 to 355 feet, and on an average amounts to 167 feet.
4. That the temperature increases twice as rapidly in coal mines as in ore mines.

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* Naumann, Lehrbuch der Geognosie, I, 49.

† Poggend. Ann; vol. xxii, 1831, p. 497.

5. That the observations did not afford data sufficiently decided for the establishment of any law as to the progression of the increase of temperature.

The experiments instituted in the Saxony mines were under the careful direction of Reich, and made with very good thermometers, sunk forty inches into the solid rock, and with every possible precaution. They yielded the following results.*

1. That the temperature increases decidedly with the depth.
2. That the temperature is invariable at every one point of observation.
3. That the average distance, corresponding to an increase of one degree Reaumur in temperature, is 129 feet.
4. That a general law with regard to the relative increase of temperature cannot be deduced from these experiments.
5. That the rock in the underground workings and in the course of time becomes somewhat cooled by the air of the mine, and that on the whole the cooling influences overbalance the heating ones.

Among other observations the following may be mentioned:— The distance corresponding to an increase of temperature of one degree was determined by:

Oldham in Waterford, Ireland, as	165	Feet.
Phillips in New Castle	100	"
Hodgkinson in Manchester	115	"
Hinzeau in Belgium	102	"
Cordier near Canneaux	111	"†

It will be observed that in the observations mentioned above, the depth corresponding to an increase of 1° varies from 92.3 to 167 feet.

Conclusive as are the experiments in mines with regard to the increase of temperature, they after all refer only to comparatively slight depths. The depths at which observations have been made in artesian wells exceed those of the mine experiments. As is well known, by means of these artesian wells, a vent is opened whereby the water of subterranean reservoirs or springs, confined

* Reich: Beobachtungen über die Temperatur des Gesteines, 1834.
† Naumann; Lehrbuch der Geognosie, I, 54.

at great depths, finds a passage to the surface. This water, having found its way from the surface into those depths, is generally subject to a very strong hydrostatic pressure, and possesses the temperature of the depth from which it is liberated. The bore-holes, by means of which these subterranean reservoirs are tapped, are especially fitted for experiments as to the temperatures of various depths, since their depth, while being bored is accurately known, and since they are always filled with water. Such experiments have repeatedly been made, and have led to the complete and incontrovertible confirmation of the fact that the temperature of every constant depth, beneath the influences of the variations of temperature on the surface is invariable, and that the temperature increases continually with the depth. The following tables contain some of the most remarkable observations of this nature.

Artesian well at Rudersdorf, near Berlin :—

Depth.	Temperature.
380 feet	17.12° Centigrade.
500 "	17.75° "
655 "	19.75° "
880 "	23.50° "

Artesian well of Grenelle, in Paris :—

Depth.	Temperature.
917 feet	22.20° Centigrade.
1231 "	23.75° "
1555 "	26.43° "
1684 "	27.70° "

Artesian well of Neusalzwerk, Westphalia :—

Depth.	Temperature.
580 feet	19.7° Centigrade.
1285 "	27.5° "
1935 "	31.4° "
2144 "	33.6° "

In the artesian well at Mondorff, in the Grand Duchy of Luxemburg, at a depth of 2066 feet, a temperature of 34° Centigrade was even observed. We have already seen that the results of the experiments in mines, as to the depth corresponding to one degree of increase, varied considerably. The results obtained in artesian wells as to this point were much more satisfactory. The distance corresponding to an increase of 1° was found to be:

At Rouen	90. 8	Feet.
At Mondorff	91. 1	"
At Rüdersdorf	92. 0	"
At Neusalzwerk	92.27	"
At Grenelle	95. 0	"
At St. Andre (Eure)	95. 3	"

These results shew a remarkable coincidence, but there are others which shew extraordinary differences, such as the following:—

At La Rochelle	60. 6	Feet.
At Pitzbuhl near Magdeburg	80. 0	"
At Artem in Thüringia	120. 0	" *

These latter results, as well as those differing widely from each other, which have been obtained in mines, are not to be regarded as at all invalidating the general result. These differences may be caused by variations in the conducting capacity of the various rocks; by the neighborhood of subterranean water courses; but especially by the greater or lesser distance of the point of observation from the source of the internal heat; in other words by the varying thickness of the earth's crust.

We have thus seen that actual observations have been made as to the temperature of the crust at various depths beneath the surface, sometimes as much as 2000 feet, and the result of these has been to prove that an increase of temperature takes place with the depth, amounting on the average to about 1 ° Cent. for every 100 feet. We have next to enquire as to whether any increase of temperature takes place at still greater depths. We have abundant proofs that this further increase does take place, in the temperatures of the thermal springs so widely distributed over every part of the surface of the globe. These temperatures are much higher than those which have been observed in mines or artesian wells. The waters of these springs rush with extraordinary force out of the ground, from which circumstance we may conclude that they ascend from their sources, with a rapidity which does not permit them to cool very considerably in their passage through the upper and colder strata. Although we are ignorant of the exact depth from which the waters of these springs rise, we are nevertheless justified in assuming that they come from greater depths than those of mines or artesian wells.

* Naumann's Geognosie, I, 48.

The highest temperature yet observed in the latter was at Mundorff, viz,, 34° Centigrade. The following is a list of remarkable thermal springs whose temperatures exceed that just mentioned.

Spring.	Temperature.	
Pfäffers	37.2°	Centigrade.
Wildbad	37.5°	"
Barrèges	40.0°	"
Aix-la-Chapelle	44° to 57.5°	"
Bath	46.25°	"
Leuck	50.2°	"
Aix in Savoy	54.3°	"
Ems	56.25.°	"
Baden-Baden	67.5°	"
Wiesbaden	70.0°	"
Carlsbad	75.0°	"
Burtscheid	77.5°	"
Katherine Spring in Caucasia	88.7°	"
Trincheros in Venezuela	97.0°*	"

We have here a series of temperatures, from the warmest yet observed in artesian wells to that of boiling water, and it would seem not unreasonable to suppose that the differences in their temperatures correspond to differences in the depths of their sources. It is true that the neighborhood of volcanoes or of igneous rocks may heighten the temperature of springs rising from comparatively shallow depths, but it is also the case that many very hot springs occur in districts far distant from volcanic regions. Thus it is with the hot spring of Hammam-mes-Kutin, betwixt Bone and Constantine, the temperature of which is stated at from 60° to 95° Cent.; and also with the warm springs in Cape Colony, which, according to Kraus, break forth from sandstone, far from any plutonic rock.† It is clearly impossible to account for the differences in the temperatures of thermal springs in any other way than by supposing that the springs possess very nearly the temperatures of the depths from which they rise, and that the higher the temperature of the water the deeper is the source from which it springs. We are therefore justified in regarding it as fully proved that the temerature of the earth increases with the depth, until a point is

* Muller's Kosmische Physik, p. 340.

