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SECTION II.

DESCRIPTIONS OF FOSSIL FISHES.

BY

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THE

CLASSIFICATION AND GEOLOGICAL DISTRIBUTION

OF OUR

FOSSIL FISHES.

So little is generally known in regard to American fossil fishes, that I have thought the notes which I now give upon some of them would be more interesting and intelligible if those into whose hands they will fall could have a more comprehensive view of this branch of palæontology than they afford. I shall therefore preface the descriptions which follow with a few words on the geological distribution of our Palæozoic fishes, and on the relations which they sustain to fossil forms found in other countries, and to living fishes. This seems the more necessary, as no summary of what is known of our fossil fishes has ever been given, and the literature of the subject is so scattered through scientific journals and the proceedings of learned societies, as to be practically inaccessible to most of those who will be readers of this report.

I. THE ZOOLOGICAL RELATIONS OF OUR FOSSIL FISHES.

To the common observer, the class of Fishes seems to be well defined and quite distinct from all the other groups of vertebrate animals; but the comparative anatomist finds in certain unusual and aberrant forms peculiarities of structure which link the Fishes to the Invertebrates below and Amphibians above, in such away as to render it difficult, if not impossible, to draw the lines sharply between these great groups. *Amphioxus,* the lowest of the Fishes, has a structure much simpler, and organs and senses more rudimentary, than some of the two higher of the invertebrate classes, Mollusks and Crustaceans; while in *Lepidosiren* we find an organization that is as much amphibian as piscine. In the judgment of some anatomists, the *Dipnoi*—which include *Lepidosiren* of South America, *Protopterus* of Africa, and *Ceratodus* of Australia—should be set off in a distinct class by themselves, or be united with the *Ganocephala* (the Carboniferous salamanders), as holding an intermediate position between the true Fishes and Amphibians. Nearly all fishes, however, possess in common a structure which may be very readily de-

fined. They have a fusiform bo dy, adapted to rapid motion through a resisting medium, and they are aquatic in habit and respiration. From their mode of life—floating freely as they do in a fluid having approximately the same specific gravity as their own—they have no occasion for limbs, such as serve to support the body in antagonism to gravitation, and act as locomotive organs in the higher vertebrates. Their movements are therefore effected only by fins, into which the anterior and posterior extremities and tail are developed. As the highest efficiency of these locomotive organs is incompatible with their use as organs of prehension, they are never employed for seizing their prey, but this is accomplished by an unusual development of the mouth and its appendages. Not being required to sustain the weight of the body, the framework is much less rigid than in terrestrial animals, and the bones are softer and more elastic. This last feature in their organization has prevented the perfect preservation of many fishes in the fossil state, and has greatly increased the difficulty of the study of some groups, especially the sharks, of which the cartilaginous skeletons have generally disappeared, and the teeth, fin-rays and dermal tubercles, disconnected, and perhaps widely scattered, are all that remain.

Various schemes of classification of fishes have been proposed by different zoologists; the changes and additions made to the earlier systems having, for the most part, followed closer study and a better knowledge of their anatomy. The first scientific system of classification proposed was that of Cuvier, who divided the class of fishes into three great orders—the *Chondropterygii* (cartilaginous fishes), the *Acanthopterygii* (fishes with spined fins), and *Malacopterygii* (fishes with soft fin-rays). Agassiz, who followed Cuvier in time, divided fishes into four orders, according to the character of their scales, viz; *Cycloidii* (fishes with rounded, entire scales, as the salmon), *Ctenoidii* (fishes with serrated scales, as the perch), *Ganoidii* (fishes with brilliant, glistening, enameled scales, such as the gar-pike), and *Placoidii* (fishes with dermal tubercles or plates, such as the sharks and rays). Johannes Muller divides fishes into five orders, viz: *Leptocardia* (amphioxus), *Cyclostomata* (lampreys), *Teleostei* (bony fishes), *Ganoidei* (ganoid fishes), and *Selachii* (sharks and rays). Professor Richard Owen proposed to divide the vertebrates into two classes—*Hæmatocrya,* cold-blooded, and *Hæmatotherma,* warm-blooded animals—the class *Hæmatocrya* including Fishes, Amphibians and Reptiles. In Owen's classification, fishes may be said to comprise three of the five sub-classes of *Hæmatocrya,* viz: *Dermopteri, Teleostomi* and *Plagiostomi*—the first including Agassiz's *Ganoidii* and Muller's *Leptocardia;* the *Teleostomi* including the *Cycloidii* and *Ctenoidii* of Agas-

siz; the *Plagiostomi,* the sharks, rays and chimæras. Of these sub-classes of fishes, Owen makes ten orders, viz: I. *Cirrostomi* (lancelet); II. *Cyclostomi* (lamprey and hag); III. *Malacopteri* (soft finned fishes, herring, salmon, etc.); IV. *Acanthini* (cod, etc.); V. *Acanthopteri* (perch, etc.); VI. *Plectognathi* (file-fish, trunk-fish, etc.); VII. *Lophobranchii* (seahorse); VIII. *Ganoidei* (ganoids); IX. *Holocephali* (chimæra); X. *Plagiostomi* (sharks and rays): his order XI., *Protopteri,* being considered transitional. Other systems have been framed by Hæckel, Gunther, Lutken, Cope, Gill, etc.,* but perhaps the most satisfactory, inasmuch as it includes a discussion of fossil forms, is that of Prof. Huxley, proposed within the past year. Huxley divides the class PISCES into two sub-classes, of which the first includes only *Amphioxus,* and is equivalent to "*Leptocardia*" of Hæckel. In this subdivision "the notochord extends to the anterior end of the body. There are no skull, auditory or renal organs, such as exist in the higher vertebrata. The heart is a simple tube, and the liver is saccular." In the second subclass of Huxley (=*Pachycardia,* Hæck.), "the notochord extends behind the pituitary fossa. A skull, auditory and renal organs are developed. The heart is divided into auricular and ventricular chambers. The liver has the ordinary structure." The orders into which Huxley divides the class PISCES are as follows:

1. PHARYNGOBRANCHII (*Amphioxus*).
2. MARSIPOBRANCHII (Lamprey and Hag).
3. ELASMOBRANCHII (Sharks, Rays and Chimæras).
4. GANOIDEI (Ganoids).
5. TELEOSTEI (Bony Fishes).
6. DIPNOI (*Lepidosiren*, etc.).

When we add fossil forms to the living groups of fishes, and trace the history of this class from its first appearance in far-off geological ages up to the present time, some very interesting facts are brought out; to a few of which I will very briefly allude.

In the first place, we learn from the study of fossil fishes that in all probability no fishes swam in the most ancient Silurian sea; that they began to appear in the sea of the Upper Silurian age, and in the Devonian existed in large numbers, attained a magnitude equal to that of any

* Professors Gill and Cope are agreed in separating *Amphioxus, Myxine* and *Petromyzon* from fishes, and in forming three classes out of the old class of fishes, viz: PISCES (which includes the sub-classes *Teleostei, Ganoidei* and *Elasmobranchii*), MARSIPOBRANCHII and LEPTOCARDII. (Smithsonian Miscell. Coll., No. 247; Annals and Mag. Nat. Hist., Vol. IX., 1872.)

fishes of the present day, and possessed, in some instances, a structure scarcely less highly organized than that of the highest group of modern fishes.

In tracing the history of fishes through the successive geological ages, we also find that in later times they have been greatly diversified by divergence from some of the earlier and simpler forms; and that while the number of individuals may not be greater now than in the Jurassic or Carboniferous periods, the number of genera and species is certainly much greater now than formerly. This multiplicity of form has apparently been produced by differentiation; that is, by the exaggeration of certain characters possessed by a remote ancestor, in different groups of his descendants, until nearly all traces of relationship and common parentage are lost. It will be readily understood from these remarks that fossil fishes, in many instances, present "synthetic types"; that is, a single genus and species will be found to combine characters which are distributed among different families, and perhaps orders, of living fishes; hence, before a truly comprehensive and intelligent view can be taken of the class of fishes, it is essential that the fossil forms, which are so often connecting links, and which fill many of the gaps that exist in our present fauna, should be carefully co-ordinated with living species. The study of fossil fishes becomes, therefore, intensely interesting and highly instructive to the zoologist. It is to be regretted, however, that the rarity of the remains of fishes and the imperfection of their preservation make it impossible that they should solve all questions with regard to the relationship of living fishes, or of the life-history of the class; but every year new light is thrown upon the structure and relationship of fishes by the discovery of some new or unusually well preserved fossil. I have, therefore, ventured to hope that the remains of the remarkable fishes which are for the first time made known in this report, will be objects of more than mere idle curiosity, and that they will contribute something to the better understanding of the organization and genesis of all the great groups of fishes.

As I have before said, the dismembered condition and incomplete preservation of many fossil fishes, and the entire absence of their soft parts make it exceedingly difficult to determine in all cases accurately their relationship to each other and to living fishes. Enough, however, has been learned of their structure to permit us to group many of them with a good degree of confidence; and quite a number of families and many more genera and species have been established to receive them.

One of the most striking results of the study of fossil fishes is the discovery that in the earlier geological ages the order which includes

much the largest part of our present ichthyic fauna (the Teleosts) had no existence, and that it was only introduced in the Cretaceous period. We also learn that Placoderms and Elasmobranchs constituted the earliest groups of fishes: that during the Devonian, Carboniferous and Jurassic ages the Ganoids attained great development, and that they subsequently dwindled away—giving place to the Teleosts—until now they are represented by but seven genera on the face of the globe.

Of existing Ganoids, by far the larger number are found in North America. Five of the seven genera occur on this continent, and four of the five nowhere else. The living Ganoids are distributed among the genera *Lepidosteus* (Gar-pikes), *Amia* (Dog-fish of the Lakes), *Accipenser* (Sturgeons), *Scaphirhynchus* (Shovel-fish), and *Spatularia* (Paddle-fish) all of which are North American—and *Polypterus* and *Calamichthys,* found in Africa.

The persistence of the ancient fishes in North America is doubtless due to the fact that certain parts of this continent are the oldest known portions of the earth's surface. The Canadian highlands have, so far as we know, never been submerged since the beginning of the Silurian, and nearly all of the interval between the Mississippi and Atlantic has existed as dry land since the close of the Carboniferous age. Hence, though exposed to extreme alternations of climate—as in the Tertiary and Glacial periods—parts of our continent have apparently always remained as asylums where some representatives of its ancient tribes of fishes have found a safe retreat, and where the chain of descent has been unbroken from remote geological ages.

A general view of the zoological relations and geological distribution of fossil fishes may be gathered from the following table, and the notes which follow it:

Table showing Classification and Geological Distribution of Fossil Fishes.

	Palæozoic.				Mesozoic.			Cenozoic.	
	L. Sil.	U. Sil.	Dev.	Carb.	Trias.	Juras.	Cret.	Tert.	Rec't
Dipnoi									*
Teleostei							*	*	*
Placodermi		*	*						
Ganoidei									
a. Amiadæ									*
b. Lepidosteidæ			*	*	*	*	*	*	*
c. Crossopterygidæ			*	*	*	*			*
d. Chondrosteidæ			*?			*		*	*
e. Cephalaspidæ		*	*						
f. Pycnodontidæ				*	*	*	*	*	
Acanthodidæ			*	*					
Elasmobranchii									
a. Squalli		*	*	*	*	*	*	*	*
b. Rajæ						*	*	*	*
c. Chimæroidi			*			*	*	*	*
Marsipobranchii									*
Pharyngobranchii									*

So far as is at present known, no fishes belonging to the orders *Pharyngobranchii* or *Marsipobranchii* have been found in the fossil state. This is probably due to the soft and perishable nature of their skeletons and integuments. It is evident that no traces of *Amphioxus* would remain if buried in sediments at the bottom of the water it inhabits; and the same is true of the Hag (*Myxine*), though if Lampreys existed in former times it is somewhat singular that no traces of their horny teeth should have been discovered.

The *Elasmobranchii* seem to be represented in the earliest traces of fishes known, and they have continued to exist in large numbers, and apparently with no very radical change of structure, from the Devonian and Carboniferous ages to the present day. From the fact that the skeleton in the *Elasmobranchii* is generally cartilaginous, it has almost always disappeared in the process of fossilization; and the more indestructible organs—the teeth, spines, and dermal tubercles—have alone resisted decay. These are also usually disconnected and often widely separated. Hence it is exceedingly difficult to say with certainty to what order of Elasmobranchs many of these *disjecta membra* belong—whether the fishes that wore them were Sharks, Rays or Chimæroids. The teeth will, however, frequently permit us to decide this question, and it would seem that the most ancient Elasmobranchs were mainly sharks. Of these we find great numbers of spines, teeth and dermal ossicles in the sediments of the Carboniferous sea, and many, though not as many, in those of the Devonian and Upper Silurian. The teeth of these ancient sharks present all the varieties of crushing, cutting and piercing organs; and it seems that there was even a greater variety among the sharks of the ancient seas than in those of the present day. It will also be remarked, that these old-time sharks were much more generally provided with defensive spines; some of which attained dimensions entirely unparalleled in our present fauna. Another characteristic of this ancient group of cartilaginous fishes is, that their superficial bony organs were generally highly ornamented. The spines to which I have referred are often most elegantly sculptured, and the dermal tubercles are embellished in various ways to a degree rarely observed in living species. Agassiz has shown that a large part of the ancient sharks are zoologically allied to *Cestracion*—the Port Jackson shark—so that this isolated genus, of which there are now but two or three species, may be considered, like the Ganoids and Chimæroids, as a relic of a fauna once immensely developed, but now on the eve of total extinction.

The Chimæroids are now represented by the two genera *Chimæra* and *Callorhynchus*—two species only of the former and one of the latter being

known. Numerous teeth of extinct Chimæroids have been found in the Tertiary, Cretaceous and Jurassic rocks of the Old World, and it was long ago shown by Sir Philip Egerton, who described these fossil forms under the names of *Edaphodon, Passalodon,* etc., that the Chimæroids were numerous and attained large size in the Mesozoic seas. But up to the date of the publication of this report, no unmistakable remains of Chimæroids have been announced as discovered in Palæozoic rocks. It will be seen, however, that in the fossils which are figured and described in the present volume as different species of *Rhynchodus,* we have satisfactory proof of the existence in the Devonian seas of Chimæroids, apparently closely resembling in structure the best known of the more recent *Holocephali*. As has been remarked elsewhere, the Conodonts obtained by Pander from the Lower Silurian rocks of Russia, were described by him as the teeth of Elasmobranchs, and as affording evidence of the existence of sharks or rays at a much earlier period in the world's history than had been before suspected. Since the character of these organs is still under discussion, they can not be accepted as conclusive evidence of the truth of Prof. Pander's generalization.

