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ORIGINAL ARTICLES.

I.—ON NEW SPECIMENS OF *DENDRERPETON ACADIANUM*, WITH
REMARKS ON OTHER CARBONIFEROUS AMPHIBIANS.

By Sir J. WILLIAM DAWSON, LL.D., F.R.S., etc.

THE genus *Dendrerpeton* was established by Owen on the evidence of remains found by Sir C. Lyell and the writer in an erect tree at the South Joggins in Nova Scotia in 1852.¹ Other specimens were afterwards obtained, and the most complete, presented by me to the Cabinet of the Geological Society, was found in 1861, and described in my "Airbreathers of the Coal Period."² These remains rendered it certain that the animal belongs to the order Labyrinthodontia,³ and it is regarded by Lydekker as the type of a family in that group.⁴

As the characters of the type-species ascertained by Owen and by the writer have not as yet been stated in connected form, and the genus may in consequence be said to be still imperfectly known, it may be useful to sum them up before proceeding to notice some specimens recently obtained, and which have added somewhat to our knowledge of the type-species.

Dendrerpeton Acadianum, Owen, Journ. Geol. Soc. Lond. vol. ix. 1853.

Skull of moderate size and rounded broadly in front. Nostrils small and near the muzzle. Orbits nearly in the middle of the length. Occipital condyle double. Parietal foramen small. Surface of cranial bones sculptured with relatively deep pits. Teeth conical, smooth above, grooved at base, especially on the inner side; enamel simply plicated at base. Outer series of teeth somewhat unequal and larger anteriorly in the intermaxillary bones. A few large teeth within on the inner surface of the maxillaries. A group of small simple teeth on the vomerine bones. Mandibles sculptured like the skull, but much more feebly. Teeth similar to those in the upper jaw, but not larger in front. For the arrangement of the central cranial bones see diagram in Memoirs on Animal Remains in Erect Trees, Phil. Trans. Royal Society, 1882, pl. 44.

¹ Journ. Geol. Soc. of London, vol. ix. p. 66. A preliminary examination of the specimens had been made by the late Prof. J. Wyman, of Cambridge, U.S., and was quoted by Prof. Owen.

² Montreal, 1863. See also Journ. Geol. Soc. vol. xvi. p. 273; vol. xviii. p. 5; and vol. xix. p. 470.

³ Journ. Geol. Soc. vol. xv. p. 274; also "Airbreathers of the Coal Period."

⁴ Brit. Museum Catalogue, Reptiles and Amphibia, vol. iv. p. 170; also Nicholson and Lydekker, Manual of Palaeontology, vol. ii. p. 1032.

Vertebrae imperfectly ossified, very slightly biconcave, with large and broad neural processes in dorsal region. Those of the tail have spines above and below. Ribs of moderate length, with expanded head and slight shoulder; solid towards the head, but hollow and thin-walled at distal end, the longest barely equal to the breadth of the skull, curved, the anterior ones very much so, scapular and pelvic bones large and well ossified. Ilium? broad.

Limbs well developed, especially the anterior pair. Limb-bones ossified and cancellated at the extremities, and with bony walls of considerable thickness. Humerus equal to more than half of the length of the mandible. Femur smaller than humerus, the tibia flattened at the extremity. Toes five in each foot, somewhat broad and short.

Chest covered with bony scales, which are thin, unequally ovate and about half as wide as long, and marked with obscure concentric lines. They have a thickened edge or margin interiorly. They are arranged in chevron and close together, forming a compact armour. There appears to have been a rhombic breast-plate in front, with obscure radiating lines, but this has only been found detached.

Skin of upper surface of body minutely granular or scaly, with a semicircular patch of horny tubercles in front, which I have referred to the snout, but it may have belonged to the back of the head. On the throat or sides were flat, pointed, and apparently flexible lappets marked with elongated areoles and pores. Nearly the whole skin of some specimens has been preserved in the erect trees apparently by a sort of tanning process, but it is so flattened and crumpled that its form is scarcely discernible.