† Naumann's Geognosie, I, 306.

reached at which water boils. It is a matter of much difficulty however to determine, with any degree of precision, the depth at which this heat is attained. If we assume that the same increase of 1° Centigrade for every 100 feet depth, which takes place at the surface, continues to greater depths, the calculation is very simple. The temperature of the Mondorff artesian well was 34° Cent., at a depth of 2066 feet. If we add 100 feet for each of the remaining 66° C, we have a temperature of 100° C, at a depth of 8666 feet. It will however be shewn in a subsequent part of this paper, that we are not justified in assuming that the increase of temperature follows such a regular progression, that the rapidity with which the temperature increases, diminishes with the depth, and that consequently the depth at which a constant temperature of 100° C. reigns, is much more considerable than that above stated; that it is at least 10,000 feet, and probably even as much as 20,000 feet.* It is quite possible that under the great pressure which must exist at this latter depth the boiling point of water may be higher than 100° C., but then however, this might be it could not retain this higher temperature until it reached the surface. Because however rapidly it might ascend, its temperature would on the way decrease with the removal of the pressure, steam being at the same time generated. It is not improbable that the waters of the Geyser and the Strokkr have at their sources a much higher temperature than 100° C., and that the eruptions observable at these springs are caused by the generation of steam in the canal of egress, owing to the removal of the pressure. This view is supported by the observations made on the temperature of these springs. The water of the Geyser at the surface has a temperature of 76° to 89° C., but at a depth of twenty-two meters it is from 122° to 127° C. The water of the Strokkr is continually boiling at the surface, and has, at a depth of forty-one feet, a temperature of 114° C.† But although it is possible for water to exist at a much higher heat than 100° C, at such great depths, it is nevertheless also evident that at still greater depths, and increased temperatures, it can only exist in the form of steam. We can moreover readily conceive a depth and temperature to which it would be impossible for water to penetrate. If the temperature of the earth's crust continues to

* Naumann, Geognosie, I, 66.

† Krug von Nidda, in Karsten's Archiv für Mineralogie, &c., ix, 247.

increase with the depth, there must exist at some depth, sufficiently great, a point beyond which the rocks are heated to such an extent that before water can penetrate to them it is resolved into steam and expelled.

Beyond this point there is a long interval, regarding the increase of temperature in which, we have no direct evidence until we arrive at that furnished by the fused rock which in the form of lava is poured forth by volcanoes, which are even more widely and generally distributed over the earth's surface than thermal springs. This however supplies indirect evidence sufficient to prove that during this great interval the heat must increase with the depth, until the temperature of fused lava is reached, at which point we must suppose everything to be in a fluid state, and consequently the temperature from that point to much greater depths to continue about the same. The lavas which have been emitted by volcanoes in historic times, have been both of a trachytic and a basaltic nature, but those of the latter character seem to have predominated. Many of these doleritic or augitic lavas from very recent lava-streams have been described and analysed. They are of a comparatively basic composition, seldom contain more than 50 per cent of silica, and are much richer than other volcanic rocks in iron-oxide. The lava which constituted the stream from Etna, that destroyed a great part of Catania in 1669, had the following composition:—

Silica	48.83	
Alumina	16.15	
Protoxide of iron	16.32	34.97
Protoxide of manganese	.54	
Lime	9.31	
Magnesia	4.58	
Soda with some potash	3.45	
Potash	77	
	99.95.*	

This analysis bears a general resemblance to those of other augitic lavas. It also bears a resemblance to that of the slag produced in smelting the copper schists of Mansfeldt. According to Hoffman, the composition of the slag produced at Kupfer Kammerhütte in the first or raw smelting, is as follows.

* Bischof; Chemical and Physical Geology, ii, 235.

Silica	48.22	
Alumina	16.35	
Protoxide of iron	10.75	35.28
Lime	19.29	
Magnesia	3.23	
Protoxide of copper	75	
" " zinc	1.26	
	99.85.*	

According to Plattner, the melting point of these slags is about 1400° Centigrade.† If we suppose that the increase of temperature downward in the earth's crust progresses at the rate of 1° C. for every 100 feet, the thickness of the earth's crust may be calculated as follows. The temperature of the Mondorff artesian well was 34° C, at a depth of 2066 feet. If we add 100 feet for each of the remaining 1366° (136,600 ft.)—the temperature of 1400° would exist at a depth of 138,666 feet, (26¼ English, or 22¾ geographical miles.) However crude and uncertain this method of calculating the thickness of the earth's crust may be, it appears nevertheless to have been almost the only one hitherto employed for that purpose. It seems to have been assumed on all hands that the increase of temperature takes place in the ratio of a simple arithmetical progression. Humboldt‡ adopts the idea that "granite is in a state of fusion about "26 or 30 geographical miles beneath the surface." At another place§ he states it at "somewhat more than 20 geographical "miles ($21\frac{6}{10}$=25 English)." "45,000 metres=24 geographical "miles, was named by Elie de Beaumont (Geologie, edited by "Vogt, 1846, I, 32) as the thickness of the solid crust of the "earth. Bischof (Warmelehre des Innern unseres Erdkör-"pers, pp, 271 and 286,) estimated it between 122,590 feet and "136,448 feet, or on the average 21⅓ geographical=24½ English "miles." The average diameter of the earth being 6864 miles, it follows from the above estimate, that the thickness of the earth's crust only amounts to about $\frac{1}{150}$th of the radius of its circumference. When we reflect on this result, it would appear that this thickness is altogether insufficient to lend to the earth's crust that stability which it now possesses. Moreover, there are other estimates than those above quoted, which give to the earth's

* Kerl. Handbuch der Huttenknude, I, 296.

† Ibid; I, p. 282. ‡ Kosmos; English edition, I, 26. § Ibid V, 169.

crust a much more considerable thickness. Cordier assuming 100° Wedgewood as the melting point of lava, determined the depth at which everything is in a fluid state, from his observations:—

At Canneaux, to be	148	English geographical miles.
At Littry	84	do.
At Decise	·64	do.