The *Ganoidei.* The order of Ganoids, as at present constituted, includes among its living and fossil genera a multitude of forms, some of which seem to have very little in common. The most striking characteristics of the living Ganoids are the possession of bony or horny scales covered with enamel, the multiple valves of the *bulbus arteriosus,* the non-decussating optic nerves, and the abdominal ventral fins. It has also been ascertained that they generally have unequally-lobed or heterocercal tails, in which the vertebral column is prolonged into the superior lobe. The latter character is, however, by no means universal; although, so far as known, the caudal fins of Ganoids differ in structure from those of Teleosts. Whatever differences they may exhibit among themselves, they may in all cases be said to be *vertebrated*; that is, penetrated to a greater or less degree by the extension of the vertebral column; but in many of the Ganoids of ancient times (e. g. *Cœlacanthini*) the tail was equally divided by the prolongation of the spine—a phase of structure to which McCoy has applied the term *diphycercal.*

A large part of the Ganoids, both living and extinct, are provided with a coat of mail in a series of rhomboidal, bony and enameled scales, of which a typical example may be seen in the Gar-pike (*Lepidosteus*). But to this prevalent character we have a striking exception in the "Dogfish" of the lakes (*Amia calva*), which is an undoubted Ganoid, but is provided with thin, circular, imbricated scales, very similar to those of most osseous fishes. On recurring to the past history of the order, we

find both of these varieties so fully represented in fossil forms that we are able to arrange them in two great groups—the Cycliferous and Rhombiferous Ganoids. If it contained only these two forms, the order of *Ganoidei* would be well defined; but we must make it hold among living fishes the strange group composed of the Sturgeon, the Shovel-fish and the Paddle-fish, in which the body is either naked or covered with large plates, and is never, properly speaking, scaled. To these fishes the name Chondrostean Ganoids is given, from the preponderance of cartilage in their structure. The co-ordination of the extinct forms with those I have enumerated is a matter of no little difficulty, since they present marked peculiarities in their exoskeletons, and their internal anatomy is necessarily unknown. By Prof. Huxley the order of *Ganoidei,* when made to include both fossil and living forms, is divided into the following sub-orders:

1. The *Amiadæ*, having a single representative in the rivers and lakes of North America (*Amia calva*), and no member of the group is certainly known to exist in a fossil state. The characteristics of this sub-order, as given by Huxley, are cycloid scales, preoperculum, single median jugular plate, branchiostegal rays, non-lobate paired fins, and heterocercal tail.

2. The *Lepidosteidæ* include fishes which have rhomboidal, enameled scales, a preoperculum, branchiostegal rays, non-lobate paired fins, and heterocercal tails. Fishes of this group occur in the rivers and lakes of North America. Several species of the genus *Lepidosteus* also occur in Tertiary rocks. In the Cretaceous, Jurassic and Triassic strata, the *Lepidosteidæ* are represented by numerous genera—*Dapedius, Lepidotus, Æchmodus,* etc.—and in the Palæozoic formations by *Palæoniscus. Amblypterus* and *Eurylepis* in the Carboniferous, and perhaps *Cheirolepis* in the Devonian.

3. The *Crossopterygidæ.* The most striking character in this group is found in the paired fins, which are lobate; that is, having their solid, central portions covered with scales, and appearing like prolongations of the abdominal walls. The scales may be cycloid or rhomboid. The dorsal fins are either two in number, or, if single, very long, or composed of many subdivisions. There are no branchiostegal rays, the jugular plates are two principal, with sometimes several supplementary ones. The tail may be heterocercal or traversed centrally by the vertebral column (diphycercal). The only members of the sub-order now living are *Polypterus* of the Nile, and *Calamichthys,* which inhabits the rivers of Senegal. One of the most remarkable groups of this sub-order, found in the fossil state, is that which has been designated as the family of *Cœlacanthini.* The fishes of this group are found in the Chalk, where

they are represented by *Macropoma,* in the Jurassic, represented by *Undina,* and in the Permian and Carboniferous, where the genus *Cœlacanthus* occurs, of which three species are described in the present volume.

All of these last-mentioned fishes are characterized by hollow fin-rays—whence their name—and by paired, elliptical, jugular plates, two dorsals which are sustained by palmated, inter-spinous bones, and by diphycercal tails, through which the vertebral column extends, and bears at its extremity a minute, supplementary caudal fin. In the Devonian and Carboniferous formations a large number of genera represent the *Crossopterygidæ,* viz.: *Osteolepis, Diplopterus, Glyptolæmus, Megalichthys, Holoptychius, Rhizodus, Dipterus, Phaneropleuron,* and probably the American genus *Onychodus.* In some of the fishes of this sub-order the bodies of the vertebræ are ossified, and it is the opinion of Prof. Huxley that the passage from the Fishes to the Amphibians was through this group.

4. The *Chondrosteidæ.* In the fishes of this sub-order the body is naked, or more generally protected by bony plates, which cover more or less of the surface. Neither the pectoral nor the ventral fins are lobate. The branchiostegal rays are few or absent; the tail is heterocercal. The teeth are small or absent. In this group are the sturgeons (*Accipenser*) which inhabit the rivers of all the northern hemisphere, and *Spatularia* and *Scaphirhynchus,* found only in North America. These constitute all the living members of the sub-order. In the Jurassic rocks the sturgeons are represented by *Chondrosteus,* and, as I think, in the Devonian, by *Macropetalichthys.*

5. The *Cephalaspidæ.* These form a remarkable group of fishes which occur only in the Devonian and Upper Silurian rocks, and include, perhaps, the oldest well-defined fishes yet known. The type of this sub order is *Cephalaspis,* which has been made well known to the students of geology through the descriptions given by Agassiz and Hugh Miller. In *Cephalaspis* the head and anterior portions of the body were covered by a broad, shovel-shaped, bony shield. The posterior portion was scaled. The other members of the group are *Pteraspis, Auchenaspis, Menaspis, Scaphaspis,* etc. They are all small, and their relations to living fishes are quite uncertain. Prof. Huxley has pointed out the resemblance which they bear to the Chondrosteans; comparing *Cephalaspis* with *Scaphirhynchus,* and *Pteraspis* with *Spatularia.* It is a somewhat remarkable fact that, with the exception of one well-marked species of *Cephalaspis* (*C. Dawsoni*), found by Dr. Dawson in the Devonian rocks of Gaspe, none of the *Cephalaspidæ* have been discovered in America.*

* An exhaustive monograph of the *Cephalaspidæ* has been published by Messrs. Lancaster & Powrie in the volumes of the Palæontographical Society for 1870-71.

6. The *Placodermi.* This is the name given by Pander to the group of fossil fishes called *Placoganoids* by Owen, which includes *Coccosteus, Pterichthys, Asterolepis* and *Heterostius* of Pander, and a lso the gigantic fishes, for the first time fully described in this report, and found as yet only in the Devonian rocks of Ohio—*Dinichthys* and *Aspidichthys.* In the Placoderms, the head and anterior portions of the body were protected by bony plates, which were for the most part united by sutures, and had the external surface studded with points or bosses of enamel. The posterior portion of the body was either naked, or covered with angular, e nameled scales. The vertebral column was genera lly cartilaginous; but a *Coccosteus*, with true bony vertebræ, is reported to have been recently discovered.*

The remains of these singular fishes were first found in Russia (1813) by Prof. Asmuss; and by him and by Prof. Eichwald several genera were described under the names of *Asterolepis, Bothriolepis, Homostius* and *Heterostius.* The fragmentary condition of the specimens upon which these descriptions were based created considerable confusion of nomenclature. *Asterolepis* of Eichwald is now kn own as *Pterichthys,* and *Homostius* has been superse ded by *Asterolepis;* the last two names having been firmly fixed to the icthyolites which now bear them by the graphic descriptions of Hugh Miller. Similar fossil fishes have since been found in considerable numbers in Scotland by Miller, Peach and others, in Bohemia by Barrande, and in this country by the writer. No well-marked specimens of *Pterichthys, Coccosteus* or *Asterolepis* have yet been met with in America, but I have a few detached plates, obtained from the Corniferous limestone at Delaware, which probably belong to *Coccosteus;* and the great fishes of the Huron shale, described in this report under the names of *Dinichthys* and *Aspidichthys,* exhibit such resemblances in structure to the Placoderms of the Old World, that we are compelled to place them in the same sub-order.

The Placoderms are eminently characteristic of the Devonian age; and the larger members of the group were no t only the most highly organized, but were, from their size and armament, the most formidable of then existing animals.

The affinities of the *Placodermi* are still matters of doubt and discussion among zoologists. The cartilaginous condition of the vertebral column is the only feature in their structure that indicates a low or embry onic organization; and this is a character of somewhat doubtful significance. The vertebræ are also reported to have been sometimes ossified, as in the

* Murchison's Siluria, p. 478.

case referred to above. The amount of true bony tissue that composed their cephalic, dorsal and ventral shields, and their massive jaws, was far in excess of that secreted by most of our so-called bony fishes. Prof. Huxley, who has discussed this question with characteristic sagacity, compares the bony armor of the Placoderms with that of the plated Siluroids, and is disposed to consider them as connecting links between the physostome Teleosts—the highest of the order—and the typical Ganoids.

7. The *Acanthodidæ*. These were small fusiform fishes, of which the remains are not rare in the Palæozoic strata of the Old World, but have never yet been met with in America. Their geological range is from the base of the Devonian to the Permian. A large number of species have been described by Agassiz, Sir Philip Egerton, Mr. Powrie, Profs. Kner, Roemer and others, in the genera *Acanthodes, Diplacanthus, Climatius, Parexus,* etc.

The Acanthodians derive their name from the numerous and relatively large spines which are set at the anterior margins of the fins, and elsewhere on the body. These spines are implanted in the integuments like those of sharks; and like them also are often ornamented and sometimes set with rows of denticles. The surface of the body in the Acanthodians was covered with closely-set, shagreen-like scales; the spine was "notochordal," and the cranium mostly cartilaginous.

By Prof. Agassiz the Acanthodians were regarded as Ganoids; but Mr. Powrie considers them as Elasmobranchs, while Prof. Huxley is disposed to regard them as annectant forms between the Elasmobranchs and Ganoids.

8. The *Pycnodontidæ* are also fishes of somewhat questionable relations, though generally considered as Ganoids. In form and in some points of structure they resemble the Plectognath-Teleosts—*Balistes, Ostracion,* etc.—but the spinal column was cartilaginous, and the dentition consisted of a series of bony and enameled bosses set in a kind of pavement, and adapted to crushing mollusks and crustaceans. The Pycnodonts range from the base of the Carboniferous series to the Tertiary, but are now all extinct. Few Pycnodont fishes have as yet been found in the rocks of America. I have identified *Platysomus* among the fossils collected from the Coal Measures of Illinois, and have seen the teeth of undescribed Pycnodonts collected from the Lower Carboniferous of Arizona by Mr. G. K. Gilbert, from the Cretaceous of Brazil by Prof. Hartt, and from the Green Sand of New Jersey by Prof. Marsh.

II. GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF OUR FOSSIL FISHES.

FISHES OF THE SILURIAN SYSTEM.

Most students of geology are aware that the remains of fishes are reported as occurring in considerable numbers in the Upper Silurian rocks of Europe, and that it is generally believed that no traces of fishes have been discovered in the Lower Silurian strata of any country; and also that in America no fishes have been met with in strata of earlier date than the Devonian age. While statements of this purport correctly express the present state of our knowledge on this subject, they require a word of explanation and perhaps of qualification.

That there were no fishes in our Lower Silurian seas, seems indicated by their entire absence from the abundant and carefully made collections of fossils that have been obtained from our Trenton and Cincinnati limestones. The exposures of the Cincinnati group, for example, are so numerous and ample, and they have been studied with such industry and care, that it seems improbable, if any remains of fishes exist in this formation, that they should have been overlooked. The fidelity with which even the most delicate mollusks, radiates and crustaceans have been preserved in the sediments of our old Silurian seas, goes far to prove, that if any vertebrates had inhabited these seas, at least some fragments of them would have remained. It should be remembered, however, that all the evidence hitherto obtained on this subject is negative. Not a millionth part of the deposit from the great Trenton sea has been yet exposed to our observation; and it may happen again, as it has happened so often already, that some fortunate discovery will revolutionize, or at least modify, all our notions in regard to the fauna of the earlier geological ages.

In Russia, Prof. Pander has discovered in Lower Silurian strata a multitude of tooth-like organs, which he announced to be the teeth of fishes; and if this conclusion were accepted, the dawn of ichthyic life would be carried far backward in geological history. It should be said, however, that the views of Prof. Pander in regard to his *Conodonts* have not been accepted by other palæontologists; as the denticles which he regarded as the teeth of fishes have, by Owen and others, been considered as more probably the teeth of mollusks, or as spinous appendages of crustaceans.

In regard to the fishes of the European Upper Silurian rocks, there can be no doubt. In England twelve species have been described, from the Upper and Lower Ludlow rocks, and from the passage beds between the Silurian and Devonian systems, viz:

1. *Auchenaspis ornatus*.....Egerton.
2. *A. Salteri*..... "
3. *Cephalaspis Murchisoni*..... "
4. *Onchus Murchisoni*.....Agass.
5. *O. tenuistriatus*..... "
6. *Plectrodus mirabilis*..... "
7. *P. pustuliferus*..... "
8. *Pteraspis Banksi*.....Hux. and Salt.
9. *P. Ludensis*.....Salter.
10. *P. truncatus*.....Hux. and Salt.
11. *Sphagodus pristodontus*.....Agass.
12. *Thelodus parvidens*..... "

Of these the oldest is *Pt. Ludensis,* Salter, from the Lower Ludlow rocks, and this is the most ancient vertebrate now known. The fossils described by Agassiz, under the name of *Ptectrodus* (figured in "Siluria," Pl. XXXV.), are considered by Dr. J. Harley to be the "posterior spines of the cephalic plates of some Cephalaspidian fish," but by Mr. Salter are regarded as true jaws; and he suggests that they may form the dentition of *Cephalaspis* or *Pteraspis.*

Sphagodus and *Thelodus* of Agassiz are undoubtedly the dermal tubercles (shagreen) of Selachians, perhaps of the fishes of which the spines are called *Onchus.*

In Russia a large number of genera and species of fossil fishes have been found in Upper Silurian strata. These have been described by Eichwald* and by Dr. C. H. Pander.† They were obtained mainly from the Island of Oesel, and from strata supposed to represent the Ludlow and Wenlock rocks of England. Forty-three species of Silurian fishes are enumerated as occurring in Russia; of which one only is reported to have been derived from the equivalent of the Wenlock limestone, the others all coming from the Ludlow beds. It should be said, however, that this long list of species is, for the most part, based upon fragments only, and in all probability several of these were portions of the same fish; so that it doubtless exaggerates the richness of the ichthyic fauna of the Silurian seas of Russia.