The following are the dimensions of two specimens, one of them (No. 2), that of 1890, and the largest yet obtained:—

	No. 1.	No. 2.
Length of Skull *	7 centimetres.	9 centimetres.
Breadth of Skull *	5 " ...	6 " ...
Length of Mandible	6·6 " ...	8·6 " ...
" Humerus	3·5 " ...	4·3 " ...
" Ulna	2·5 " ...	— " ...
" Femur	2·6 " ...	— " ...
" Rib	2 " ...	2·8 " ...
" Eleven vertebrae ...	5·6 " ...	— " ...

* The skulls being flattened and crushed, these measurements are not certain.

In form, *Dendrerpeton Acadianum* was probably elongated and lizard-like; with a broad flat head, short stout limbs, and an elongated tail; and having the skin of the belly protected by small bony plates closely overlapping one another, while the upper part of the body was covered with a tough skin more or less scaly and ornamented in parts with lappets or pendants. As in the case of other small Reptilians of the Coal, its enemies were found rather below than above. Its armour therefore was beneath.

The bone-cells are broad and with much-branched canaliculi, those of the bony scales being similar to those of the other bones. The hollow bones are occupied with calcite stained brown and probably representing cartilage.

Not having visited the Joggins for some years, and the gentleman on whom I had relied to give me intimation of new exposures of reptiliferous trees having left the locality, I made a short excursion to the place last summer, and found two trees partially exposed in the reef. These were extracted with the kindly aid of Mr. McNaughton, Superintendent of the Joggins Mine, but unfortunately proved unproductive. A large tree had fallen from the cliff in the previous winter and had possessed a layer of very productive material in its lower part, much of which had however been removed by the waves. I succeeded in obtaining a portion of this material, which on examination proved to contain parts of the skeletons of two specimens of *Dendrerpeton Acadianum* and one of *D. Oweni*. No other reptilian bones nor remains of millipedes or of land shells were observed.

The specimens of *D. Acadianum* were the largest yet found, and some of the bones were in a more perfect state. As examples of these I figure (Fig. 1) the two mandibles of the largest specimen. These seem to have separated on the decay of the body and to have fallen across one another, so that they lie side by side and reversed. They are 8·6 centimetres in length, and one of them shows very well the corrugated sculpture of the bone and a number of the teeth. On the same slab, represented in Fig. 1, is a well-preserved humerus. It has been exposed by cleaning away some of the stone, which probably contains other bones of the fore-leg; but they cannot be worked out without destroying those in sight.

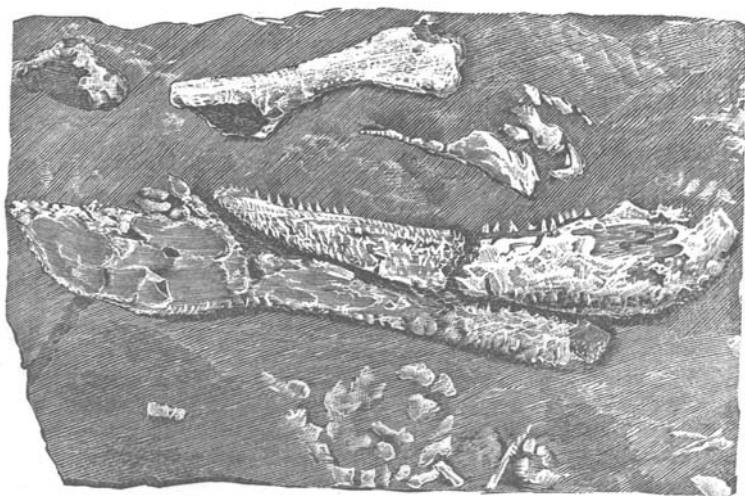


FIG. 1.—Humerus and Mandibles of *Dendrerpeton Acadianum*. Natural size.

I would call attention to the humerus as indicating the development of the fore-limb in this species. The bone in this probably mature specimen is better ossified than in smaller and probably younger specimens. In length it is 4·3 centimetres, or half that of

the mandible, thus exceeding in relative size the humerus of the American Alligator, while its form indicates a limb of much muscular power. Other specimens show that the hind-limb was not larger than the fore-limb; on the whole it was perhaps feebler, so that in this animal there was no approach to that exaggerated size of the hind-limb seen in some of the larger Labyrinthodonts.