And he finally draws the conclusion that the average thickness of the solid crust of the earth cannot well exceed 56 English geographical miles.* Sartorius von Waltershausen's estimate will be referred to when we come to take into consideration the density of the earth. Naumann remarks as follows on the subject: "the "temperature of the fused lava may certainly in the depths of "the earth be estimated as at least 2000° C. If the increase of "temperature follows the law of an arithmetical progression, then "such a temperature would be reached at a depth of 200,000 feet, "or nine German,(=36 English) geographical miles. But since "it is more probable that the distance corresponding to an in- "crease of 1° Centigrade augments with the depth, we are jus- "tified in assuming a much greater depth, and in supposing it not "at all impossible that the seat of the fluid lava is to be found at "a depth of twenty and perhaps even upwards of thirty geogra- "phical miles (=80 or 120 English geographical miles,)"† There are not wanting observations to prove that the temperature of the earth's crust increases less rapidly towards the interior. Thus from a comparison of several observations, Fox deduced the result that within the first 600 feet, the temperature increases more quickly than in the following 600 feet. Henwood obtained similar results within the first 950 feet, and Rogers found in Virginia a notable enlargment with the depth, of the space corresponding to 1° increase. In the artesian well at Grenelle the temperature observed at

700 feet depth was	20.00° C.
1555 "	26.43° C.

The thermometer in the cellar of the Paris observatory shews a constant temperature of 11.7° C. Calculating from this depth of 86 feet, the distance corresponding to one degree's increase of temperature within the first 677 feet is 81.6 feet; and within the

* Naumann, Geognosie, I. 74.
† Naumann, Geognosie, I, 67.

next 792 feet, 123 feet; which figures plainly shew an increase with the depth of the distance corresponding to 1° C. Bischof's experiments on the cooling of large masses of melted basalt also furnish a very convincing proof that the increase of temperature takes place less rapidly at greater depths. 48 hours after casting a globe of melted basalt, having a diameter of 27¼ inches, he found it to possess the following temperatures :—

In the centre...........................	153.5°	R.
45 inches from do........................	136.0°	"
6.75 " " "	124.9°	"
9. " "	109.8°*	"

These observations also shew with increasing depth a diminution of the rapidity with which the increase of temperature takes place. They by no means furnish us however with secure data upon which to found a calculation as to the thickness of the earth's crust. Like the careful experiments in the mines of Prussia and Saxony, "a general law with regard to the increase of tempera-"ture cannot be deduced from them." They are useful in so far as they prove the inaccuracy of all estimates of the earth's thickness founded upon the arithmetical progression of the increase of temperature, and justify the supposition of Naumann, that the crust of the earth may have a thickness of upwards of 120 English geographical miles.

There is however yet another estimate of the thickness of the earth's crust, the consideration of which will lead us to refer to the various views entertained as to the constitution of the interior of the earth. This estimate is thus referred to by Naumann: "W. "Hopkins has adopted a peculiar method for the solution of "this problem. By very acute observation and reasoning on the "nutation of the earth's axis, and the precession of the equinoxes, "he finds that these two phenomena must come out with different "values according as the earth is solid throughout, or fluid "throughout, or solid externally and fluid internally; in which "latter case different thicknesses of the solid crust will produce "different results. It is certainly the case that in order to a cor-"rect estimate, the values of two important elements are necessary, "which are as yet unknown, viz., the condensing action of pres-"sure, and the expanding action of such high temperatures. "Nevertheless, Hopkins has attempted to answer the question ap-

* Naumann, Geognosie, I, 63.

"proximately, and gained the result, that according to the known "values of the nutation and precession, the thickness of the solid "crust cannot be less than one fourth or one fifth of the radius "of the earth and must at least amount to 172 to 215 "German geographical miles (=688 to 860 English geogra-"phical miles.) Such a thickness of the earth's crust seems indeed "to stand in the necessary relations to the stability of the exterior "surface of the earth, but also almost completely to exclude the "possibility of a communication with the interior of the earth, "which is really so decidedly shewn to exist by varied volcanic "phenomena. Hopkins also adopts the view that with such a "thick crust a direct communication is impossible between the "interior of the earth and the surface. In order therefore to "explain the phenomena of volcanoes, he supposes the existence "of very large cavities here and there within the solid crust, "which are filled with easily fusible materials, still in a liquid "state, and which resemble colossal bubbles, enclosing whole seas "of fused substance.* Elie de Beaumont and others, on the other hand, entertain the view that spaces were formed between the solid crust, and the fluid centre which, at least in earlier geological periods, caused partial depressions of the earth's crust, and which are still to be considered as the real laboratories of volcanic activity.

Somewhat allied to Hopkins's supposition is Bunsen's theory, which rests upon certain ascertained facts with regard to the composition of igneous rocks generally, but more especially to that of lavas. Bunsen supposes the existence in the interior of the earth of two enormous reservoirs of fused matter having each a different composition, and from the amalgamation of which all the known varieties of trachytic and doleritic rocks result. This theory is based upon two series of analyses of Icelandic lavas, the one comprising, according to Bunsen, those richest in silica (trachytes), the other those containing the largest amount of bases, (trap rocks, basalts and basaltic lavas). The first series of analysis comprised those of the following rocks :—

1. Trachyte from Baula.
2. Do from Kalmanstunga.
3. Do from Langarfjäll near the Geyser.
4. Trachyte from Arnar Knipa on the Laxa.
5. Do from Falklaklettur near Kalmanstunga.

* Naumaun, Geognosie, I, 75.

6. Trachyte from Krabla.
7. Obsidian from Krabla.

	1.	2.	3.	4.	5.	6.	7.
Silica	75.91	77.92	75.29	78.95	76.42	76.38	75.77.
Alumina	11.49	12.01	12.94	10.22	9.57	11.53	10.29.
Ferrous oxide	2.13	1.32	2.60	2.91	5.10	3.59	3.85.
Lime	1.56	0.76	1.01	1.84	1.53	1.76	1.82.
Magnesia	0.76	0.13	0.03	0.14	0.20	0.40	0.25.
Soda	2.51	4.59	2.71	4.18	5.24	4.46	5 56.
Potash	5.64	3.27	5.42	1.76	1.94	1.88	2.46.
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The mean of these analyses is:

Silica	76.662	
Alumina	11.150	
Ferrous oxide	3.071	
Lime	1.469	23.338
Magnesia	0.274	
Soda	4.178	
Potash	3.196	
	100.00.	

This Bunsen assumes to be the composition of the normal trachytic mass, which occupies one of the reservoirs of his theory. The second series of analyses comprised those of the following rocks:

1. Trap rock from Esiaberg.
2. Trap from Vidoe.
3. Light fine grained basaltic rock from Hagafgëll on the right bank of the Thiorsa.
4. Basaltic rock from Skardsfjäll.
5. Lava from an old stream of Hecla.
6. Rock from the precipice of Almannagjö near the lake of Thingvalla.

	1.	2.	3.	4.	5.	6.
Silica	50.05	47.48	49.17	47.69	49.37	47.07.
Alumina	18.78	13.75	14.89	11.50	16.81	12.96.
Ferrous oxide	11.69	17.47	15.20	19.43	11.85	16.65.
Lime	11.66	11.34	11.67	12.25	13.01	11.27.
Magnesia	5.20	6.47	6.82	5 83	7.52	9.50.
Soda	2.24	2.89	0.58	2.82	1.24	1.97.
Potash	0.38	0.60	1.67	0.48	0.20	0.58.
	100.00	100.00	100.00	100.00	100.00	100.00.