* Bulletin de la Soc. Imp. des Natur., Moscow.

† Monographie der Fossilen Fische des Silurischen Systems, etc., St. Petersb.

Prof. Barrande has given us, in his splendid illustrations of the Silurian fauna of Bohemia, descriptions of six species of fossil fishes, viz:

Asterolepis Bohemicus.....Bar
Coccosteus Agassizii..... "
C. Fritschi ..... "
C. primus ..... "
Ctenacanthus Bohemicus..... "
Gompholepis Panderi..... "

Of these, *Coccosteus primus* occurs only in Barrande's *Etage* F, *Cten. Bohemicus* in F and G, the others in G only.

It will be noticed that the English genera of Silurian fishes are all wanting in Bohemia, and that *Asterolepis, Coccosteus* and *Ctenacanthus* of the Bohemian list are characteristic of the Devonian strata of England.

Prof. Giebel has announced the discovery of numerous fragments of fossil fishes in the Upper Silurian strata of the Hartz, and has described three species, viz:

Dendrodus lævis .....Gieb
Ctenoptychius Hercynix ..... "
Ctenacanthus abnormis ..... "

These come from the extreme summit of the Silurian system or the base of the Devonian.

From these facts it will be seen that in various parts of Europe the remains of fishes are met with in greater or less abundance in Upper Silurian rocks; but if we exclude the Conodonts of Pander, of which the zoological relations are doubtful, no fishes have been as yet any where found in strata of *Lower* Silurian age.

As has been already stated, no unequivocal fish remains have as yet been discovered even in the *Upper* Silurian of America, although such discoveries have from time to time been reported. Some of these reported cases require a word of explanation.

Sir Charles Lyell, in his "Travels in North America" (English edition, Vol. II., p. 37), says that he was informed by Prof. H. D. Rogers that he and his brother (Prof. W. B. Rogers) "had traced the scales of fishes through strata of Clinton age from the south-western part of Virginia to the north branch of the Susquehanna, in Pennsylvania;" but no such statement is made by Prof. Rogers in his "Geology of Pennsylvania"; and indeed he says distinctly (Vol. II., p. 824) that the oldest remains of fishes known to him are such as occur in the Corniferous limestone.

Prof. James Hall has described and figured, under the name of *Onchus*

Deweyi, what he considered the dorsal spines of fishes from the Clinton of New York (Palæontology of New York, Vol. II., p. 320, pl. 71); but it is now generally admitted that these are the spines of crustaceans and not of fishes.

The fish spine figured by Hugh Miller—"Footprints of the Creator," 143, copied from the American Journal of Science, 2d Ser., Vol. I., p. 62, and referred to the *Onondaga salt-group*—is really from the *Onondaga limestone,* the lower member of the Corniferous. The specimen figured is the upper extremity of *Machæracanthus major,* of which a description and figure are given in another portion of this report.

I have elsewhere shown that the specimen of *Macropetalichthys* obtained near Madison, Indiana, described by Drs. Owen and Norwood, and which was referred by these gentlemen, and, following them, by Murchison and Owen, to the Upper Silurian, was in fact found in the Corniferous limestone.

These are, I believe, all the cases which have been cited of the occurrence of fish remains in the Upper Silurian rocks of America, and each of these has been proved to be a mistake; so that I am fully justified in saying that, up to the present time, no fish remains have been found in American Silurian strata. As the progress of life seems to have been nearly the same in all parts of the world, and the most remarkable parallelism has been found to prevail between the faunas and floras of each of the great geological systems in Europe and America, it was to be expected that the remains of fishes would be found on both continents at nearly the same horizon. There is indeed a strong probability that some traces of fishes will hereafter be found in our Upper Silurian strata, but if any such exist, they have, as yet, escaped detection.

The zoological relations of the Silurian fishes have been referred to in another place, and I will only allude to them here, in order that the life history of the Class of Fishes may be properly connected with the succession of events which constitute the physical history of the globe.

The fishes found in the Upper Silurian rocks of England belong to two very distinct groups, viz., the Placoderms and the Elasmobranchs. Of these, the first includes that singular series of armor-clad fishes, such as *Pteraspis, Cephalaspis, Pterichthys, Coccosteus,* etc., in which the head and vital portions of the body were protected by bony, tuberculated plates. The Elasmobranchs (Placoids of Agassiz) include the shark, rays and chimæras, in which the skeleton is almost entirely cartilaginous, and the only true bony appendages are the teeth, the dermal ossicles (shagreen) and the dorsal spines. These spines are the largest bony organs, and such as are most frequently found in the fossil state. The spines of

a Selachian called *Onchus,* and the cephalic buckler of a small Placoderm, *Pteraspis,* from the Lower Ludlow rocks, constitute the oldest remains of fishes found in Great Britain. These are mentioned, as similar forms are to be looked for in our Upper Silurian rocks. The fin spines of *Onchus* indicate an affinity with the spined sharks which were so common in the Carboniferous and Jurassic seas, and which are now represented by the Port Jackson shark (*Cestracion*). All these were cartilaginous fishes, and they are thought by some zoologists to hold a low place in the scale of being, as we might naturally expect of the earliest appearing of the class of Fishes. By other, and, perhaps, equally good authority, they are assigned a relatively high place. They are certainly far removed from the most embryonic and rudimentary forms of fishes, *Amphioxus, Petromyzon,* etc. The affinities of the Placoderms are not yet fully established. Prof. Huxley is inclined to connect the peculiar group of small buckler-headed fishes which form the sub-order *Cephalaspidæ* with the sturgeons; while *Coccosteus, Pterichthys* and the larger Placoderms he compares with the living Siluroids, and is disposed to regard them as being connecting links between the scaled Ganoids and Teleosts. This conclusion has been strengthened by the recent discovery of a specimen of *Coccosteus* with ossified vertebræ (referred to p. 257).

Prof. Owen, speaking of the fish spines found in the Upper Silurian of England (*Onchus Murchisoni* and *O. semistriatus*), says: "We may infer that there co-existed a larger and more powerful predatory fish against whose attacks the *Onchus* was thus defended." This inference seems to me unwarranted, as the fishes of the Silurian were living under the "Reign of Mollusks," and the Cephalopods of both the Lower and Upper Silurian seas, from their numbers and size, must have been formidable enemies to such fishes as *Onchus.* The Cephalopod, the pneumatic apparatus of which we now call *Orthoceras Titan,* must have weighed some tons; and if at all like his congeners of the present day—the cuttle-fishes—was capable of easily overcoming any Palæozoic fish.

FISHES OF THE DEVONIAN ROCKS.

As has been already stated, the oldest remains of fishes yet found in America are obtained from the Devonian rocks. This formation has now furnished us with a long list of genera and species, part of which have been heretofore described by myself; part are described for the first time in this report; and still others, of which more or less complete portions have been obtained, remain for further study.

FISHES OF THE CORNIFEROUS LIMESTONE.

The first reference made to the ichthyic fauna of the Corniferous, so far as I can learn, is in the "Geology of the State of New York," Part IV., p. 174, 1843. There a nearly complete specimen of *Machæracanthus sulcatus,* Newb., is figured, and recognized by Prof. Hall as an ichthyodorulite. In the review of the Geology of New York (Am. Jour. of Sci., 2d Ser., Vol. I., p. 162), another species of the same genus is figured, without name or description. It apparently represents, however, the upper portion of a spine of *Machæracanthus major*, Newb.

The next allusion to the Corniferous fishes is formed by the "Description of a new Fossil Fish from the Palæozoic rocks of Indiana," by J. G. Norwood, M.D., and D. D. Owen, M.D. (Am. Jour. of Sci., 2d Ser., Vol. I., p. 367). This is based upon the cranium of a fish obtained from the Corniferous limestone, near Madison, Indiana.* The description is vague, and in many points erroneous. The figure is also very poor, but it is easy to see from it that the authors of the paper had before them an exceedingly imperfect specimen of the ichthyic cranium, since so frequently met with in Ohio, and for which I have felt compelled to retain their somewhat unwieldy name of *Macropetalichthys.*

In 1851 David Christy, Esq., exhibited to the American Association, at its meeting in Cincinnati, a jaw, with teeth, taken from the Corniferous limestone at Delaware, Ohio. This is referred to by Prof. Agassiz, in his report on the vertebrate fossils exhibited at that meeting, "as the jaw of an unknown Ganoid fish." To this fish I have since given the name of *Onychodus sigmoides,* and it will be found described and illustrated in another portion of this volume.

In 1853 a brief popular description of the head of *Macropetalichthys* was given by myself in the Annals of Science, Vol. I., p. 12. Figures were given also, in this article, of two teeth, which, because found in proximity to the cranium, were supposed to appertain to it, but we have since learned that they belong to another fish (*Onychodus*), and so far as at present known, *Macropetalichthys* was toothless.

In 1854 some interesting and beautiful specimens of *Machæracanthus* were exhibited by Prof. Wm. Hopkins at the meeting of the American Associa-

* This specimen was supposed by Messrs. Owen and Norwood to have been obtained from Upper Silurian rocks, but we now know that it was found in the Corniferous limestone. The error has been perpetuated by references made to Prof. Owen's article in Silliman's Journal, by Murchison, Owen, and other European writers. It is corrected on another page, where it is shown to be one of the many fictitious instances reported of the discovery of fishes in our Upper Silurian.

tion for the Advancement of Science. Of these specimens, figures and a brief popular notice are given in the "Proceedings" of this meeting, p. 287. They were obtained from the Corniferous limestone at Auburn, Cayuga county, and Waterloo, Seneca county, New York.

In 1857 a communication was made by the writer to the National Institute, on the "Fossil Fishes of the Devonian Rocks of Ohio." This paper was printed in the Bulletin of the National Institute for 1857. It contains descriptions of the following species:

Macropetalichthys Manni.....Newb.
M. Sullivanti ..... "
Onychodus Hopkinsii..... "
O. sigmoides ..... "
Psammodus antiquus..... "
Machæracanthus major ..... "
M. peracutus..... "
M. sulcatus ..... "
Oracanthus fragilis..... "
O. granulatus..... "
O. multiseriatus ..... "
O. abbreviatus ..... "

In the progress of the Geological Survey of Canada, well-marked specimens of *Machæracanthus* were found at Gaspe, which, through the kindness of Prof. Dawson, I have had an opportunity of examining.

A very fine collection of the ichthyolites of the Corniferous limestone of Delaware county, Ohio, was made some years since by Dr. Mann, of New Milford. A part of these were described by me in the paper read before the National Institute. Others yet remain to be described. Dr. Mann's collection is now in the museum of the Wesleyan University at Delaware, Ohio.

I should also mention among the fish remains of the Corniferous limestone a peculiar and interesting specimen obtained by Mr. G. K. Gilbert at Sylvania, Lucas county, Ohio. This seems to be a dorso-median plate of a Placoderm. It is about eight inches in length and breadth, rounded at one end, emarginate at the other, and evidently represents a hitherto unknown genus and species.

In this connection I will call attention to a bone-bed contained in the Corniferous limestone at North Vernon, Indiana. We here find considerable portions of the rock—a sheet sometimes two inches in thickness—in large part made up of dermal tubercles and teeth of Selachians. This deposit is the more remarkable from the fact that the remains of sharks are comparatively rare elsewhere in the Corniferous limestone: a single

mass of dermal tubercles, found by Mr. Hertzer at Delaware, forming the only other instance known to me.

Perhaps the most interesting discovery that has ever been made among the fishes of the Corniferous limestone, is that of *Chimæroids,* for the first time announced in this volume. As is well known, the group of *Holocephali* is represented in our present seas only by the genera *Chimæra* and *Callorhynchus.* Of the former genus, one species only is known; of the latter, two. The remains of Chimæroids have been found in Secondary and Tertiary strata in the Old World, and of these Sir Philip Egerton has described several genera (*Edaphodon, Passalodon,* etc.), the oldest having been obtained from the Jurassic rocks. In the genus *Rhynchodus,* however, of which the teeth have been found in several localities in Ohio, we have what seems to me good evidence of the existence of Chimæroids in the Corniferous sea. The specimens here referred to will be found described in detail in another part of this report, and it will be seen that they possess considerable zoological, as well as geological, interest.

The spines which I have described under the name of *Machæracanthus* are quite unlike any defensive organs worn by the fishes of the present day, and are also unlike any fish spines that have been described from any of the formations that have yielded the remains of fishes. I have elsewhere given the reasons for supposing them to be the spines of Selachians, and probably the defenses of the pectoral fins. If this was their true nature, they are without example in our recent fauna. It seems, however, that the armament of the sharks which inhabited the ancient seas was more complete than that of those of the present day. Very few of the living sharks have dorsal spines, but their abundance in some of the geological formations would seem to indicate that they were worn by a majority of the ancient sharks. The significance of this apparent difference we perhaps cannot fully comprehend at present, but it has doubtless an important zoological meaning. The changes in the "habits of good society," as illustrated by our history during the last two centuries, may perhaps help us to explain the phenomenon. A hundred years ago every gentleman wore his small sword, and was so prompt and skillful in its use that he who was without the weapon or the power to wield it, was at a great disadvantage among his fellows. When, therefore, the habit was general, it was necessarily universal. But now a general disarmament has put all members of society on an equality, though the sword element is entirely absent. In reviewing the various phases of armament, offensive and defensive, worn by the animals of different ages, we find such an infinite variety, and such

complete changes of style, that it almost seems that the caprice of fashion ruled the world in former times as now; but all this diversity was doubtless controlled by profound physiological laws. There can be little question that both utility and beauty took part in producing the varied results; and both sexual selection and the survival of the fittest combined to produce the variety we see.* A curious parallelism is discoverable in the changing styles and in the effectiveness of cotemporaneous offensive and defensive armor; and we see that all through the ages the same contest has been maintained, that is now going on between our improved projectiles and plate-armor. It is a singular fact that in the spine of *Machæracanthus* we have nearly the same principle of construction as in our bayonets. *Machæracanthus* is really a double bayonet; that is, a blade strengthened by two longitudinal central ridges, the material being economized by making the slopes from the ridges to the margins concave.