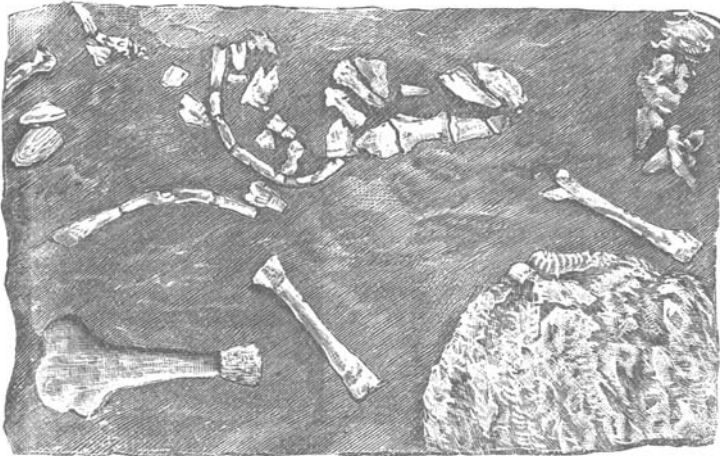


FIG. 2.—Ribs, Phalanx, Scales, Scapular bones, and part of Skull of *Dendroperpeton Acadianum*. Natural size.

The slab represented in Fig. 2 shows the anterior part of the crushed skull, giving its broadly rounded form in front, and the sculpturing of the bone. After the photograph from which the cut is copied was taken, a portion of the matrix was removed, so as to expose the outer teeth on one side and one of the large inner teeth. One of the former with the sculpturing of the edge of the maxillary bone is represented enlarged in Fig. 3.

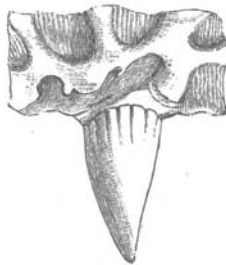


FIG. 3.—Outer tooth and portion of Maxillary bone of *Dendroperpeton Acadianum*.—Enlarged.

On the slab Fig. 2 are two slender bones and a larger bone which I suppose to be parts of the shoulder-girdle. There are also two of the anterior ribs and some bones of the foot (among them a phalanx)

showing portions of four of the bones in position, and giving for one of the toes of the fore-foot a length of about 2·3 centimetres; also a few of the anterior abdominal scutes. All the bones represented belong to the anterior parts of the animal; the portion of the tree containing its posterior parts had unfortunately been destroyed or removed by the sea.

I have remarked in previous memoirs that possibly the animals found in the erect trees, while they must all have been of terrestrial rather than aquatic habits, may in some cases have been young individuals of the species to which they belonged. This supposition is to a certain extent borne out by the present specimens, which are considerably larger than the corresponding parts of individuals previously found, and have the bones more ossified and more strongly sculptured. Possibly, however, we may not yet know the species in its full magnitude.

This suggests the question whether *D. Oweni* may be founded on still younger individuals of the same species. The likelihood of this is not, however, increased by the new discoveries. The specimen of *D. Oweni* found in the tree of 1890 is quite as distinct as those previously found. It has longer, more curved and pointed teeth, thinner and less sculptured cranial bones. The mandibles are only very feebly sculptured. The limbs and feet seem to have been similar to those of *D. Acadianum*, but the abdominal bony scales were narrower and more pointed or "oat-shaped," and the skin of the upper surface more distinctly scaly. On the whole, therefore, the evidence is in favour of *D. Oweni* having been a smaller species allied to, but presenting so far as known no connecting links with, its larger congener.

Hylonomus Lyelli, Dawson, Journ. Geol. Soc. Lond. vol. xv. 1859, p. 274.

Though the newly-found specimens throw no farther light on the amphibians of the group *Microsauria* found in the same repositories with *Dendrerpeton*, they have invited comparison and fresh study of the material previously obtained, and I desire in this connexion to state the reasons which have induced me from the first to maintain that *Hylonomus*, *Hylerpeton*,¹ *Smilerpeton*, and *Fritschia*² are not Labyrinthodonts properly so called, and belong to a quite distinct group, making in some respects nearer approach to the reptilian order to which the *Proterosaurus* of the Permian belongs.