The mean of these analyses is:

Silica	48.472	
Alumina	14.781	
Ferrous oxide	15.383	
Lime	11.866	51.528
Magnesia	6.890	
Soda	1.957	
Potash	0.651	
	100.000	

This Bunsen assumes to be the composition of the normal pyroxenic mass, which fills the second supposed reservoir of igneous fluid material in the centre of the earth. He further argues that all volcanic rocks, that is to say rocks belonging to the trachytic, basaltic or lava eruptive formations, may be regarded as mixtures of these two fluid materials, and shews that after merely determining how much silica they contain, it can be ascertained by calculation in what proportions these two materials from the different reservoirs are present. With regard to this theory Sartorius von Waltershausen remarks: "It is evident "that this average (that of the normal pyroxenic mass) can "just as little be regarded as the limit on the basic side, as the "so called normal trachytic average on the other. Nor is it "apparent why the above-mentioned six analyses only were used "in computing the average, while others, such as lava from Thiorsa, "and trap rock from Esia were neglected."*

Mr. Sterry Hunt, who as we shall see, rejects altogether the theory which derives the eruptive rocks from a portion of the primitive fused mass of the globe, and supposes them to consist of altered, fused, and displaced sediments, (Can. Naturalist, Dec. 1859], remarks, with regard to Bunsen's hypothesis, that the calculated results as deduced from the volcanic rocks of Hungary and Armenia, often differ considerably from those obtained by analysis; a result which will follow, when as is often the case, different triclinic feldspars replace each other in the pyroxenic rocks. He also shows that the composition of certain eruptive rocks, like phonolites, (which are highly basic, and yet contain but little lime, magnesia, or iron-oxide) is such that they cannot be derived from either of the magmas of Bunsen.

* Ueber die vulcanische Gesteine in Sicilien und Island, und ihre submarine Umbildung; Göttingen, 1853.

Naumann quietly remarks that the theory of the two separate reservoirs is surely not yet sufficiently proved, and characterises Von Waltershausen's theory of the constitution of the interior of the earth as more natural, and more in accordance with our knowledge regarding the probable condition of the earth's centre.* This theory, which the author first promulgated in the work from which we have just quoted, deserves to be better known. It is principally founded upon certain reasonings deducible from the density of the earth, and for this reason a recapitulation of what is known concerning this point may not be inappropriate here.

In 1776 Hutton and Maskelyne determined the density of the earth from the attraction exerted on the plumb line by the mass of the mountain Schiehallion in Perthshire. Assuming the mean of specific gravities of the three principal rocks, of which it consists, viz., mica slate, limestones, and quartzite, to be the density of the whole mass, they calculated from their experiments the density of the earth to be 4.713.

The density of the earth has also been determined from observations on the oscillations of the pendulum on high mountains. In this way Carlini found from experiments on Mount Cenis the density of the earth to be equal to 4.37, which value was however raised by Schmidt to 4.837, by correcting an error in Carlini's calculations.

The most exact method however yet applied towards determining the density of the earth is that by means of the torsion balance invented by the Rev. John Mitchell, and used after his death by Cavendish. In 1798 this philosopher communicated to the Royal Society the result of his experiments with this apparatus. From seventeen sets of experiments he deduced twenty-three results, from the mean of which he computed the density of the earth to be equal to 5.48. Bailly, correcting an error in Cavendish's calculation, makes it 5.45. Schmidt, likewise, after a revision of Cavendish's computations, alters the result of these to 5.52. In 1837, Reich of Freiberg performed a series of experiments with the same apparatus, much improved in various particulars. Fifty-seven experiments were made in all, from which fourteen results were deduced, the mean of which makes the density of the earth equal to 5.44. In 1848 Baily, at the request of the Astronomical Society, undertook to repeat Cavendish's experiments.

* Lehrbuch, ii, 1101.

It was not however until 1841 that the apparatus was modified and improved to such an extent as to give the most satisfactory results. The experiments with the perfected apparatus were continued till May, 1842, when the result was arrived at that the mean density of the earth is 5.66. From this enumeration of all the experiments which have been made for the determination of the mean density of the earth, it will be evident that the result as given by Baily, is one of the most unequivocally established scientific facts. Not only is there (considering, the different times and circumstances when they were instituted) a surprising coincidence in the results obtained by the torsion balance, but these are confirmed in the mean by the results obtained from the less accurate methods first described.

If we compare the mean density of the earth, as found by Baily, with the specific gravities of a few well known minerals, we find that it equals the density of copper glance, and exceeds that of magnetic iron ore, iron pyrites, variegated copper ore, and copper pyrites. If we moreover compare it with the specific gravities of these minerals or rocks which constitute the great bulk of the earth's crust, we find it to possess twice as great a density. The inference is unavoidable that the centre of the earth is much more dense than its crust, and is also possessed of a higher density than that of the earth's whole mass. This conclusion has, nevertheless, been received by many with grave doubts. It has even been supposed that the increased density at the earth's centre is attributable to the increased density which the substances there existing acquire from the enormous pressure of the superincumbent mass. This explanation rests upon the groundless supposition that solids may be compressed to an indefinite extent. It further neglects the very essential circumstance that the attraction exercised on any material point in the interior of the earth is only exerted by that part of the earth which lies within the spherical surface passing through the given point, and that the mass of the earth outside of this surface exercises no attracting influence on it. Since therefore the weight of a body is determined by the sum of the attracting forces acting on it, it follows that the weight of one and the same body must be less in the interior of the earth than on the surface.* Moreover, it is very certain that an extraordinarily high temperature exists in the interior of our planet, which

* Naumann, Lehrbuch, i, 40.

must cause the bodies existing there to expand, and which must thus neutralise much of the compression exercised on these bodies by the masses lying above them. Finally, it seems that the compressing powers of the superincumbent masses have been somewhat over estimated. The crust of the earth must be regarded as a self-supporting arch, exercising a pressure only on the elastic fluids occurring in it, and not as resting or floating on the fluid interior. The latter has then only to bear the weight of the columns of lava which may exist in the interior of volcanoes, and which is certainly not inconsiderable. From these considerations it would seem perfectly correct to suppose that what the crust of the earth wants in density as compared with the whole mass of the planet, must be made up by the centre.