In reviewing the ichthyic fauna of the Corniferous limestone, we find that it includes, besides some imperfectly known material, the following elements:

ELASMOBRANCHS.

Machæracanthus major	Newb.
M. sulcatus	"
M. peracutus	"
Rhynchodus frangens	"
R. secans	"
R. crassus	"
Oracanthus? fragilis	"
O.? abbreviatus	"
O.? granulatus	"
Psammodus antiquus	"
Cyrtacanthus dentatus	"

GANOIDS.

Macropetalichthys Sullivanti	Newb.
M. rapheidolobis	N. & O.
Onychodus sigmoides	Newb.

* It is not claimed nor believed by the writer that these were the only influences which controlled ornamentation and armament. This is no place to discuss the question, but abundant instances can be cited where ornamentation at least is beyond the reach of any explanation afforded by either of these confessedly potent causes. For example, the ornamentation, both in color and form among the Radiates—especially in the Polyps and Echinoderms—is as elaborate and striking as in any other group of organic forms; and yet it must have been sometimes an incumbrance, and never an attraction, where there is no vision, and propagation is not effected by concurrence of the sexes.

Asterosteus stenocephalus ..... Newb.
Acanthaspis armatus ..... "
Liognathus spatulatus ..... "
Acantholepis pustulosus ..... "
Coccosteus ?

FISHES OF THE HAMILTON GROUP.

It is a little singular that the Hamilton group, up to the present time, has yielded very few remains of fishes. This I suspect, however, is largely due to the fact that the exposures of this formation have not been carefully examined, as we generally find those things we look for, or rather, are unlikely to find those for which we do not make a special search. Several species of fish-teeth were obtained by Prof. F. H. Bradley from the Marcellus or Hamilton shales of central New York, and an altogether new and yet undescribed genus has been found in the Hamilton at Ithaca, New York, by Mr. H. H. Smith. I have also seen in the cabinet of Yale College a large plate, evidently of a Placoderm—and different from anyone with which I am acquainted—which is said to have been obtained from the Hamilton of Michigan. At Delaware, Delaware county, Ohio, there is found a bed of calcareous clay lying immediately below the Huron shale and above the Corniferous limestone; and this we have considered the representative of the Hamilton in central Ohio. In this shale Mr. Hertzer discovered a number of small concretions, each of which has a fish bone—jaw or plate—as its nucleus. These belong to small Placoderm fishes which are new to science. They will be described in a future volume of our report.

The few specimens I have enumerated are all which, so far as my knowledge goes, the Hamilton has yielded in this country; but we have every reason to expect that when this formation shall be more thoroughly searched, the remains of many other fishes will be found in it. In Ohio we can expect little from this group, as it is thin and rarely exposed; but in the State of New York, where it is thicker and much more fully opened, there is every probability that many interesting things will be obtained from it.

FISHES OF THE HURON SHALE.

This formation—the equivalent of the Genesee and Gardeau shales of New York—though extending through most of the western and southwestern States, and exposed at a thousand points, has been usually regarded as the most barren of fossils of all the members of our geological series. This is a somewhat surprising fact, when the amount of organic matter contained in this great carbonaceous deposit is considered. There

is no doubt, however, that as a general rule the Huron is very barren ground for the palæontologist. That it is not always and everywhere so, is proven by the interesting discoveries of gigantic fossil fishes made in it at Delaware by Rev. H. Hertzer, and which are referred to in other parts of this report. The larger fishes of the Huron—*Dinichthys Hertzeri, Aspidichthys clavatus* and *Ctenacanthus vetustus*—are so fully described on succeeding pages that no analysis of their structure or affinities is required here. I will merely call attention, therefore, to the zoological aspect which they collectively present, and to the clue which they give us to the life of the Huron epoch.

Of the fishes I have enumerated, *Dinichthys* and *Aspidichthys* were Placoderms, and the largest and most formidable of the group yet known. They were probably from ten to twenty feet in length and very massive in form. The *Ctenacanthus* was the dorsal defensive spine of a shark, perhaps eight or ten feet long. In numbers, *Dinichthys* preponderates, immensely over the others, as remains of at least a hundred individuals of this genus have been found, while fragments of only two or three of *Aspidichthys* are known, and the beautiful spine of *Ctenacanthus vetustus* now figured, is unique. Nothing is known of the dentition of *Aspidichthys*, nor of that of its diminutive congener *Pterichthys*, and therefore we can not speak with any confidence in regard to the nature of their food. But we can at least say that their plate-armor must have perfectly protected them from attack, and they could not have served as food for other fishes. *Dinichthys* was eminently carnivorous; and we might infer from the extraordinary size and strength of its dental apparatus that it preyed upon fishes of large size, and such as offered obstinate resistance, positive or negative, to its attacks. The shark *Ctenacanthus*, whose dorsal spines were a foot in length, was probably carnivorous; and from the extreme rarity of the remains of mollusks in the formation where it is found, we may conclude it was not conchivorous.

Perhaps the bony shields worn by *Dinichthys* were for the protection of the wearers against the powerful jaws of their own kin. But it is very improbable that the species was, to any great degree, self-devouring; for the double reason that cannibalism is an offense against a far-reaching law of nature, and the carapaces of even the younger individuals of *Dinichthys* must have been very hard to crack, even for the all-embracing and massive jaws of their parents and adult relatives.

All that we know of the economy of ich thyic life leads us to infer, therefore, that we have in the great fishes which I have mentioned, a mere fragment of the fauna of the Huron sea, and that with these there were tribes of lesser fishes, some of which were vegetable feeders, and

these formed the base upon which the superstructure of the ichthyic fauna rested; this base being in turn supported by the great mass of plant-life from which the carbonaceous element in this deposit was derived. This view is confirmed through the discovery by Mr. Hertzer of the dismembered remains of several small fishes in the Huron shale at Delaware. These specimens are not numerous, nor are they quite sufficient for satisfactory description; but they are of interest as showing that the fishes yet obtained from the Huron shale formed part only, and probably a very small part, of the fish fauna of the Upper Devonian epoch.

Prof. O. C. Marsh has procured some fragmentary bones of large fishes from the Huron at the Falls of the Ohio, which, though too imperfect for accurate delineation, are certainly different from any found in Ohio.

FISHES OF THE CHEMUNG.

No well-marked fossil fishes have as yet been found in the Erie shale in Ohio; but in the Chemung at Franklin, Delaware county, New York, the late Mr. J. M. Way collected a large number of fish remains, and from specimens sent me from this locality by Prof. Edward Orton, it is evident that it is one of the richest in fossils of this character of any known in the country. Among the specimens received from Prof. Orton, the most abundant are teeth of a species of *Onychodus,* which I have described under the name of *O. Hopkinsii.* These are smaller than the full-grown central teeth of *O. sigmoides,* and show but a single curvature. They are scattered so thickly through the rock that a dozen may some times be seen on a square foot of surface. The only other fossils contained in the collection made by Prof. Orton are large plates of indeterminate form—of which the exterior surfaces are marked with strong radiating lines of ornamentation—and fragments of jaws (?) set with stout conical teeth; somewhat like *Plectrodus* of the Upper Silurian of England. Both these latter forms belong to fishes yet undescribed, and of which the specimens I have received give me but a very imperfect view. I infer from some drawings formerly sent me by Prof. Orton, that a large variety of fish remains are to be found in the Chemung of Franklin, New York; but without better material than I have yet had access to, I am unable to say much of the very interesting suite of specimens collected by Mr. Way. Unfortunately, he was one of the victims of our late war, and his collection has been disposed of, perhaps scattered.

The region from which these specimens were obtained is, in my judgment, one that promises more new material in the way of Palæozoic fishes than any other known in this country. In connection with the exploration of this district, it would be a matter of great interest to

trace the relation between the fish-bearing beds of the Chemung and the equally rich fish-beds of the Catskill, in the northern part of Pennsylvania.

FISHES OF THE CATSKILL.

In the northern tier of counties in Pennsylvania—Susquehanna, Bradford, Tioga and Potter—the Catskill group underlies the surface over a large area, and is well exposed in a great number of localities, but it is not certain that the formation can be found in any other district than that to which I have referred. Here it has a maximum thickness of 400 or 500 feet, mostly red sandstones and shales. Passing northward into the State of New York, the Catskill is found to be removed by erosion, and while it is probable that it has some representative in the upper beds of the Catskill Mountains, it has not as yet been identified there. The mass of these mountains is now known to be composed of Chemung rocks. In coming west from Tioga county, Pennsylvania, the Catskill thins out; and while it may be traced into Warren county, I found nothing of it nearer to the Ohio line than the valley of the Allegheny, near Warren. In most localities where it is exposed in Pennsylvania, the Catskill group is rich in the remains of fishes. These are generally bones and scales of ganoids of large size—for the most part *Holoptychius* and *Bothriolepis*. These combine with the lithological character of the rock to produce such a resemblance to the Old Red Sandstone of Scotland, that even the most experienced geologist would be unable to distinguish between specimens taken from the two sides of the Atlantic.

Though extra-limital to Ohio geology, the fishes of the Catskill form so important a feature in the palæichthyic life of the continent, that I cannot pass them without a brief notice.

The fish remains of the Old Red Sandstone of Tioga county, Pennsylvania, though referred to long before, are first described by Prof. James Hall in the Geology of New York, Vol. IV., p. 281, pl. III. (1843). Two forms of scales, a tooth, a portion of a mandible, and a large pectoral fin are figured by Prof. Hall, and are referred in part to *Holoptychius noblissimus,* Ag., a well-known fish of the Old Red Sandstone of Scotland, and partly to a new genus and species named by Prof. Hall *Sauripteris Taylori*. Subsequently (1856) Prof. Joseph Leidy described a number of the remains of fishes from Tioga county (Jour. Acad. Nat. Sciences, Phila., 2d ser., Vol. III., p. 162, pl. 16, 17). These include two kinds of scales, one of which is identical with that referred by Prof. Hall to *Holoptychius noblissimus,* the other larger, more angular, and having a granular rather

than a corrugated surface. Both these forms he considers as probably belonging to the same fish, to which he gives the name of *Holoptychius Americanus*. Prof. Leidy also figures and describes a flattened lancet--shaped tooth under the name of *Apedodus priscus*; also a denticulated spine, to which he gave the name of *Stenacanthus nitidus*.

Since the organization of the Geological Survey of Ohio, I have received from Mr. Andrew Sherwood, of Mansfield, Tioga county, Pennsylvania, a large collection of the remains of fishes, obtained in the vicinity of his place of residence. Considerable additional material from the same formation and district has come into my hands through other parties, and I hope soon to be able to publish elsewhere a fuller discussion than would be proper here of this interesting group of fishes, so different from any others found on the continent, and so closely resembling the most characteristic forms of the Old Red Sandstone of Scotland. I can now only very briefly indicate the general results of such examination as I have made of the materials in my hands, and of the published descriptions of that studied by others.

Never having seen the specimens named by Prof. Hall *Sauripteris Taylori*, I cannot speak decisively in regard to their relations; but I am led to conclude that the scales figured as belonging to that species are identical with the larger and granulated forms assigned by Prof. Leidy to *Holoptychius Americanus*. The scales referred by Prof. Hall to *Holoptychius noblissimus* are much like some of those which are figured by Agassiz in his splendid plates of *H. noblissimus* (*Poiss. Foss. d. Vieux. Gres. Rouge*), but some of those which I have, and have seen, are much larger than any of the scales of that species. It is perhaps well enough to consider them as the scales of *H. noblissimus* until proof to the contrary is found; but it should be understood that much more material must be obtained before the specific identity of the scales found in England and Pennsylvania can be said to be established, and before any important deductions are made from them.

The two forms of scales regarded by Prof. Leidy as belonging to his *H. Americanus*, as my specimens prove, appertain to different fishes, one of which is the so-called *H. noblissimus,* and the other apparently a *Bothriolepis*. If, as seems probable, the latter is identical with the fish described by Prof. Hall as *Sauripteris Taylori,* it should be hereafter called *Bothriolepis Taylori*. In Prof. Dana's excellent "Manual," p. 292, fig. 509, a scale of this fish is represented with the name of *Holoptychius Taylori*; but in my judgment the fish which bore it was generically distinct from *Holoptychius,* as the scales were *not imbricated*, and the exterior surface was entirely covered with an ornamentation different from that of any

known species of *Holoptychius,* and precisely like that ascribed by Agassiz to his genus *Bothriolepis.*

If now we take a retrospective view of the ground gone over in the preceding notes, and compare the ichthyic fauna of the American Devonian with that of the same geological system of the Old World, we shall find some marked differences, and even contrasts, which suggest inquiry, and for which it would be pleasant to be able to give a full explanation. The most conspicuous difference between the American and European Devonian fish faunæ, is the entire absence from all our collections of many of the most abundant and best known genera of the Scotch and English Old Red Sandstone fishes. For example, we have as yet found in America no traces of *Pteraspis, Auchenaspis, Scaphaspis, Menaspis, Pterichthys, Asterolepis, Osteolepis, Dipterus, Diplopterus, Glyptolepis, Platygnathus, Cheiracanthus, Diplacanthus, Cheirolepis* or *Climatius*; while of *Cephalaspis,* only one well marked specimen has been obtained, viz., *C. Dawsoni,* from the Devonian of Gaspe, Canada, and *Coccosteus* is only doubtfully represented by a dorsal plate from the Corniferous limestone of Delaware, Ohio.

On the other hand, nearly all the most important ichthyolites of our American Devonian are unknown in Europe. For example, no traces of *Dinichthys, Aspidichthys, Machæracanthus, Macropetalichthys, Onychodus* or *Acanthaspis* have been found in the British Islands, and only one of these, *Macropetalichthys*, has been met with on the continent of Europe.