We may take *Hylonomus Lyelli*, the best known of these animals, as a type, and I would state the following points of comparison with *Dendrerpeton*, and most if not all other typical Labyrinthodonts.

1. As to the skull, this is large behind and pointed in front, and its bones are smooth, while the teeth are perfectly simple, without any trace of fluting or plication of the enamel, and there are no interior large teeth. The nasal and maxillary bones are smooth, thin, and elongated. The parietal bones larger and more convex

¹ Owen, J.G.S. vol. xviii. 1862, p. 241.

² Dawson, Phil. Trans. Royal Society, 1882, pt. ii. pp. 638, 641.

than in most other amphibians. The bone which I suppose to be the parasphenoid has a long axial process, and the posterior end moderately broad. On the other hand, it is certain that the skull has an open parietal foramen, has a group of small palatal teeth, and has two occipital condyles.

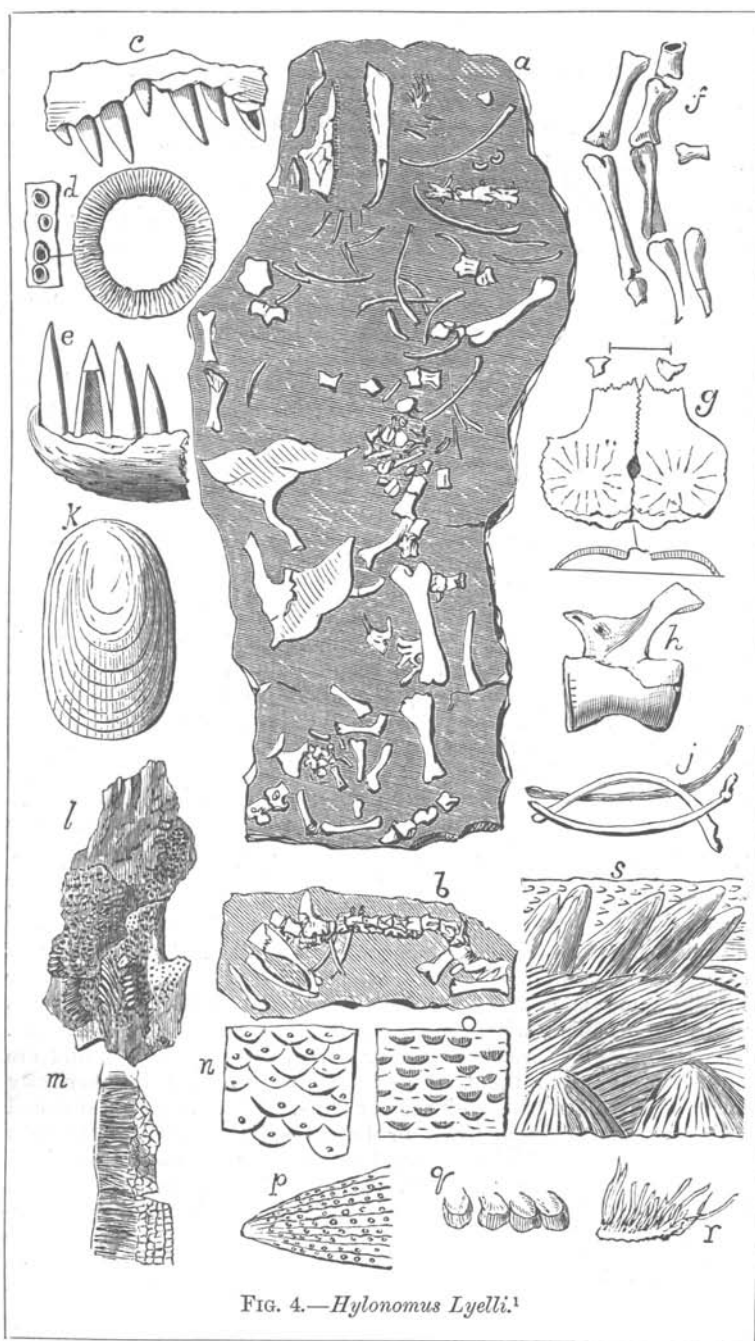
2. As to the trunk. The vertebræ are long, hour-glass-shaped, biconcave, and ossified exteriorly, with large and broad neural and lateral processes. The ribs are well developed, curved, and with a double head. The scapular and pelvic bones are large, especially the latter, which has a very broad well-ossified principal bone, perhaps the ilium. The pelvic bones thus resemble those of *Diplovertebron*¹ of Fritsch, which is, however, an animal very different in other respects. I regret that I have had no means of ascertaining whether the pelvis of *H. Lyelli* was attached to one sacral vertebra or more. The large size of the pelvis would, however, render its attachment to a single vertebra improbable, and in the skeletons on the slabs (a) and (b), Fig. 4, there are in the vicinity of the pelvis pairs of vertebræ attached to each other in such a manner as to suggest that they were permanently united.