Naumann finds that assuming the average density of the earth's crust to be 2·5, and the increase of density to take place according to arithmetical progression, the density of the centre would be 8·5, consequently considerably more than the specific gravity of iron, and almost equal to that of cobalt. A similar calculation is the starting point for the theory already mentioned of Sartorius Von Waltershausen. He finds the mean of the specific gravities of orthoclase, albite, quartz, crystalline limestone and mica to be 2·66, and assumes this as an approximation to the mean density of the outer crust. Calculating, first, three fifths of the total volume of the earth to possess this specific gravity, he finally computes the density of the centre to be 9·585. He moreover calculates the densities which exist at various depths beneath the earth's surface. These depths, converted into English geographical miles, with their calculated densities are as follows:—

Miles from surface.	Density.	
0	2·66	
34	2·79	
68	2·93	
103	3·07	Lime.
137	3·20	Magnesia.
171	3·34	
206	3·47	
240	3·60	
274	3.72	
309	3·85	
343	3·99	Alumina.
686	5·15	Iron-oxide.
1029	6·29	Tellurium, Chromium

Miles from surface.	Density.	
1372	7·09	Zinc, Iron, Antimony
1716	7.85	Cobalt, Steel.
2059	8·47	Uranium, Nickel.
2402	8·96	Copper.
2745	9·31	
3088	9·51	
3432	9·59	Bismuth, Silver.

The theory maintained by Sartorius Von Waltershausen regarding the constitution of the earth's interior, (in opposition to Bunsen's hypothesis of the two separate reservoirs of acid and basic molten rock,) is indicated by the above series of calculated densities. He supposes that from the interior of the earth's crust to its centre a gradual increase of density takes place in the fluid mass, or that this fluid mass in its present condition, as in former ages, consists of a series of concentric layers of molten matter, which are the denser the nearer they approach to the earth's centre. Instead therefore of regarding trachytic and basaltic lavas as the products of the two separate reservoirs, he considers them as the products of two different concentric layers, or as originating from two different levels in the fluid mass, the basaltic lava occupying the lower layer or level, and the trachytic floating above it; the one, both as regards chemical composition and density, graduating into the other. Von Waltershausen found the mean specific gravity of seven different Icelandic trachytes to be 2,524, while that of ten different basaltic lavas amounted to 2,911. With the increase of specific gravity towards the centre, Von Waltershausen supposes also an increase in the basic constituents of the molten rock, a change from a purely feldspathic material, yielding trachytic rocks mainly composed of feldspar, to one much richer in lime, magnesia and iron-oxide, and yielding dolerites consisting of feldspar, hornblende or augite, and in smaller quantity magnetic iron ore. He further supposes that beneath this doleritic material the quantity of iron-oxide, capable of producing the last named mineral, goes on increasing, and that ultimately a point is reached from which to the centre metallic elements alone exist. In further reasoning as to the condition of this metallic centre, Von Waltershausen takes into consideration the influence of the superincumbent pressure upon the fusing point of the metals. The following is a translation of his remarks on this subject: "For sometime past Bunsen has devoted his at-
" tention to this subject, and described (in Poggendorff's Annalen,

" LXXXI, 562) a series of experiments from which it appears " that the temperature of the fusing point of various substances " increases with pressure. These experiments have it is true only " been made on two easily fusible organic substances, spermaceti " and paraffine. The melting point of the former is under a " pressure of 100 atmospheres raised 2.1° Centigrade, while that " of paraffine is raised 3.6° Centigrade. It cannot be doubted that " a heavy pressure acts in a similar manner, although possibly not " to such an appreciable extent, upon solidifying masses of silicates. " If the point of fusion of the latter, under a pressure of 100 atmos- " pheres, only increased 1° Centigrade, this would still be sufficient " to explain many important points in geology, and especially in " the formation of crystalline rocks. Although the law of the " dependance of the point of fusion upon pressure is far from " being known, the observations of Bunsen already mentioned " have incited me to enquire as to what pressure, on the basis of " the increase of density already mentioned, may be expected to " exist at any given point in the interior of the earth. If we " imagine the whole globe to be in a fluid condition, the following " pressures would be experienced at the respective depths men- " tioned.

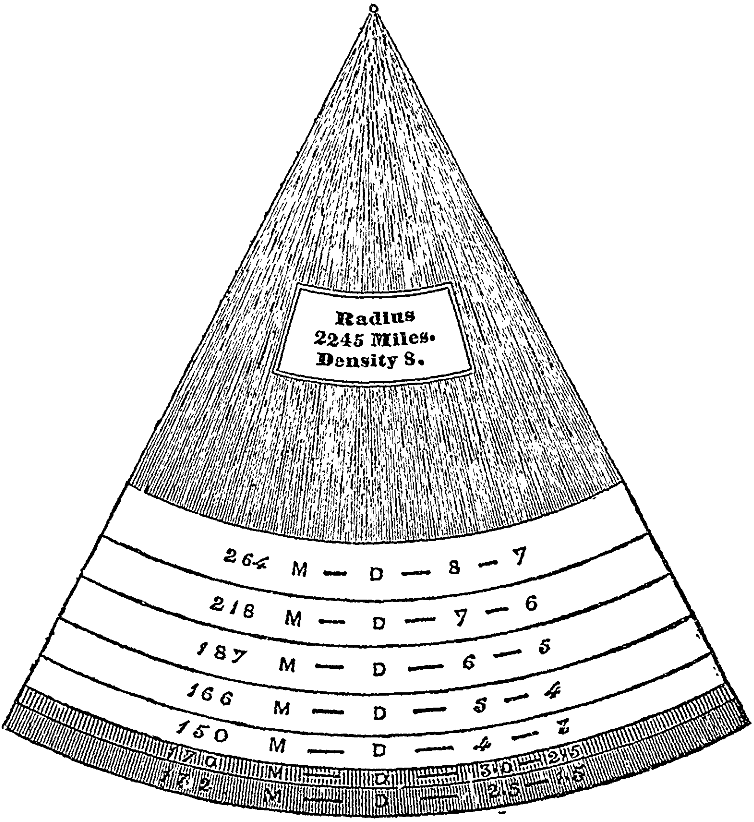
Depths in miles.	Pressure in atmospheres.
34	17138
68	34591
103	53070
137	72195
171	92432
206	113180
240	134660
274	156840
309	179680
343	203320
686	471680
1029	786080
1372	1125690
1716	1468000
2059	1701500
2402	2297500
3088	2441900
3432	2492600