Another fact of interest is, that the only American representatives yet known of *Holoptychius* and *Bothriolepis* are found in the Catskill group (which has been regarded as the extreme summit of the American Devonian), in Northern Pennsylvania.

In comparing the American and foreign Devonian fishes zoologically, it will be noticed, First, that up to the present time, not a trace of the little Acanthodian fishes—*Cheiracanthus, Diplacanthus, Climatius,* etc.—have been found in this country. Second, among the Placoderms we have *Dinichthys* and *Aspidichthys* as representatives of *Coccosteus* and *Pterichthys,* but exceeding their European congeners at least a hundred fold in bulk. Third, we have none of the lobate-finned Ganoids—*Crossopterygidæ*—in the fauna of the Corniferous limestone, unless *Onychodus* be a gigantic member of this group; and our only other Devonian Crossopterygian fish is *Holoptychius* of the Catskill. Fourth, a striking feature, which the Devonian fish faunæ of both countries have in common, is the great preponderance of Ganoids over Elasmobranchs.

When now we come to seek an explanation of the differences that have been referred to, we shall perhaps be somewhat helped to a con-

clusion by noticing the nature of the strata containing fossil fishes in the two countries. In America, by far the greater number of Devonian fishes have been obtained from the Corniferous limestone, plainly an open sea deposit, and they are nearly all of large size. The Huron shale, which contains the gigantic remains of *Dinichthys* and *Aspidichthys*, is also the sediment of an open, though shallower sea; and the fishes which it contains must have inhabited relatively deep water, as we do not find them associated with any traces of shore-lines. In striking contrast with these facts, the Catskill fishes are buried in mechanical sediments, such as could only have accumulated immediately along the shore of the continent.

When now we examine the deposits which contain the fossil fishes of the Devonian in the Old World, we see (1) that nine-tenths of the whole number are enveloped in mechanical sediments—sandstones and shales—evidently shore deposits; (2) that the great Devon limestone of England—the deposit of the open Devonian sea of that country, and the homologue of our Corniferous limestone—has contributed almost nothing to the list of English fossil fishes; and (3) that the only one of our Corniferous fishes found abroad, *Macropetalichthys,* was obtained from the Devonian limestone of the Eifel. It will also be noticed that the sediments which compose the Catskill group are precisely like those that hold the same genera of fossil fishes in Scotland, England and Ireland.

From these facts it is easy to see that at least a part of the difference between the American and European Devonian faunæ is due to the difference in the physical conditions under which the fishes that have been collected lived. The American Devonian fishes have been mainly taken from deposits of the open sea, where they were naturally larger, and somewhat different zoologically from those which inhabited the bays and shore-lines of the European continent and islands. Where the circumstances were similar, we have similar deposits and similar fishes, as in the Upper Old Red and Catskill. These considerations will, I think, go far to explain the absence from the American strata of the smaller Crossopterygians, *Osteolepis, Dipterus, Diplopterus*, etc., and of the little Acanthodians, *Cheiracanthus, Diplacanthus, Clirnatius*, etc., all of which we may suppose were the inhabitants of rivers, lakes, estuaries and shore-lines. It should be remembered, in this connection, that all our living scaled Ganoids are the inhabitants of rivers and lakes; only one of the seven living genera, under any circumstances, entering salt water.

Differences in geological position must also be considered as contributing something to the differences of fauna that I have referred to. It

will be remembered that the group of Placoderms which are found in such abundance at the base of the Devonian in Scotland and England—*Pteraspis, Cephalaspis, Scaphaspis,* etc., all of which are wanting in America—began their existence in the Upper Silurian; occurring in the Lower and Upper Ludlow rocks, the Tilest ones, or passage beds, and in the lower and middle portions of the Old Red Sandstone. Hence they belong to a geological horizon below any that has furnished fossil fishes in this country, and represent the fauna of an age anterior to that of the Corniferous limestone. We must therefore look for corresponding members of that fauna in our Helderberg and Oriskany, where as yet we have found no fishes. Since almost no fishes have been obtained from the Devonshire limestone, it will be seen that on the two sides of the Atlantic we have been collecting Devonian fishes for the most part from very different members of the series; and hence it is not surprising that our lists of genera and species are different.

The correspondence of the fauna of the Catskill and Upper Old Red Sandstone of the British Islands is associated not only with a correspondence in physical conditions—to which I have already called attention—but also in geological age. It is now known that the Old Red Sandstone of Caithness, Orkney, Cromarty, etc., which supplied the fish fauna so eloquently described by Hugh Miller, forms the central portion of the great mass of the Old Red Sandstone, and its characteristic fishes are *Pterichthys, Coccosteus, Asterolepis, Osteolepis, Dipterus, Diplopterus, Cheiracanthus, Diplacanthus, Cheirolepis,* etc. With these fishes no mollusks are found, but numbers of bivalve crustaceans of the genus *Estheria.* These latter fossils are almost universally found in the sediments of lakes, lagoons and bays, and confirm what has been said in regard to the circumstances under which the Old Red Sandstone fishes lived and died.

The upper portion of the Old Red Sandstone of England, Scotland and Ireland consists of a series of yellow and red sandstones, which reach up without sensible change to the Lower Carboniferous limestone. In these rocks are a different group of fishes from those below, and differing notably in the absence of the Placoderms of the lower series, and in the presence of several species of the great Crossopterygian genus *Holoptychius.* This genus begins in the famous fish-bearing strata of Dura Den, and runs up into beds which are unmistakably Carboniferous, though represented at different horizons by different species. It has troubled the English geologists much to draw any well-marked line, in the series to which I have referred, between the Devonian and the Carboniferous systems; but there are none who do not regard as Carboniferous at least

a portion of the yellow sandstones which underlie the Carboniferous limestone, and contain *Holoptychius* as a characteristic fossil. Hence it will be seen that in the Catskill of Pennsylvania we have strata which are not only lithologically similar to those which in Scotland and England lie at the top of the Devonian and base of the Carboniferous system, but that this similarity of mineralogical character and geological position is accompanied by a similarity of fauna.

The bearing of the facts that have been cited on a question somewhat discussed in another portion of this report, viz., the question as to where the division line between the Devonian and Carboniferous should be drawn, is obvious. From the fact that the Catskill has usually been referred to as the American representative of the Old Red Sandstone, and its fossil fishes are generically such as are characteristic of the Upper Devonian of Europe, it has been naturally reckoned to be the summit of the Devonian, and to prove the Devonian age of the underlying Chemung rocks. In opposition to this view, I have contended that though the Catskill be the *conventional* summit of the Devonian system, the great geological cycle which we call the Carboniferous age, and of which we have a record in the circle of deposits described in the geological portion of our report, really begins with the Portage sandstones, and thus that the Chemung and Catskill should be included in the Carboniferous.

FISHES OF THE CARBONIFEROUS SYSTEM.

The Carboniferous rocks have furnished a large number of fossil fishes, both in the Old World and the New. These exhibit considerable diversity of size and structure, according to the geological positions which they occupy in the system, and the local physical conditions in which they lived. For example, the open sea of the period from which was deposited the Carboniferous limestone had quite a different ichthyic fauna from that of the bays and lagoons of the Coal Measure epoch. These differences will be indicated in the notes which follow on the fishes of the different members of the great Carboniferous system.

Considered in its general aspects, the Carboniferous fish-fauna contrasts strongly with that of the Devonian, and equally so with the ichthyic fauna of the Mesozoic ages, which is so fully represented in the collections made from the Jurassic and Cretaceous strata. The most striking changes which took place in the fishes of the world, as the Carboniferous succeeded the Devonian age, may briefly be sketched as follows:

First. We discover that the great group of Placoderms, which gave character to the fauna of the Devonian, have entirely disappeared; and

the names of the genera *Pterichthys, Coccosteus, Asterolepis, Dinichthys,* etc., which have been so frequently repeated on the preceding pages, appear no more in all the records of geological history.

Second. The Elasmobranchs, which held a subordinate position in the Upper Silurian and Devonian seas, are greatly multiplied and increased in size in that of the Carboniferous age.

Third. The Acanthodians maintain in the Carboniferous the numerical importance they held at the close of the Devonian; as they are represented by numerous species, though of diminutive size, till near the close of the Palæozoic era, when they apparently disappear forever.

Fourth. The Crossopterygians, which, as represented by *Holoptychius,* etc., enter the Carboniferous age in full force, though having, even in the Coal Measures, some members of great size and power—like *Megalichthys*—rapidly diminish in the later portion of the Carboniferous age, and in the Permian and Mesozoic formations are represented by only a single known family, the *Cœlacanthini.*

Fifth. The *Lepidostidæ*, which are supposed to be represented in the Devonian by *Cheirolepis,* exhibited in the Carboniferous a large increase of numbers, both of genera and species, but all of small size; and it would seem that the different species of *Palæoniscus, Amblypterus, Eurylepis,* etc.—all glittering in enameled and highly ornamented scales and head-plates—peopled the bays, lakes and rivers of the Carboniferous continents in the same way that our Cyprinoid Teleosts (Chubs, Shiners, etc.), and indeed, as we may say, the Gar-pikes—the lineal descendants of the Carboniferous Ganoids—do at the present day.

Sixth. The singular family of the Pycnodonts, unknown in the Devonian fauna, begin with the Carboniferous, and running through all its epochs with increasing force, assuming still greater development in the Mesozoic ages, disappear early in the Tertiary, and have no living representatives.

Seventh. Among the groups wanting in the Carboniferous, we should mention the Teleosts, of which no representatives are found anterior to the Mesozoic ages; and of the higher and true Teleosts, none below the Chalk.

All traces of the lowest orders of the class of fishes—the *Pharyngobranchii* and *Marsipobranchii*—are wanting in the Carboniferous strata, and indeed in all other members of the geological series. As has been remarked elsewhere, this fact, so inconsistent with the views generally entertained of the progress of life on the globe, may perhaps be accounted for on the supposition that the soft and destructible tissues of these embryonic forms of fishes have entirely disappeared.

In all the lists of Carboniferous fishes yet made out, no Chimæroids appear. And it has been heretofore supposed that they began in the Jurassic, and had no existence on the globe at so early a date as the Carboniferous age. If we are right, however, in considering the species of *Rhynchodus* now described, as Chimæroids, the absence of all members of the order *Holocephali* from the Carboniferous rocks would be very remarkable. And this difficulty suggests the question whether some of the great number of Elasmobranchs of which the teeth and spines are found in the Carboniferous limestone, such as *Deltodus, Trigonodus,* etc., should not rather be considered Chimæroids than Cestracionts. As comparatively few of the many Elasmobranchs of the Carboniferous have been found in Ohio, this group of fossil fishes will be very imperfectly illustrated in our report. In the Geological Survey of Illinois, however, an immense collection of Carboniferous sharks has been made. Over one hundred species have been described by Mr. A. H. Worthen and the writer. In Vols. II. and IV. of the Report of the Illinois Survey, some illustrations of the fauna referred to are given, which will be found of interest in this connection.

The new element which is introduced into the fauna of the globe in the Carboniferous age—the *Amphibia*—furnishes an interesting subject for investigation and speculation, but one that need not be pursued here. The Amphibian fauna which we have discovered in the Coal Measures of Ohio (including more than twenty species), will be illustrated by Prof. Cope in another volume of our report. The question of the origin of this fauna, and its relation to the fishes by which it was accompanied and preceded, it is hoped will be fully discussed by him. I will only say here, in reference to this subject, that some of the Amphibians found in the Coal Measures seem to have so much in common with the Crossopterygian fishes, that the opinion prevails among our best zoologists that these forms have a genetic relationship.

FISHES OF THE WAVERLY.

As has been shown in the geological portion of this report, the Waverly series consists of the shore and off-shore deposits of the Carboniferous sea, which gradually encroached upon, and finally submerged, a large portion of the previously existing continent. The strata which compose this series are mainly formed of mechanical material, though containing locally considerable lime or carbonaceous matter, the latter apparently derived from marine plants. From the nature of these strata, and the circumstances under which they were deposited, the re-

mains of fishes are less abundant in them, as a general rule, than in the sediments of the open ocean, or of the lagoons in the coal marshes. Still, in some localities, the remains of fishes are quite abundant in the Waverly, and a thin band in the carbonaceous shale which underlies the "city ledge" of Southern Ohio and Northeastern Kentucky, is a genuine "fish-bed." The surfaces of the laminæ composing this band are sometimes thickly strown with the spines, teeth and dermal tubercles of sharks, and the scales and bones of *Palæoniscus*. The fishes of this horizon—which is near the base of the formation—consist of two species of *Ctenacanthus* (*Ct. formosus* and *Ct. furcicarinatus*), one species of *Orodus* (*O. variabilis*) and one of *Cladodus* (*C. Pattersoni*), all of which will be found described in other portions of this report. There is little doubt that some of the teeth and spines named above were associated as organs of the same fish. From the dismembered condition in which we find the remains of these cartilaginous fishes, it rarely happens that the spines, teeth and dermal tubercles are so associated that we can determine satisfactorily their relations. The companionship, however, of some of these fish remains, leads me to conjecture that the teeth called *Orodus variabilis* formed the dentition of the fish which carried the dorsal spine I have named *Ctenacanthus furcicarinatus*. In this formation and locality was discovered a unique specimen of a jaw of *Cladodus Pattersoni*, on which several hundred teeth occupy nearly their normal positions. This specimen will be figured and described elsewhere. I should also mention, in this connection, a remarkable shark's tail, found at Vanceburg, Kentucky, by Capt. Patterson, in the fish-bed before alluded to. This specimen, which is nearly a foot and a half long, shows the outline of the heterocercal tail of a shark which must have been eight or ten feet in length. The vertebral column is seen to reach far into the upper lobe of the tail. The vertebræ have entirely disappeared, leaving a smooth band to mark the space they occupied. This is bordered on either side by the impressions of linear, pointed, apophysial bones, which were evidently much better ossified than the centra of the vertebræ. The lower lobe of the tail is formed by a number of *strong, ossified rays!* This shows that this Carboniferous shark—which I suppose to have been the same that had *Orodus* for his teeth, and wore *Ctenacanthus* as a dorsal spine—had a skeleton in some respects more fully ossified than most of the sharks of the present day.