3. The limb-bones and ribs have a thin and hard outer bony coat, the interior being usually filled with calcite darkened by organic matter, probably remains of cartilage. The bones of the limbs and feet are long and slender, with well-ossified extremities, and their forms indicate slender limbs and active habits. The hind-limb in particular is somewhat larger than the anterior; and this with the size of the pelvis indicates a form of body broader behind, narrower in front. In farther connexion with this I have remarked in former papers that the skeletons of this animal always lie *on the side*, indicating that the body was flattened, not vertically, but laterally, as in some Lizards. This I regard as an important diagnostic character for *Hylonomus*, and it does not seem to apply to the genus *Hyloplesion* of Fritsch, which is flattened vertically, as well as much inferior in development of pelvis and limbs.

4. As to dermal covering, *Hylonomus* has the abdomen protected by bony scales, but differing in form and probably in arrangement from those of *Dendrerpeton*. The covering of its upper part was however peculiar to itself, presenting a perfectly scaly surface of true corneous scales and with ornamental tubercles and spiny epaulettes on the shoulders, of which there is no trace in any other known amphibian, recent or fossil. It also possessed pendant fringes of cuticle like those of *Dendrerpeton*.

In connexion with this statement, I copy here (Fig. 4) from my "Airbreathers of the Coal Period" an illustration of the scattered bones of a skeleton of *Hylonomus Lyelli*, and some of the parts enlarged, which will serve with the accompanying description to illustrate some of the structures. I have given in the paper above referred to, in the "Transactions of the Royal Society," a copy of a portion of the scaly armour from a micro-photograph.

¹ Plate 52, Fauna der Gaskohle. As interpreted by Fritsch, the flat bone is called the pubis.



¹ Reprinted from "Airbreathers of the Coal Period," 1868.

FIG. 4.—*Hylonomus Lyelli*. EXPLANATION TO PAGE 151.

- a. Skeleton in matrix, showing jaws, ribs, vertebrae, pelvis, and bones of limbs.
- b. Portion of skeleton in matrix, showing vertebrae and limb-bones.
- c. Portion of maxilla with teeth; enl.
- d. Cross-sections of teeth; enlarged.
- e. Anterior end of mandible with teeth; enlarged.
- f. Bones of foot; enlarged.
- g. Parietal bones, showing foramen; enl.
- h. Vertebra; enlarged.
- j. Ribs; enlarged.
- k. Bony scale; enlarged.
- l. Portion of scaly cuticle.
- m. to s. Horny scales, bristles, tubercles, and other appendages of the same; magnified.