"If it is the case that the fusing point of metals (of which un- " doubtedly the greater part of our planet consists,) increases with " increasing pressure, then the question arises as to whether under "such enormous pressures as those above calculated, even with "the high temperatures which we have to expect in the interior "a fluid condition is conceivable. The hypothesis of a solid "metallic nucleus in the interior of the earth has nothing con- "tradictory in it, and indeed the phenomena of terrestrial mag- "netism would appear to confirm this view. It is not to be "doubted that the so-called magnetic storms have their seat in "the atmosphere, or perhaps over it, and that the diurnal and "secular variations of the magnetic elements are only to be "sought in the exterior solid or solidifying crust of the earth. "If the seat of the greater part of the terrestrial magnetic "power is in the earth's crust, then we must suppose such a dis- "tribution of the magnetic fluid in it, as if on the average eight "hard steel bars weighing one pound each, magnetised to the "highest power, were present in every cubic metre. According "to geological observation, however, we can scarcely suppose the "seat of the magnetic power to rest in the earth's crust, since it "does not seem to possess either a very great thickness, or a "very intensive magnetism. According to an approximative cal- "culation which my friend W. Weber has made, a globe of the "hardest steel, magnetised to the highest degree, and having a "diameter of nearly 476 (English) geographical miles, situated "in the centre o the earth, would be able to produce the mag- "netic phenomena which we observe on the earth's surface. In "reality however these suppositions are not reliable, since we can "neither expect to find hard steel nor a perfect magnetism in "the centre of the earth. With less favorable circumstances "than those above supposed, it would be necessary to assume the "existence of a much larger solid globe in the interior of the "earth in order to account for the magnetism on its surface. "The radius of this globe would possibly extend far beyond the "point at which, according to the calculations already mentioned, "a density equal to that of metallic iron exists."

In whatever degree Von Waltershausen's method of determining the earth's density at its centre, may be looked upon as uncertain, it is scarcely possible to regard his theory of the gradual increase of density as otherwise than very reasonable. Indeed since it is certain that the centre of the earth is much more dense than the surface, it is scarcely possible to conceive how the increase can take place otherwise than gradually. Moreover Laplace deduced a similar result from his investigations regarding the decrease of gravity from the pole to the equator. It appears however that Sartorius Von Waltershausen's estimate of the average specific gravity of the constituents of the earth's crust at its surface is too high, since it is well known that the land only occupies one-fourth of the earth's surface, and that the sea has sometimes a depth of more than 27,600 feet. It may probably be assumed with some degree of reason that the average specific gravity of the first few thousand feet of the earth's crust below the level of the sea, does not exceed 1.5. With regard to the metals constituting the earth's centre, it will probably be admitted that they exist there somewhat in the same proportion as they occur on the surface, that consequently iron constitutes by far the greater portion of the central mass. This supposition seems confirmed by the fact that among the gaseous products emitted by volcanoes, chloride of iron is very abundant, while traces only of the chloride of lead and copper have been detected. Since further, meteoric iron may be supposed to come from bodies having a common origin with our earth, their composition might be supposed to afford a clue, however slight, to the composition of the metallic centre of the earth. It would therefore seem not unreasonable to suppose that this centre is mainly composed of metallic iron, combined with copper, cobalt, nickel, lead, and perhaps silver, gold and platinum in comparatively small quantity, and that its specific gravity may be estimated on account of this admixture of heavier metals at 8. 0 (Sp. gr. of malleable iron 7. 78; cast iron, 7. 1 to 7. 5.) If we assume 1. 5 as the density of the earth's surface, and 8. 0 as that of its centre, we must also—since the average density of the earth is 5. 56—suppose the existence at the centre, of a globe of metallic matter having a radius of 2245 English geographical miles. Assuming further a gradual increase of density from the surface of the earth to the surface of this metallic globe, we may calculate that at a depth of 132 miles the density of trachytic lava is reached, (2. 5), and at 202 miles the density of doleritic lava is slightly exceeded (3. 0). According to this calculation therefore the crust of the earth has a thickness of from 132 to 202 miles, a result somewhat exceeding Naumann's estimate. Calculating in the same way we further find that from a depth of 202 miles to that of 352, molten rock would exist having a specific gravity of from 3. 0 to 4. 0, and containing much more basic matter and iron-oxide than any rock now visible on the surface. At a depth of from

352 to 518 miles, substances may exist having a density of from 4. 0 to 5. 0; such as magnetic iron ore, ilmenite, copper, iron, and magnetic pyrites, variegated copper ore, sulphuret of antimony, and perhaps antimonio-sulphurets. From 518 to 705 miles in depth, substances may be present having a specific gravity of from 5. 0 to 6. 0 such as iron pyrites, millerite, and copper glance. Deeper still, and until a depth of 923 miles, a density of from 6. 0 to 7. 0 may be supposed to exist, and consequently arsenio-sulphurets of iron, cobalt and nickel, such as arsenical pyrites and speiss-cobalt, cobalt glance, and tesseral pyrites to be present. Between this depth of 923 miles, and that of 1187 miles, where according to the calculation already mentioned, the surface of the metallic globe may be found, we may suppose a density of from 7. 0 to 8. 0 to exist, and more or less pure arseniurets, such as the purest speiss-cobalt, arseniurets of copper and nickel, &c, to be present. It will be evident that in calculating the results above given, I have only been endeavouring to develope Von Waltershausen's theory, and in some measure to correct his results. I say correct them, because in one instance assuming the sp. gr. of the surface as 2.66, he arrives at the result that the thickness of the earth's crust does not exceed 67 English geographical miles. So far as regards the composition of the various concentric layers deduced from their specific gravities, I may remark that I have observed a similar succession to that above indicated, manifest itself in smelting cobalt ores. This operation is carried on at Modum in Norway, where on drawing the metal from the furnace there are formed in the crucible receiving it, four different layers of material, which from the surface downwards, are as follows, viz.: Slag, containing about 60 per cent. of lime and oxide of iron; 2nd, sulphurets of copper, iron and cobalt; 3rd, Arseniosulphurets of iron and cobalt, graduating into 4th, impure metallic iron, malleable and containing cobalt. The accompanying sketch shows part of a section of the earth, exhibiting the size of the central metallic globe, the thickness of the concentric layers, and of the solid crust according to the above calculations. As to whether the metallic globe in the centre is in a solid state, there would appear to be good grounds for this supposition, because apart from the consideration that the solidifying point rises with the pressure, it is well known that in many smelting furnaces, metallic iron can accumulate in the bottom, while the slag maintains its fluidity and runs perfectly free from the furnace. Mr. Sterry

Hunt inclines also to the supposition that the centre of the earth is solid, although he is of opinion that the fluid matter resting above it is altogether of sedimentary origin, and is in a state of igneo-aqueous fusion. He remarks "that beneath the outer crust of sediments, and surrounding the solid nucleus, we may suppose a zone of plastic sedimentary material adequate to



explain all the phenomena hitherto ascribed to a fluid nucleus." (American Journal of Science for May, 1861.) If, further, iron when fused loses its magnetic power, and the phenomena of magnism on the surface of the earth can be explained on the supposition that the metallic centre has assumed the solid form, then this supposition would appear to be very reasonable indeed. It would of course be impossible to assume that the metals have not only solidified but also cooled to such an extent as to be capable of being magnetised to the most powerful degree. On the contrary, we must suppose them to be still very considerably heated, and consequently to possess but feeble magnetic properties. According to Humboldt, "all magnetism is certainly not lost until we "arrive at a white heat, and it is manifested when iron is at a "dark red heat." * The feeble magnetic power of the metallic globe would however be amply compensated for by its enormous size.