The *Cleveland Shale*, a bituminous stratum twenty to sixty feet in thickness, holding in Northern Ohio the same position as that which in Southern Ohio includes the fish remains last described, every where contains traces of fishes. In general, these are small, rhomboidal, polished

scales, which belonged to a species of *Palæoniscus* of which no good specimens have as yet been obtained. At Bedford, Cuyahoga County, the Cleveland shale contains, with *Cladodus Pattersoni*, a small and highly ornamented species of *Orodus* and a small *Polyrhizodus*, both yet undescribed. The surfaces of the laminæ of the shale are locally covered with beautifully defined Conodonts—the little comb-like denticles over which there has been so much discussion by zoologists. These Conodonts will be figured and described in another volume of this report.

The *Bedford Shale*, which lies next above the black Cleveland shale last mentioned, has yielded, so far as I know, but a single fragment of a fish. In one of the calcareous bands which traverse this deposit on the banks of Black river below Elyria, I found a portion of the bone of a fish which must have been as large as *Dinichthys*. It was only a fragment when imbedded in the calcareous mud, which subsequently became the rock in which it was found. This fragment is rudely triangular in form, one side being arched, and this was evidently a part of the margin of the plate. It was originally quite solid and nearly an inch and a half in thickness. I do not recognize in this piece of bone any portion of the carapace of *Dinichthys*, or indeed of any other known fish. It is perhaps more likely that it was a part of the posterior extremity of the dentary bone of a species of *Dinichthys* or some other allied Placoderm. If this was its position, it belonged to a fish larger than any *Dinichthys* yet discovered. Although affording a very imperfect idea of the structure to which it belonged, this bone is of great interest and significance, inasmuch as it proves that very large fishes lived in the water from which the Bedford shale was deposited, and gives good cause to hope that, with careful search, this deposit, hitherto considered barren of fish remains, may be made to contribute some most interesting material to the known fauna of the Lower Carboniferous epoch.

The *Berea Grit*, being a coarse mechanical deposit, would seem to promise very little in the way of fossil fishes. And yet, while it is true that as a general rule it is barren of fossils of all kinds, at one locality, Chagrin Falls, the upper layers of the Berea are found to contain a large number of a distinct species of *Palæoniscus* (*P. Brainerdi*), of which, so far as I can learn, no traces have yet been discovered elsewhere. Among the fragments thrown out in working the quarries at Berea, I found a detached piece of bone several inches in diameter, which must have belonged to a large and as yet unknown fish. It is also reported that in the same quarries, some years since, a complete fish spine was obtained, and for a long time preserved. This specimen is now lost, but, from the description given me, I infer that it was a species of *Ctenacan-*

*thus.** In the equivalent of the Berea my assistant, Mr. G. K. Gilb ert, discovered, on Oil creek, Pennsyl vania, the most remarkable accumulation of fish spines of which I have any knowledge. These were scattered over the surface of a block of sandstone which had become detached from the cliff, and their num bers may be inferred from the fact that more than a dozen spines are imbedded in that portion of the rock, less than two feet square, which Mr. Gilbert brought away with him. All these spines apparently belong to one species, *Ctenacanthus triangularis,* which will be found described on anoher page. In the same locality other layers of san dstone were covered thickly with the scales and teeth of fishes. Of these, the scales are those of *Palæoniscus,* perhaps *P. Brainerdi.* The teeth are those of S elachians, mainly *Helodus* and *Orodus*; among others *O. coniculus*, a common fossil of the Keokuk limestone in Illinois. I should also mention that in the very basal portion of t he Berea sandstone at Berea, Mr. Hertzer found two species of *Cladodus,* both of which are as yet undescribed.

The *Cuyahoga Shale,* the uppermost member of the Waverly, has no where yielded any considerable number of the remains of fishes, and yet a few specimens of great interest have been obtained from it. At Berea a species of *Cladodus,* perhaps not distinct from *C. Pattersoni,* is found at the base of the Cuyahoga shale, immediately above the sandstone; and at Chagrin Falls, in precisely the same geol ogical position, scales of *Palæoniscus* are thickly scattered among the *Lingulæ*; with which the shale is crowded. In the upper part of the Cuyahoga shale, fish remains of much greater size and interest h ave been discovered. At Bagdad and Lodi, Medina County, we have obt ained spines of two species of *Gyracanthus, G. Alleni,* and *G. compressus.* These spines have more than ordinary interest, from the fact that they bel ong to a genus whi ch is characteristic of the Carboniferous rocks of Europe and Nova Scotia, but one that has never before been found wi thin the limits of the United States. At Warren, Ohio, Mr. M. C. Read discovered in the upper part of the Cuyahoga shale a m agnificent specimen of *Ctenacanthus formosus*, which has a length of fourteen inches.

It will be seen from the notices I have given of the fishes of the Waverly, that there can be n o reasonable doubt of its Carboniferous age. Indeed, they practically decided this much-discussed question before the

* Since the above paragraph was written, Mr. C. T. Blakesley, of Chagrin Falls, has found in his quarries worked in the Berea grit, a di stinctly marked specimen of *Ctenacanthus formosus,* similar in size and form to that obtained by Mr. Read from the Cuyahoga shale, and mentioned in another paragraph.

molluscous fossils and stratigraphical relations had given their testimony in the case. With the combined evidence we may say that the proof amounts to a demonstration. It will also be noticed that *Cladodus Pattersoni* and *Ctenacanthus formosus*, running through the formation, with *Syringothyris typa, Orthis Michelini* and other mollusks, bind its subdivisions together into one whole.

FISHES OF THE SUB-CARBONIFEROUS LIMESTONE.

The Lower Carboniferous limestone is, in other States and countries, perhaps more prolific in the remains of fishes than any other formation. In Illinois, Iowa and Missouri, nearly a hundred species of the teeth of Selachians have been obtained from this formation, and the very similar fish remains described by Agassiz, Portlock and McCoy, from the Carboniferous limestone of Armagh, Ireland, are well known to geologists. The general character of this fauna has been already alluded to. Being an open-sea deposit, the Carboniferous limestone would naturally contain a different group of fishes from th ose entombed in the mec hanical sediments that accumulated along the shoals and shores of this sea; hence the fishes of the Carboniferous limestone are quite different from those of the Waverly, even where the beds are cotemporaneous. We naturally find, among the fishes of the limestone, the teeth and spines of sharks; in the Waverly, the scales of the shore-loving Lepidoganoids. It is somewhat remarkable that while the remains of sharks are so plentiful in the limestone, we have as yet found among them no traces of fishes which correspond to *Macropetalichthys* and *Onychodus*, the great, omnipresent Ganoids of the Devonian sea. We must, therefore, conclude that while the Placoderms and Crossopterygians were the monarchs of the *Devonian* sea, and the Elasmobranchs were then much fewer in number and smaller in size than they, when the submergence took place which buried so much of our continent beneath the Carboniferous sea, and spread its calcareous sediment over the area where now we find the Carboniferous limestone, in the lapse of thousands, perhaps millions of years, the fauna of the globe had been revolutionized. In this latter age the Elasmobranchs had become both relatively and absolutely more numerous and powerful; the Placoderms were nearly extinct; and the Ganoids of all groups had pretty much abandoned the sea, but in various forms thronged the quiet waters of bays and rivers. By what influence this difference of destiny was brought about we can, as yet, only conjecture; but the contrast in the life-histories of these great groups of fishes is very striking. So far as we know, they began almost simultaneously, but for a long time—all through the

Upper Silurian and Devonian ages in fact—the Ganoids* were the ruling dynasty. But somehow and somewhere in the long interval between the Devonian and Carboniferous seas the sceptre passed from them. They were elsewhere still powerful, however; for *Dinichthys,* or some congener, lorded it over the weaker tribes along the shores of the Lower Carboniferous continent, and *Megalichthys* and *Rhizodus* disputed with *Ctenacanthus* and *Edestus* the rule of the bays and lagoons during the Coal Measure epoch. In the Mesozoic, too, the Ganoids were respectable in numbers, and, when we think of the great *Lepidotus,* six feet in length, we may say, in size; but they were then the ruled, and not the rulers. Most of them were pretty well defended, but inoffensive creatures, and they were the natural prey of the predaceous and powerful Hybodonts, whose spines and teeth so thicky strew the bottom of the Jurassic sea. In later times the preponderance of the Elasmobranchs has grown more and more conspicuous; for, while the Ganoids have dwindled to a mere hand-full, the sharks have become the tyrants of the ocean. The Selachians now number hundreds of species; and the basking shark attains a length of thirty feet. But even this monster shrinks into insignficance when compared with the great *Carcharodon* of the Tertiary, whose length could not have been less than fifty feet, and whose lancet-shaped teeth are as large as one's hand.

The exposures of the Carboniferous limestone in Ohio are few, and they have never yet been carefully searched for fish remains. It is to be expected, however, that some fishes will be obtained from them, and these are likely to be those found in the upper or Chester subdivision, the only portion of the great, western limestone mass that is represented in our State.

FISHES OF THE COAL MEASURES.

The Conglomerate, so far as I know, has yielded no fishes, either in our own State or elsewhere; but the limestones of the Coal Measures, and especially the Cannel coals (which were formed from the accumulation of carbonaceous mud in the lagoons of the coal marshes), have furnished quite a long list of genera and species. Here we find repeated, though on a small scale, the differences of fauna to which I have already alluded. In the limestones, which mark periods of submergence, and the wide spread of the waters of the ocean over the coal marshes, there are few traces of the scaled Ganoids; but many teeth of the peculiar sharks of the period (*Petalodus, Cladodus, Ctenoptychius,* etc.); while in the sediments of the lagoons are great numbers of the smaller Ganoids, *Palæoniscus, Amblypterus, Eurylepis* and *Cœlacanthus.* Here, too, we find

* Ganoids of Agassiz, including Placoderms and Cephalaspids.

the teeth and spines of that peculiar Elasmobranch, *Diplodus,* in which the teeth are like a pair of minute horns, and the serrated spine was set immediately back of the head. The most striking features in the ichthyic fauna of the Coal Measures are, however, the great spines of the different species of *Ctenacanthus* and *Edestus.* Of these, *Ctenacanthus,* though running through several formations, seems to have attained its greatest development in the Coal Measure epoch. *Edestus* constitutes the most peculiar organ of defense among all the tribes of fishes. It seems to have been a dorsal spine, but was sometimes a foot and a half in length, three inches deep, composed of solid bone, and having the upper margin set with triangular, crenulated, enameled denticles, of which the largest were an inch and a half in length. No remains of this remarkable genus have yet been found in Ohio, but several species described by Prof. Leidy and myself have been obtained from the Coal Measures of Indiana, Illinois and Arkansas. For further description of *Edestus,* the reader is referred to page 286.

As the spines of *Ctenacanthus* were sometimes scarcely less formidable than those of *Edestus,* we must conclude that the sharks which bore these weapons were the rulers of the waters during the Coal Measure epoch. It is true that, before their reign was ended, the pioneers of a new dynasty, and one destined in the next age to completely supplant them, made their appearance on the stage. The Amphibians of the Coal Measure epoch were, however, for the most part small and weak; and it was only in certain of the steaming pools and lagoons of the coal marshes that carnivorous salamanders enjoyed a brief and local rule.

In the descriptive portion of this volume, quite a number of species of fossil fishes from the Coal Measures of Ohio are figured and described. A large part of these are from a single locality, which has already become somewhat celebrated for the number and interest of the fossil forms it has furnished. I refer to Linton, on the Ohio river, at the mouth of Yellow creek. The fossils are found there in a thin stratum of cannel which underlies a thick seam of bituminous coal, that we have called Number 6, because it is the sixth workable seam from the base of the productive Coal Measures. Already about twenty species of fishes have been obtained from this deposit, and at least as many Amphibians; and all-found here for the first time, although two or three species have since been met with in other localities, in this or adjoining States. On tracing Coal-seam No. 6, in various directions from Linton, the cannel at its base is found to thin out and soon disappear. We learn, from a careful study of the deposit, that there was in this locality at the time when the coal was forming, an open lagoon, densely populated with fishes and salaman-

ders; and that after a time this lagoon was choked up with growing vegetation; and peat (which afterward changed to cubical coal) succeeded to the carbonaceous mud (now cannel) that had previously accumulated at the bottom of the water. The fishes of this pool were mostly small, tile-scaled Ganoids, belonging to the genus *Eurylepis*. Though here extremely abundant, they have not been found elsewhere. I have enumerated nine species of this genus, but possibly some of them should be considered as mere varieties. There were also in this lagoon two, or perhaps three, species of *Cœlacanthus* (one of which is so closely allied to *C. lepturus* of the Coal Measures of Europe, that they should perhaps not be separated), and yet this genus has been no where else recognized on the American continent. There are also found here the thin scales, from one to two inches in diameter, some ornamented and some plain, and also the lance-head teeth of *Rhizodus*, and the teeth and spines of *Diplodus*. On the whole, this must be looked upon as one of the most interesting localities of vertebrate fossils known on this continent; and it is even doubtful whether *any* other equals it in the number of new species or in their zoological and geological interest.

The following is a list of the fossil fishes which have, up to the present time, been found at Linton:

Cœlacanthus robustus	Newb.
C. elegans	"
C. ornatus	"
Palæoniscus peltigerus	"
Eurylepis tuberculatus	"
E. corrugatus	"
E. ovoideus	"
E. insculptus	"
E. ornatissimus	"
E. granulatus	"
E. minimus	"
E. striolatus	"
E. lineatus	"
Rhizodus angustus	"
R. lancifer	"
R. quadratus	"
Orthacanthus arcuatus	"
Compsacanthus lævis	"
Diplodus compressus	"
D. latus	"
D. gracilis	"

A few other localities in the Coal Measures of Ohio deserve notice for the remains of fishes which have been obtained from them. In the can-

nel coal of Canfield, Mahoning County, a single, nearly complete specimen of *Palæoniscus peltigerus*, N., was found in a wonderful state of preservation—having not only all the scales in place, but the expanded fins nearly as perfect as in life. This species has been met with in several other places in the country, and, though much less common at Linton than *Eurylepis,* seems to have been more widely disseminated.