Hylonomus Lyelli was an animal of small size. Its skull is about an inch in length, and its whole body, even if, as was likely, furnished with a tail, could not have been more than six or seven inches long. No complete example of its skull has been found. The bones appear to have been thin and easily separable; and even when they remain together, are so much crushed as to render the shape of the skull not easily discernible. They are smooth on the outer surface to the naked eye, and under a lens show only delicate uneven striæ and minute dots. They are more dense and hard than those of *Dendroperpeton*, and the bone-cells are more elongated in form. A specimen in my possession shows the parietal and occipital bones, or the greater part of them, united and retaining their form. We learn from them that the brain-case was rounded, and that there was a parietal foramen. Well-preserved specimens of the maxillary and mandibular bones have been obtained. They are smooth, or nearly so, like those of the skull, and are furnished with numerous sharp, conical teeth, ankylosed to the jaw, in a partial groove formed by the outer ridge of the bone. In the anterior part of the lower jaw there is a group of teeth larger than the others. The intermaxillary bone has not been observed. The total number of teeth in each ramus of the lower jaw was about forty, and the number in each maxillary bone about thirty. The teeth are perfectly simple, hollow within, and with very fine radiating tubes of ivory. The vertebrae have the bodies cylindrical or hour-glass-shaped, covered with a thin, hard, bony plate, and having within a cavity of the form of two cones attached by the apices. This cavity was completely surrounded by bone, as it is filled with stained calc-spar in the same manner as the cavities of the limb-bones. It was probably occupied with cartilage. The vertebrae were biconcave. The neural spines are short and broad, with zygapophyses, and are not separable from the bodies, the neural arches being perfectly ankylosed to the bodies of the vertebrae. There are, on the dorsal vertebrae, strong diapophyses or lateral spines, to which the ribs were articulated. The ribs are long, curved, and at the proximal end have a shoulder and neck. They are hollow, with thin, hard, bony walls. There are short ribs which may be cervical. The anterior limb, judging from the fragments procured, seems to have been slender, with long toes, four or possibly five in number. The posterior limb was longer and stronger, and attached to a pelvis so large and broad as to give the impression that the creature enlarged considerably in size towards the posterior extremity of the body, and

that it may have been in the habit of sitting erect. The thigh-bone is well formed, with a distinct head, and the lower extremity flattened and moulded into two articulating surfaces for the tibia and fibula, the fragments of which show that they were much shorter. The toes of the hind-feet have been seen only in detached joints. They seem to have been thicker than those of the fore-foot. Detached vertebræ, apparently caudal, have been found, but the length of the tail is unknown. The limb-bones are usually somewhat crushed and flattened, especially at their articular extremities, and this seems to have led to the error of supposing that this flattened form was their normal condition; there can be no doubt, however, that it is merely an effect of pressure. The limb-bones present in cross-section a wall of dense bone with elongated bone-cells, surrounding a cavity now filled with brown calc-spar, representing cartilage. Nothing is more remarkable in the skeleton of this creature than the contrast between the perfect and beautiful forms of its bones, and their imperfectly ossified condition, a circumstance which raises the question whether these specimens may not represent the young of some reptile of larger size.

The dermal covering of this animal is represented in part by oval bony scales, which are so constantly associated with its bones that I can have no doubt that they belonged to it, being the clothing of its lower or abdominal parts; while above it was clad in the beautiful scaly covering above described. The scales are thicker than those of *Dendroperon*. On the inner side they are concave, with a curved ledge or thickened border at one edge. On the outer side they present concentric lines of growth. The companion genera above named are not known so completely as *Hylonomus*, but all their characters so far as known would place them with it as members of the same group rather than with *Dendroperon* and its allies. Of other American forms it appears to me probable that *Sauroplorea digitata* of Cope¹ may be very near to my genus *Fritschia*, and agrees with it in having rod-like abdominal scales, but its head is not yet known. *Brachydectes* of the same author is very near to *Hylroperon*, especially as specimens of the latter recently obtained show some characters, as the ascending ramus of the lower jaw, on which Cope distinguishes this genus.

Of Fritsch's species several may come within the group of Microsauria. The genus *Hylroplezion* of this author has indeed been united by Credner with *Hylonomus*, a position to which it scarcely seems entitled, and *Petrobates* of Credner is nearly allied, while *Seelya* and *Dawsonia* of Fritsch also approach to the characters of this order. Still the whole of these animals seem very inferior in development of limb and form of body to *Hylonomus*.