The possibility of the existence of such a metallic centre having been once admitted, the field opened for further reasoning as to the influence which cosmical bodies may exert upon its position, and consequently upon that of the earth's centre of gravity, is very wide indeed. That these changes may affect the phenomena of volcanic eruptions, I shall endeavour to shew in Part II. of this paper. In the meantime it may be remarked that there exists a decided connection between magnetic, and volcanic phenomena. In the year 1767, Bernouilli observed that during an earthquake the inclination decreased half a degree, and Father de la Torre remarked that during an eruption of Vesuvius the declination varied several degrees. On the 18th April, 1842, at ten minutes past nine, Kreil in Prague observed that the needle received a very sudden stroke, and the same oscillation in the same direction was observed at the same instant by Cella in Parma, and Lamont in Munich. Shortly afterwards it was ascertained that exactly at the same minute a violent earthquake had been felt in Greece.† From the irregularities in the course of the magnetic curves, Lamont regards it as in the highest degree probable that the seat of terrestrial magnetism is to be sought in a compact nucleus which lies under the earth's crust. Müller is of opinion that the magnetic variations and oscillations can be most simply explained by considering terrestrial magnetism as dependent on electric currents which pass through the nucleus in ever varying direction and intensity.‡

That the magnetic variations stand in connection with the movements of certain of the heavenly bodies is a well ascertained fact. Sabine came to the conclusion that the disturbances belong

* Humboldt's Cosmos, English Edition, I, 183.

† Müller's Kosmische Physik, p. 497.

‡ Ibid, p. 498.

"to a special kind of periodically recurring variations, which "follow recognizable laws, depend upon the position of the sun "in the ecliptic, and upon the daily rotation of the earth round "its axis, and further ought no longer to be designated as irreg- "ular, since we may distinguish in them, in addition to a special "local type, processes which affect the whole earth."* The hypothesis of a metallic centre would seem to be capable of forming the connecting link between the magnetic and astronomical phenomena here referred to. The relation of the sun to the earth, and the revolution of the latter on its axis, would naturally effect a change in the position of the metallic globe in the centre of the earth, which change might alter the direction of the electric currents through the earth's crust, and these again the position of the needle. Thus it seems not at all unreasonable to adopt the theory of a metallic centre, since it alone is capable of affording a solution of many problems in geology, magnetism and astronomy, and since it is capable of uniting harmoniously and explaining the most varied natural pnenomena.

ART. XXIII.—*On the Earth's Climate in Paleozoic Times;* by T. STERRY HUNT, M.A., F.R.S.

The late researches of Tyndall on the relation of gases and vapors to radiant heat are important in their bearing upon the temperature of the earth's surface in former geological periods. He has shown that heat, from whatever source, passes through hydrogen, oxygen and nitrogen gases, or through dry air, with nearly the same facility as through a vacuum. These gases are thus to radiant heat what rock-salt is among solids. Glass and some other solid substances, which are readily permeable to light and to solar heat, offer, as is well known, great obstacles to the passage of radiant heat from non-luminous bodies; and Tyndall has recently shown that many colorless vapors and gases have a similar effect, intercepting the heat from such sources, by which they become warmed, and in their turn radiate heat. Thus while for a vacuum the absorption of heat from a body at 212° F. is represented by 0, and that for dry air is 1, the absorption by an atmosphere of carbonic acid gas equals 90, by marsh gas 403, by

* Humboldts, Cosmos, v, 138.

olefiant gas 970, and by ammonia 1195. The diffusion of olefiant gas of one inch tension in a vacuum produces an absorption of 90, and the same amount of carbonic acid gas, an absorption of 5·6. The small quantities of ozone present in electrolytic oxygen were found to raise its absorptive power from 1 to 85, and even to 136; and the watery vapor present in the air at ordinary temperatures in like manner produces an absorption of heat represented by 70 or 80. Air saturated with moisture at the ordinary temperature absorbs more than five hundredths of the heat radiated from a metallic vessel filled with boiling water, and Tyndall calculates that of the heat radiated from the earth's surface warmed by the sun's rays, one tenth is intercepted by the aqueous vapor within ten feet of the surface. Hence the powerful influence of moist air upon the climate of the globe. Like a covering of glass, it allows the sun's rays to reach the earth, but prevents to a great extent the loss by radiation of the heat thus communicated.

When however the supply of heat from the sun is interrupted during long nights, the radiation which goes on into space causes the precipitation of a great part of the watery vapor from the air, and the earth, thus deprived of this protecting shield, becomes more and more rapidly cooled. If now we could suppose the atmosphere to be mingled with some permanent gas, which should posses an absorptive power like that of the vapor of water, this cooling process would be in a great measure arrested, and an effect would be produced similar to that of a screen of glass; which keeps up the temperature beneath it, directly, by preventing the escape of radiant heat, and indirectly by hindering the condensation of the aqueous vapor in the air confined beneath.

Now we have only to bear in mind that there are the best of reasons for believing that during the earlier geological periods, all of the carbon since deposited in the forms of limestone and of mineral coal existed in the atmosphere in the state of carbonic acid, and we see at once an agency which must have aided greatly to produce the elevated temperature that prevailed at the earth's surface in former geological periods. Without doubt the great extent of sea, and the absence or rarity of high mountains, contributed much towards the mild climate of the carboniferous age, for example, when a vegetation as luxuriant as that now found in the tropics flourished within the frigid zones; but to these causes must be added the influence of the whole of the carbon which was afterwards condensed in the form of coal and carbonate of lime, and which then existed in the condition of a transparent and permanent gas, mingled with the atmosphere, surrounding the earth, and protecting it like a dome of glass. To this effect of carbonic acid it is possible that other gases may have contributed. The ozone, which is mingled with the oxygen set free from growing plants, and the marsh gas, which is now evolved from decomposing vegetation under conditions similar to those then presented by the coal fields, may, by their great absorptive power, have very well aided to maintain at the earth's surface that high temperature the cause of which has been one of the enigmas of geology.

Montreal, August 1st, 1863.

MISCELLANEOUS.

THE CONFUSED MONOHAMMUS!

To the Editor of the Canadian Naturalist.

The longicorn described by me (Canadian Journal, 1st series, vol. iii, p. 212) as *Monohammus titillator*, Fab., was determined by Mr. Ibbetson and myself from the best American Entomological authority that could be obtained at the time.