In the black shale over Coal No. 5, at Mineral Point, Tuscarawas County, I found a large number of scales of *Megalichthys,* the only case in which this genus has been recognized on this continent. Higher up in the series a well-marked fish-bed occurs in the Barren Coal Measures. This is the limestone band which has been called by Prof. Stevenson the Crinoidal limestone; by Prof. Andrews it is styled the Ames limestone. It is about 140 to 150 feet below the Pittsburg Coal seam (No. 8). From this limestone I have obtained in several localities *Petalodus Allegheniensis*, Leidy, and apparently a new species of *Ctenoptychius.* Detached scales of fishes have been found in the limestones of the Upper Coal Measures, but none that are sufficiently perfect for description.

To give completeness to this review, I ought, perhaps, to mention a few "extra-limital" Carboniferous fishes. I have referred incidentally to the spines of *Edestus* found in the Coal Measures of some of the States west of Ohio. Of this remarkable genus, three species are now known. *E. vorax,* Leidy, the largest of the group, is described in the Jour. Acad. Nat. Sci., Phila., 2d Ser., Vol. III., p. 159, Pl. 15. *E. Heinrichi,* N. and W., is from the coal of Belleville, Ill. This latter species is described in the report of the Geological Survey of Illinois, Vol. IV., p. 350, Pl. 1 *a,* 1 *b.* Since the publication of this description, I have received from Vermillion County, Ind., through the kindness of Prof. F. H. Bradley, a small and evidently young specimen of *E. Heinrichi,* which shows the superior extremity of the spine, and illustrates in a very interesting manner its mode of growth. This specimen will be figured and described in another volume of our report, where the structure and relations of this remarkable genus will be more fully discussed than they have heretofore been.

The third species of *Edestus,* but first in date of discovery, is *E. minor*, N., of which the best specimen known is in the cabinet of Amherst College. This is described and figured in the report of the Geological Survey of Illinois, Vol. II., p. 84, Pl. IV., fig. 24; Vol. IV., p. 351, Pl. I., fig. 2. It is also badly figured and imperfectly described in the proceedings of the ninth meeting of the American Association, and in Owen's Palæontology. It is a striking fact that all the specimens of *Edestus* known were found in bituminous shale associated with coal seams, or in cannel coal; and we may infer from this that the fish, of which this was the

defensive spine, was the inhabitant of the lagoons of fresh? water which were scattered over the great coal marshes.

In the interesting group of fossils contained in the nodules of iron ore found in the Coal Measures at Mo rris, Grundy Count y, Illinois, are a number of fishes which have not yet ben met with elsewhere, but which may be looked for in other localities at the same horizon. Among these are a small *Paæoniscus,* and, what are of much greater interest, species of *Amblypterus* and *Platysomus,* fishes sufficiently common in the Coal Measures of Europe, but not elsewhere known in this country. Both of these fishes, *Amblypterus macropterus,* Ag., and *Platysomus circularis,* N. and W., are described in the report of the Geol ogical Survey of Illinois, Vol. IV., p. 347. The ve ry close resemblance or specific identity of this species of *Amblypterus* and the most common *Cælacanthus* of Ohio, (*C. elegans*) with the most a bundant species of these genera in Euro pe, affords another and interest ing illustration of the remarkable unity which has been discovered in the fauna and flora of the Coal Measures of Europe and America. The *Platysomus* mentioned above is of additional interest, as it is t he first of the Palæozoic Pycnodonts found in America. To this, however, I can add another in the dentition of a much larg er fish found by Mr. G. K. Gilbert in the Sub-Carboniferous limestone of Arizona.

In New Bru nswick and Nova Scotia the Carbon iferous rocks have yielded quite a large number of fish remains, most of which have been described by Prof. Dawson in his charming "Acadian Geol ogy." *Ctenoptychius, Ctenodus, Rhizodus, Diplodus* and *Gyracanthus* are enumerated and figured by Prof. Dawson (Acadian Geology, p. 210). In the strata which contain the Albertite, at Hillsborough, New Brunswick, specimens of *Palæoniscus* are of frequent occurrence. A num ber of species have been described by Dr. Ch as. T. Jackson, of Boston, in a special paper descriptive of the Albertite and its associated fossils.

The reader is also referred to the following papers for interesting information in regard to our fossil fishes:

"Descriptions of the remains of fi shes from the Carboniferous lime-stone of Illinois and Missouri," by Joseph Leidy, M.D., Trans. Amer. Philos. Soc., Vol. XI., p. 87.

"Descriptions of some remains of fishes from the Carboniferous and Devonian formations of the United States," by Joseph Leidy, M.D., Jour. Acad. Nat. Sci., Phila., 2d Ser., Vol. III., p. 159, Pl. 15, 16, 17.

Also, notices of some Carboniferous fishes of Alabama, by Prof. Toumey, contained in the Second Report on the Geology of Alabama.

ORIGIN OF OUR ICHTHYIC FAUNA.

The following brief summary comprises all that we can at present safely say in regard to the derivation of our fossil fishes. As has been repeatedly stated on the foregoing pages, the oldest remains of fishes yet found in the world are in the Upper Silurian rocks of Europe. These are Placoderms and Elasmobranchs, generally of small size, but existing in large variety, and exhibiting a structure so elaborate and highly organized, that by some zoologists they are thought to rank among the highest in the class of Fishes. By others they are ranked lower; but by none is an embryonic or rudimentary character assigned to them. These earlier fishes were the cotemporaries of large and powerful Cephalopods, and of Crustaceans (*Pterygotus*, etc.) much larger than any now living. With the latter the Placoderms have been compared, from the fact that defensive shields were worn by both. But they were as different in organization as *Scaphirhyncus* and *Limulus,* and we are, up to the present time, without links which connect them, or any proof of relationship or derivation.

In America, the first remains of fishes are found in the Corniferous limestone; but here they appear in great force, consisting of several genera and species, some of which attain gigantic dimensions. Of the origin of this fauna we now know nothing, and probably never shall know much. It will be remembered by those who have read the geological portion of this volume, that I have ascribed the several circles of deposition which form our geological systems to successive invasions of the land by the sea. The first submergence of the old Eozoic continent resulted in the deposition of the great limestone group of the Lower Silurian. In these sediments we have the remains of probably all the forms of life that inhabited this sea, except such as were without hard parts; and, as we have seen, the ocean of that period teemed with protozoans, radiates, mollusks and crustaceans, but, so far as we yet know, was without vertebrates. After standing for perhaps millions of years over what is now North America, the Lower Silurian sea was withdrawn, and was succeeded by a land surface on which no strata were deposited. After the lapse of thousands or millions of years, this land was again submerged—the sea reaching nearly as far as before. In the advance, continuance and retreat of this second submergence, the series of strata we call Upper Silurian were deposited. Of these, the Clinton, Niagara and Helderberg limestones are made up of organic materials derived from the structures of the animals that inhabited the Upper Silurian sea. In this great calcareous mass we have a record of the marine life

of the age, so far as any record has been left of it. As before stated, even here we have in America as yet found no traces of Vertebrates. When, however, the waters retreated to the oceanic basins that have been always sea, and after, perhaps, other millions of years, came back again in the Devonian submergence, we find them inhabited by a horde of ichthyic monsters, some of which could hardly have been less formidable than the sanguinary and dreaded sharks of the present day. They were imposing, not only from their size, but from the completeness of their armor, both for attack and defense. Whether any of them had ossified vertebræ or not, remains to be determined; but that a larger part of their structure was composed of true bone than in any fishes of the present period, can be easily shown. The origin and earlier history of this great ichthyic fauna is perhaps written in the unexplored depths of the oceanic basins from which it came; but to us it "sprang, like Minerva, full-armed from the head of Jove." With the Devonian seas in their retreat, departed all the group of great bucklered fishes, never more to return. In the sea of the Carboniferous age, sharks abounded in great numbers, and they seem to have reigned at this period as monarchs of the ocean world. Along the shores, and in the lagoons and rivers of the Coal Measure epoch, a multitude of Ganoids abounded, mostly small, glittering in polished scale-armor, or having all their scales and bones elaborately chased and ornamented. In the same strata and localities, another and higher class of vertebrates, the Amphibians, have left abundant remains. Many of these were aquatic, carnivorous salamanders, not unlike in form and habit the *Menopoma* of our streams and lakes, but far exceeding that in dimensions. Others were slender and snake-like, almost without limbs. The Ganoids shade so gradually into these Amphibians, that it is impossible to draw any well-defined line between them. And there is little doubt that a connected chain of being leads from the Ganoids through the Amphibians up to the true Reptiles.

With the retreat of the Carboniferous sea, most of the interval between the Mississippi and the Atlantic was left dry land, and has never since been submerged. On this land, or the lakes and rivers of the Canadian continent, which has remained as land since a period anterior to the Silurian age, the Ganoids of the Coal period have continued to exist, and in our *Lepidosteus* and *Amia* we probably have the lineal descendants of *Palæoniscus, Cœlacanthus*, etc., of the Carboniferous age.

DESCRIPTIONS OF

FISHES OF THE DEVONIAN SYSTEM.

GANOIDEI.

CHONDROSTEIDÆ?

GENUS MACROPETALICHTHYS, N. and O.

The generic characters of *Macropetalichthys* may be thus described:

"Ganoid fishes of large size; cranium composed of large, polygonal plates, united by double suture s which are nearly concealed by the tubercled, enameled surface; tuberculation stellate; surface ornamented by double rows of pores and single thread lines, forming a pattern which does not correspond with the plates below; eye orbits conspicuous, inclosed in the orbital (Frontal?) plates; nasal plate (Ethmoid?) wedge-shaped, the apex turned backward, and reaching to the center of the cranium; occipital plate (Supra-occipital) oblong, emarginate behind, prolonged anteriorly into a point which meets the opposing point of the nasal plate; teeth and scales unknown; probably wanting."

The crania of *Macropetalichthys* constitute the most striking of the remains of fishes found in the Corniferous limestone, as they are composed of large geometrical plates, and are sometimes fifteen inches in length. They have attracted the attention of all quarrymen who work in this rock, and by them are usually regarded as carapaces of turtles. They are, however, plainly the crania of large Ganoid fishes, and are the more interesting as they occur in the Old World as well as in America, and serve as another connecting link between the Devonian limestones of the Eifel and those of our own country.

The name now borne by this fish was conferred by Drs. Norwood and Owen. The specimen described by these gentlemen was found in the Corniferous limestone near Madison, Indiana. When it came into their hands it was much broken. As a consequence, the description based upon it was very imperfect, in some respects erroneous, and, as will be seen, was sure to mislead anyone who might discover other representatives of the genus to which it belonged. Dr. Owen described his fish as "being entirely destitute of a tubercled dermal surface; without distinct

eye-orbits; provided with two spinous appendages, or horns, and having the escutcheons covered with angular, irregular, rhomboidal, enameled, but minute scales"—all of which is entirely at variance with the characteristics of the crania which I have examined, derived from the same formation, and which, judging from a plaster cast of the original which I have seen, are generically identical with that described by Dr. Owen.*

In the *Jahrbuch fur Mineralogie,* 1846, p. 596, Hermann von Meyer gives a brief notice of the discovery of what he regards as a species of *Placothorax* from the "transition limestones" of the Eifel. This fossil he named *Placothorax Agassizii*; and in the *Palæontographica* (Vol. I., p. 102, t. XII.) he gives a figure and detailed description of it.

In Von Meyer's specimen of this fish the tubercled, dermal surface is nowhere exhibited, and no characters are derived from it; his diagnosis being based on the cast of the under surfaces of the bony plates—the plates themselves having mostly disappeared.

Of these plates, the impressions of portions of six are shown. They were united by double sutures, and consist of two on the median line, and two pairs of lateral plates separated by these. Of the central plates, one is oblong, rounded at what he supposed to be its anterior extremity, and terminates "posteriorly" in a central, salient angle, which is met by the more acute "anterior" angle of a narrow, cuneiform plate, the second and "posterior" of the central plates. On either side of this narrow plate lies a broad, trapezoidal plate, the two forming a pair, in which are set the eye-orbits, "far back from the snout."

"Anterior" to the orbital plates, and joining laterally the "nasal" plate first mentioned, are two small, triangular plates, of which the exterior margins combine with the "anterior" border of the "nasal" plate to give a rounded outline to the "snout."

Dr. Giebel (*Fauna der Vorwelt*, I. 3, p. 265), and Pictet (*Paleontologie*, II., p. 224), both of whom notice this fish, accept without question Von Meyer's name and description, and with him place it among the *Cephalaspidæ*. By comparing Von Meyer's figure with that now given (Pl. 24), anyone will see at a glance that his fish is at least generically identical with our *Macropetalichthys,* and that he has mistaken the relations of the parts of his fossil, and has described as the nasal extremity of the head what is really the occiput, and the occipital plate as the nasal; in his specimen the anterior (and not, as he says, the posterior) extremity being wanting, and the posterior portion folded under and unnaturally rounded.

* American Journal of Science, 2d Series, Vol. I., p. 367 (1846).

The change of position of the head required by my specimens brings the eyes comparatively near the nose, and gives a symmetry and propriety to its appearance, the want of which is apparent in Von Meyer's figure.

That the "*Placothorax*" of Von Meyer (i. e., *Macropetalichthys*) is not generically identical with the *Placothorax* of Agassiz, is, I think, also certain.

The genus *Placothorax* was first established by Agassiz in 1845 (*Pois. Foss. Vieux Gres Rouge,* p. 134, t. 30, figs. 20-23) to receive a fossil, at that time unique, from the Devonian rocks near Elgin, in Scotland. This was but a fragment, and only a drawing of that was submitted to Agassiz. He, however, pronounced it a portion of the cephalo-thoracic buckler of a fish belonging to a new genus, and to his family of *Cephalaspides.*

In *Placothorax*, Agass., the exterior surfaces of the plates are covered with tubercles set in rows—on the superior plates parallel to their borders, on the lateral plates in longitudinal lines parallel with the axis of the fish—and the sutures of the plates are externally conspicuous.

In *Macropetalichthys* (*Placothorax,* V. Meyer), the mosaic pattern formed by the plates is quite different; the tubercles of the dermal surface—so characteristic, in their form and arrangement, of the different genera in which they are found—are stellate, as in *Asterolepis,* and are either irregularly scattered over the surface, or set in short lines radiating from different centers; and the sutures are, for the most part, concealed by them.