I regret very much that, owing, as I believe, to imperfection of material, so many palæontologists have failed to appreciate fully the characters of *Hylonomus* as a type of the higher Carboniferous Amphibia approaching to Reptilia.

Fritsch, in the conclusion of his important work on the Stego-

¹ Ohio Reports, vol. ii. p. 388.

cephala of the Gas-coal of Bohemia, has some valuable remarks on the affinities of these animals; and, though I can by no means agree with the manner in which he arranges them in families, or with the way in which he mixes up Labyrinthodontia and Microsauria with other creatures so different as the Branchiosauridæ and the Ophiderpeton group, I think his conclusions deserve mention, and may state them nearly in his own words as follows:—

After remarking on the fact that we know no clear links of derivation from any previous animals, he states that on any theory of derivation different origins must be supposed. He illustrates this by the characters of the vertebræ in different genera, as, for instance, the biconcave, the partly cartilaginous, and the diplo-vertebrate types.

Whatever view may be taken of their origin, the increased knowledge of their structures has not made clear as yet their precise relation to modern Amphibia and Reptilia; and only serves to make us doubt whether the distinctions recognized in the modern forms apply to these ancient creatures in the same degree. We seem indeed to have, both in the Labyrinthodonts and the Microsaurians, composite or generalized types having properties akin to those of both classes, and these in very different degrees. If we regard them all as agreeing in the general structure of the skull, with its free parasphenoid, and a similar set of bones in the shoulder-girdle, then we shall find that in other respects we have a heterogeneous assemblage, some agreeing in the formation of the vertebræ, ribs, and pelvis, with Amphibians, others with Reptiles; and there are corresponding differences in the dermal covering. If we attempt to group these creatures in orders and families, we are met with very great difficulties, owing to the variety and kinds of their differences, which, in connection with the imperfection of the material, almost defy the classifier.

So far Fritsch, and I may add that I consider that little is gained by grouping animals so diverse in organization under one head of Stegocephala in consequence of resemblances in certain cranial bones, and that a more general and large view should be taken of the *tout ensemble* of their structures.

With reference to that selection of these animals which has been preserved in the erect trees of Nova Scotia, the only ones which it has been necessary for me to study, I have no hesitation in placing in two orders or families, that of the Labyrinthodontia, to which *Dendrerpeton* belongs, and that of the Microsauria, including *Hylonomus*, *Hylerpeton*, *Fritschia*, and *Smilerpeton*, all of which have many important points in common. The other forms I leave to those who have to deal with them, but I feel convinced that some of them should be separated, probably ordinarily, from the above.

The following extract from Credner on the systematic position of *Hylonomus* and *Petrobates*, shows that he to some extent shares in these views.¹ It should be understood, however, that his *Hylonomus*

¹ Zeitsch. Deutsch. geol. Gesellsch., Berlin, 1890, p. 257.

is *Hyloplesion* of Fritsch, and possibly not congeneric with *Hylonomus* proper, and certainly less reptilian in its characters.

"The question whether *Hylonomus*, and especially whether *Petrobates*, is to be classed with the Stegocephala or with the Rhynchocephala, is not one which can be at once decided. The long, bent, trunk ribs, the marking off of the cervical section by short differently-shaped ribs, the rhombic horned episternum, the bony pubica, the ossification of the carpus and tarsus taken together give both quadrupeds a reptilian habitus. In the case of *Petrobates* this becomes more pronounced by the occurrence of ventral ribs and of intercentral lower arches dovetailed in between the vertebral centres of the neck. On the other hand, *Hylonomus* and *Petrobates* have, like the Amphibians, only one sacral vertebra. A more primitive habitus is also presented in the persistence of the continuous chorda, in the insignificant superficial ossification of the elements of the skeleton, the absence of ossification in the heads of the hollow bones of the extremities,¹ and in the uniform shape of the small teeth.

"In *Hylonomus* this becomes strengthened by an apparently true stegocephalic skull-cover, as well as by the thick comb-like development of teeth in the roof of the mouth, and the presence of a ventral shield of bony scales.