Mr. Billings states (Canadian Naturalist, vol. vii. p. 431), that "*M. confusor* is the largest insect." I disagree with him, because the longicorn family, and this genus especially, has its species of maximum and minimum lengths and breadths, a fact that cannot be overlooked by a person collecting a number of each species. He further says: "As neither Mr. Ibbetson nor myself mention *M. confusor*, and as the original specimen on which the species *M. titillator* was founded is an insect from the Southern States, it may be that they have applied the name to our most common and largest species."

Fabricius may have procured his specimen from the South, probably from the southern limit of pines; but since his time American Entomological authority formed a boundary, north of which our insect provinces are formed into zones; through these we may follow the species to the extreme north. Insects therefore, taken north of Mexico are considered as belonging to the northern fauna; indeed, many forms mentioned by Linnæus and Fabricius as having a southern habitat, are found commonly in the north. What then is to prevent the appearance of *M. titillator* in Western

Canada when it occurs in NewYork and Pennsylvania? The former place is in closer proximity to the land of pines and the climate congenial to its propagation.

In a letter to the Editor of the "Canadian Naturalist" (quoted below), "H. C.", confirms this idea of Mr. Billings, and at the same time states that the drawing of *Monohammus titillator* in Olivier's work (an excellent authority) agrees very well with these specimens.

Is *M. titillator* a species, and what difference is there between it and *M. confusor?* "H. C." remarks that "in a recent edition of Harris' work the name is still employed", therefore doubting its specific existence. The principal coleopterists of the United States consider it a species. (See Proceed. Ento. Soc. Philad. p. 98), and I quote the following from the Patent Office Report: Agriculture—Washington U. S., 1861, p. 613. by S. S. Rathoon: "One of the largest species of Capricorn beetles belonging to this group is the *Monohammus titillator*, or "tickling beetle." This insect is from three quarters to an inch and a quarter in length, and the antennæ of some of the males are considerably more than twice the length of the body, bristle-shaped, and tapering gradually to the end. The head is vertical in these insects, carried very much like the head of a gnat; the eyes are oval and located immediately beneath the base of the antennæ; the thorax is round in front and behind, but the middle projects out on each side in a sort of wart or rough tooth. The anterior legs are rather the longest, and the tarsal joints much dilated. The colour of the whole insect is a brown mottled with specks of gray or white. On the upper edge of the middle legs is a small obtuse tooth, but in some individuals this is hardly visible. This insect emerges from the pupa state during the months of June and July. Mr. P. Uhler, of Baltimore writes to Mr. Rathoon: "I guess you are right in supposing the larva of *Monohammus titillator* (Harris), to be brought down the Susquehanna in pine logs. It is found in pines in NewYork, from whence the river flows. The larva is a large white flesh-like grub, nearly cylindrical, without feet, numerous fine hairs of a fox colour, with fourteen segments, the second being larger, flattened, horny, inclined obliquely downward and forward; the next ones very short, and all the following except the last one with a transverse oval rough space above and beneath. The pupa state is passed in the interior of wood, into which the larva bores a cylindrical hole transversely, and which, when the perfect insect gnaws its way out, is nearly large enough to admit the little finger. It appears abundantly in some parts of New-York state in July, sometimes doing extensive damage to the pine trees."*

Mr. Billings notices "in the collection of McGill College three specimens from Toronto of the size of the smaller individuals of *M. confusor*, which have a light reddish tinge different from the usual colour of that species." If the specimens alluded to are in the "Couper Collection" of that institution, the cases containing the insects are covered with glass; and the specimens having been exposed for several years to the light, it is no wonder that they have a tinge different from the usual color.

"H. C." says:—"The description agrees very closely with the reddish brown specimens mentioned by Mr. Billings as having been obtained from Toronto, where from my own observations they seem to be much more common than those of a cinereous tint."

Which description does "H. C." allude to—that of *M. titillator* or *M. confusor?* If my memory serves me,—for I have neither my description nor a specimen of the insect, the longicorn pointed out by Mr. Ibbetson and myself as *titillator*, was a large brown or cinereous beetle, with its elytra mottled by tufts of erect short hairs of a blackish grey colour. I cannot say that the collection which I sold to McGill College contained a specimen of *M. titillator*, but I am positive that Mr. Ibbetson, an excellent coleopterist, identified the form prior to his removal from Toronto to Montreal.

WM. COUPER,
Quebec, L. C.

To the Editor of the Canadian Naturalist.

In the December number of the *Canadian Naturalist*, Mr. Billings has described some of the pine-boring beetles of Canada, of the genus *Monohammus*, and mentions that the *M. titillator* is cited by Mr. Couper and Mr. Ibbetson as occurring at Toronto, but is of opinion that the insect described is the *M. confusor*.

I can confirm this idea of Mr. Billings, as the insects in my own collection and in that of Mr. Ibbetson were named on refer-

* Mr. Rathoon's fig. of *M. titillator* (Pat. Office Rep.—Agricul. 1861) has 13 antennal joints.

ence to Harris' work. The description agrees very closely with the reddish brown specimens mentioned by Mr. Billings as having been obtained from Toronto, where from my own observations they seem to be much more common than those of a cinereous-tint.

Moreover the drawing of *Monohammus titillator* in Olivier's work agrees very well with these specimens. Those in my collection are mostly of the same size as the *M. confusor* and generally a little more robust, but are probably only a variety. The *M. scutillatus* is moderately common about Toronto, but the *M. marmoratus* quite rare; the latter easily distinguished by its smaller size, its rugosely punctured thorax, and the elytra mottled with brown and grey.

In my collection there is also a crippled specimen very like *M. scutillatus* but the elytra are covered with large white spots, in this respect resembling Leconte's *M. fatuor*, which however is now referred to *M. marmoratus*.

In the recent edition of Harris' work the name *titillator* is still employed. H. C.

"Notice of a new Species of *Dendrerpeton*, and of the Dermal Coverings of certain Carboniferous Reptiles." By J. W. Dawson, LL.D., F.R.S., F.G.S.

This paper referred to new facts ascertained in the course of re-examination of the remains of Reptiles from the Coal-formation of Nova-Scotia, and first to the characters of a new and smaller species of *Dendrerpeton*, for which Dr. Dawson proposed the name of *D. Oweni*. The author then described the remains of skin and horny scales which he had lately discovered, and which he supposed to belong to *Dendrerpeton Oweni*, *Hylonomus Wymani*, and *H. Lyelli*. He also gave restorations of these animals, according to what he regarded as the more probable arrangement of the parts; and, after expressing his belief that *Hylonomus* may have Lacertian affinities, he stated that should they prove to be really Batrachian, a new Order must be created for their reception, many of the characters of which would coincide with those of the humbler tribes of Lizards.—*Journal of Geo. Society.*

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