"These several points of resemblance connect *Hylonomus* (*Hyloplesion*) rather with the Stegocephala, while *Petrobates*, on account of its ventral ribs and intercentral arches, comes nearer the Rhynchocephala. In other words, they both possess a general, as yet but slightly differentiated, common habitus, but in *Hylonomus* (*Hyloplesion*) the primitive type is more pronounced than in *Petrobates*, in which already a great specialization in the direction of the Rhynchocephala finds expression. If one, in considering *Petrobates*, disregards the skull, which is not accurately enough known, one might hold this quadruped to be a small Rhynchocephalian, of the family of the Proterosauridæ, if it were not that the presence of only a single sacral vertebra was opposed to this view. It appears as if *Hylonomus*, *Petrobates*, *Palæohatteria*, and *Kadaliosaurus* belong to a natural group of contemporaneous quadrupeds, representing however as many stages of specialization in the direction of Reptiles."

Bearing in mind that the typical species of *Hylonomus*, represented by *H. Lyelli*, are in some important respects nearer to *Palæohatteria* and *Kadaliosaurus* (which are regarded by all palæontologists as generalized reptilian genera tending to Amphibians) than either *Hyloplesion* or *Petrobates*, this conclusion of Credner becomes very significant as to the position of the Microsauria, and may be regarded as confirmatory of the conclusions which, though not a specialist in fossil reptilia, I have ventured to suggest in connexion with the species which I have been induced to study, in consequence of their connexion with my other work in Carboniferous geology.

It must be remembered that the repositories in which *Hylonomus* and its companions are contained are of an exceptional nature, and likely to have entrapped animals specially terrestrial in their habits.

¹ These characters do not apply in so great degree in *Hylonomus* proper.

I have elsewhere¹ referred to the fact that even in the basal beds of the Carboniferous (Horton series) there are footprints of quadrupeds of larger size than *Hylonomus*, which were digitigrade, and had a length of stride comparable with that of modern carnivorous mammals. I therefore anticipate the discovery, in these Lower Carboniferous beds, of reptiles of as high or higher grade than those hitherto found in the Coal-formation or Lower Permian, throughout which periods the same or similar forms seem to have prevailed.

II.—ON THE VERY RECENT AND RAPID ELEVATION OF THE HIGHLANDS OF EASTERN ASIA.

By HENRY H. HOWORTH, Esq., M.P., etc., etc.

(Concluded from our last Number, p. 104.)

THESE opinions of Mr. Campbell, however clearly and precisely stated, are so strong and emphatic, that I wish to confirm them by those of another experienced geologist, who worked much among the Himalayas, namely, General McMahon. In "Notes of a Tour through Hangrang and Spiti," published in the twelfth volume of the Records of the Geological Survey of India, he describes the existing glaciers and their remains in the district, and then says: "I do not know whether any one has ever supposed that the Himalayas were covered during the last Glacial period with an ice-cap, but I may note that whilst I saw nothing to favour such an idea, I saw much to negative it. The contour of the hills and valleys in those parts of the interior of the Himalayas that I have visited is sharp and angular, and where rounded outlines are seen, they are sufficiently explained by the action of subaerial forces on comparatively soft and friable rocks.

"But setting aside the idea of an ice-cap, the question remains—Was there formerly any great extension of local glaciers, and if so within what limits? To this question I answer that, whilst I saw evidence of the former extension of existing glaciers, I saw nothing during my tour to lead me to believe that these glaciers had ever, within a reasonable geological period, extended lower than 11,000 or 12,000 feet above the sea.

"On looking down from a high vantage ground, deep narrow side valleys may be seen on the Upper Sutlej, below that level, in which the course of the streams flowing through them is so sinuous that the sharp headlands formed by their sudden bends interlace like the nuts of cogwheels working into each other. The flow of ice in a glacier being analogous to the flow of water in a river and its tributaries, a grand glacier filling the valley of the Sutlej would not have prevented the flow of ice from the side glaciers into the main glacial stream. But had these side valleys ever been filled with glaciers, the sharp interlacing headlands would have been gradually worn down to smooth surfaces, and the valleys straightened and

¹ Trans. Roy. Soc. part ii. 1882, p. 653.