In these characters, and in others, the *Placothorax* of Von Meyer (*Macropetalichthys*) differs from the *Placothorax* of Agassiz, and should therefore be considered as a distinct genus.*

Of *Macropetalichthys* there are now enumerated four species, viz: *M. Sullivanti,* Newb.; *M. Agassizii,* Von Meyer; *M. Manni,* Newb.; *M. rapheidolabis,* N. and O. It is, however, possible that the last two are identical with the two former; but just what Norwood and Owen's species is, we shall probably never know, as their description does not tell us, and the original specimen has been lost sight of; neither do Von Meyer's descriptions nor figures furnish the means of making an accurate comparison with our American fossils.

In the earlier notices of this genus, teeth which were frequently found associated with the crania of *Macropetalichthys* were conjecturally assigned to this fish; but it is now known that these teeth belonged to a different Ganoid, often met with in the Corniferous limestone (*Onychodus*). Though some hundreds of the crania of *Macropetalichthys,* in better or

* *Placothorax,* Agass., seems to me more likely to prove to be the arm (pectoral organ) of *Pterichthys*, than the buckler of any fish.

worse preservation, have been obtained, no teeth have been found connected with any of them; nor have any teeth been so associated with them as to render it probable that they formed the dentition of this fish. I am, therefore, led to believe that, like the Sturgeon, *Macropetalichthys* was toothless. I have two specimens which show the under side of the head, and are so fractured that what represents the head may be lifted out, exposing the under surface of the cranial plates. In these specimens the outlines of the jugular plates are shown, and anterior to them an undulated surface, apparently formed by a smooth, leathery integument, as in the Sturgeon, but no traces of teeth are anywhere visible.

Several specimens which I have seen exhibit casts of the central cavity of the skull, and prove that the volume of the brain was considerable. It occupied all the space under the Supra-occipital plate, and in large specimens was fully an inch in depth. The brain terminated in front and rear in two rounded lobes which have been sometimes mistaken for condyles.

The homologies of the skull of *Macropetalichthys* have not been fully made out. I give below a diagram showing the principal plates, but it is evident that not all are shown here. The edges of the lateral plates so overlap that it is difficult to trace the outlines of the smaller ones. This will doubtless be done, however, as more complete specimens are procured.

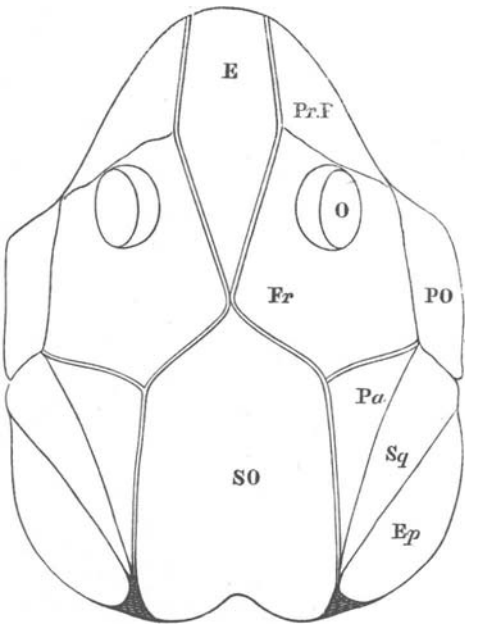
On Plate 24 the under surfaces of the cranial plates of *Macropetalichthys* are distinctly shown. From such a view it will be seen that there is very little overlapping of the margins, and that they do not unite, as do the bones of the cranium in most fossil and living fishes, by squamosal sutures, but by the direct contact of the edges. The union between the plates was, however, very close and firm, as we rarely find them disarticulated. In this respect *Macropetalichthys* offers a strong contrast to *Onychodus,* in which the numerous plates of which the cranium was composed are almost always found disconnected and scattered about in the rock which incloses them.

It will also be noticed that the plates of the cranium of *Macropetalichthys* are quite thick and continuous, with no lacunæ or cartilaginous spaces.

The zoological relations of *Macropetalichthys* can hardly be said to be determined by the remains yet found; but from the points which have been mentioned in the structure of the head, I am inclined to connect it with the Chondrosteans. The system of cranial plates in *Macropetalichthys* is simpler than in *Accipenser,* but the homologies of the more important ones seem to me to be quite plain. The character of the under surface

of the head is altogether sturgeon-like, and it is quite certain that the general plan of structure was the same in both. Prof. Huxley is inclined to connect the Cephalaspids, *Cephalaspis, Pteraspis,* etc., with the Chondrosteans as represented by *Scaphirhynchus* and *Spatularia.* If this relationship shall be proved to exist, we may very well conclude that *Macropetalichthys* is one link in the chain, and *Chondrosteus* of the Jurassic is another.

CRANIAL PLATES OF MACROPETALICHTHYS.



E. Ethmoid. Pr. F. Pre-frontal. Fr. Frontal. O. Orbital.
S. O. Supra-occipital. Pa. Parietal? Sq. Sqamosal? Ep. Epiotic?
P. O. Post-orbital.

MACROPETALICHTHYS SULLIVANTI, Newb.

Plate 24, Plate 25, Figs. 1, 1*a.*

Agassichthys Sullivanti, N.; Bulletin National Institute, 1857, p. 3.
Macropetalichthys Sullivanti, N.; Amer. Jour. Sci.,2d Series, Vol. XXIV., 1862, p. 75.

As crania of this fish have formed the basis of the generic description which I have given, comparatively little need be said in regard to the characteristics of the species. Among the specimens which have been under my observation, a great diversity in size has been noticeable, and so much variety in the details of structure, that I was at one time led to

conclude that we had in the Corniferous limestone of Ohio the representatives of two species of *Macropetalichthys*. In the paper read before the National Institute, cited above, two species were described, *M. Sullivanti* and *M. Manni*, the former including the larger and relatively broader crania—from 10 to 16 inches in length—with plates bounded by straight lines, and hence having a more geometrical appearance. The smaller crania—from 6 to 9 inches in length—having a narrower nasal plate; and the outlines of the frontals and supra-occipital gracefully curved, were set off in a species named in honor of the late Dr. Mann, an indefatigable and successful collector of Corniferous fossils of New Milford, Delaware County. After an examination of a very much larger amount of material than I had seen when these descriptions were written, I find it difficult to maintain the distinction between the species described, and am disposed to consider the differences which they exhibit as probably due to age or sex. Further observation may prove these forms to be specifically distinct; but for the present it is perhaps wiser to consider all of our specimens as varieties of *M. Sullivanti*. It would be very strange, however, if only one species of this remarkably distinct genus were found; and it is altogether probable that in the future, collections made from the Corniferous limestone in other States than Ohio, or from some other member of the Devonian system, will include forms that are more widely separated from the typical species than any that have come under my observation.

The specimen figured by Von Meyer is, so far as we know, the only one that has been discovered in Europe, and it very closely resembles those obtained in our State. The imperfect preservation of this specimen makes it impossible, however, to determine whether it is specifically identical with ours or not. The fact that one head of *Macropetalichthys* was found in the Devonian limestones of the Eifel, proves the genus to have had a very wide geographical range, and renders it almost certain that it will be met with in every other great exposure of the Devonian limestones. The specimen described by Drs. Norwood and Owen has been already referred to. It was too imperfect for accurate specific determination, and has since been lost, so that it can hardly be appealed to in a question of species. The cumbrous name given to it makes it rather fortunate than otherwise that it has been impossible to identify it, and we are therefore saved from the loss of time its frequent repetition would have occasioned.

The most important features in the structure and homologies of *M. Sullivanti* have been already given, but a few minor points remain to be noticed. The two plates which lie upon the median line of the cranium,

and which unite their salient angles at its center, I have considered the *Ethmoid* and *Supra-occipital*. The two polygonal lateral plates which inclose the eye-orbits seem to me to probably represent the *Frontals*, while the triangular plates anterior to the eyes should probably be considered as the *Pre-frontals*. The plates which form the posterior lateral portions of the skull are not distinctly separable, but they would seem to represent three, which I have fancied might be the *Parietal*, the *Squamosal* and the *Epiotic*. The exterior surface of the cranium is covered with densely-crowded, stellate tubercles, very well shown on Plate 25, Fig. 1. This sheet of tuberculated enamel, when entire, completely conceals the underlying bone. Along the principal sutures are lines of dots or pores which form a peculiar and tasteful ornamentation.

As mentioned in the generic description, several specimens of *Macropetalichthys* which have been found apparently show the under side of the head. In these a pair of plain and doubtless once thin plates occupy the posterior half of the under surface. These are united by a simple, straight, longitudinal suture. The anterior portion of the under surface is very imperfectly preserved. No osseous plates are visible here; nor are there any traces of teeth. It would seem, therefore, that this space had been occupied by soft tissues, which have disappeared in decay.

In the figure given on Plate 24, the under surface of the cranial plates of *Macropetalichthys Sullivanti* is well shown. The specimen is slightly injured by the breaking away of most of the Post-orbital plates, and by the splitting of the Ethmoid and Supra-occipital, the results of compression. In Plate 25, Fig. 1, we have a side view of the cranium of *Macropetalichthys*, showing the general character of the tuberculation of the external surface. In Fig. 1*a*, a series of the stellate tubercles which ornament the cranium are represented larger than natural, for the purpose of exhibiting their minute characters. Owing to the roughness of the tubercled surface it usually adheres to the matrix, and it is very rare to find so good an exhibition of it as that on the specimen figured.

CROSSOPTERYGIDÆ.

GENUS ONYCHODUS, Newb.

Ganoid fishes of large size; cranium composed of a great number of bony plates covered with an enameled and tuberculated surface; tuberculation relatively fine, and formed by what may be compared to small

grooved cones, pressed down and adherent; jaws set with numerous conical, acute, more or less recurved teeth, of nearly uniform size; maxillary forming a low triangle, with much-produced, acute lateral angles; dentary bones posteriorly acute, where they are overlapped by the articular portions of the mandibles, long and narrow, curving upward to the symphysis, where they support an inter-mandibular arch of bone, to which was attached a single series of large, curved, conical teeth; teeth all smooth, covered with enamel, without basal plications; those of the maxillaries and mandibles implanted in sockets or anchylosed. The teeth of the median crest are seven in number, attached (by ligaments?) to an arched base, from which they radiate. They are much curved, often sigmoidally, have a circular section near the summit, are somewhat compressed below, and expand at base into several prominent roots or tuberosities. They have a central cavity extending nearly to the point, surrounded by dentine simple in structure; the external surface is formed by a layer of smooth and polished enamel.

The body of *Onychodus* was covered with imbricated scales, nearly circular in outline, and about an inch in diameter. The under surface of the scale is marked by fine concentric lines, as in *Holoptychius*. The exposed portion of the outer surface is ornamented with a tuberculation not unlike that of the plates, consisting of radiated but broken lines, and confused groups of minute, furrowed, appressed cones.

This genus was created by the writer many years ago, to receive certain conical, curved teeth found in considerable abundance in the Corniferous limestone. Figures and descriptions of these teeth are given in an article "On the Fossil Fishes of North America," published in the American Journal of Science, July, 1862, and they are also described in the Bulletin of the National Institute, Jan., 1857. As they are generally found detached, nothing was known until recently of their relation to any other fish remains found in the Corniferous limestone; and, as the most abundant cranium in that rock is that of *Macropetalichthys*, it was suggested that they formed part of the dentition of that fish. After a time, however, these teeth were found associated together, in rows of seven; an arrangement most like that of the teeth of Sharks. And as they seem to have been connected with their basal support by only ligamentous attachment, as the teeth of Sharks are attached to their jaws, this circumstance was regarded as confirmatory evidence of their Selachian character. It happened, however, in several instances, that plates of various forms, maxillaries and mandibles set with teeth, and numerous scales—each group evidently the fragments of a single individual—were found on slabs taken out of the quarries at Sandusky and Dela-

ware. Among these fragments there was almost invariably a single series of the teeth of *Onychodus*. How to establish a relationship between these teeth and the associated remains—which were those of a well-marked Ganoid fish—was for a long time a puzzle; but, by a fortunate discovery of Mr. Hertzer, the problem was at length solved. He found at Delaware a large mandible of *Onychodus*, to which the peculiar series of large teeth are attached in their normal position; that is, between the extremities of the mandibles, where they hold precisely the position of the median row in the dentition of a Shark. They are attached to a bony arch, from which they radiate. This is inserted in the symphysis of the jaw, supported by a shoulder on the internal face of the extremity of each mandible. So far as we yet know, there are no corresponding or interlocking teeth in the upper jaw; and hence it would seem that they armed the projecting extremity of the under jaw, just as the steel point arms the prow of a steam ram. We shall probably find more perfectly preserved specimens which will fully explain this apparently anomalous structure, and perhaps correct in some degree our conclusions in respect to it; but the specimens before me seem to establish beyond question the position of these teeth in the symphysis of the jaw.

The pattern formed by the numerous plates that compose the cranium of *Onychodus* is very complicated, and presents a puzzle not yet solved, for the cranium has never been found entire; and, indeed, it has only rarely happened that any two plates have been seen in connection. In this we have evidence of a want of solidification in the structure of the cranium, such as has not been noticed among any of the congeners of this fish. A number of the plates which compose the bony structure of the head can, however, be easily identified, such as the Opercula, Parietals, Frontals, etc.; but there are many others of which the homologies are not yet determined. The plates which belong to *Onychodus* are easily recognized by their peculiar tuberculation. This is relatively fine, and may be compared to a series of small, striated, appressed cones. In some instances these cones show but a single furrow by which they are notched at the summit; their height is two or three times the diameter, but each is laid over and adherent to the plate by its entire side. A similar tuberculation, though finer, covers the exposed portions of the maxillaries and mandibles.

In Ohio, *Onychodus* has, as yet, been met with only in the Corniferous limestone; but I have received from Delaware County, New York, numerous teeth, obtained from the Chemung, of a species of this genus, apparently different from that of the Corniferous.

In regard to the affinities of *Onychodus*, it is impossible now to speak

with absolute certainty, as all the specimens yet found have been in such a dismembered condition as to leave some important points of structure undetermined. There is little doubt, however, in my mind that it belonged to the *Crossopterygidæ*. The features which lead to this conclusion are the cycloidal, imbricated scales, having the exposed portion strongly, the covered portion more delicately, yet elegantly ornamented, much as in *Glyptolepis*; the spatulate or sandal-form Jugular plates, and the large rounded Opercula. Both these latter plates, as well as the Supra-temporals, resemble in form those of *Polypterus*. Hence we may infer that when the structure of *Onychodus* is more fully made out, we shall find that the paired fins are more or less lobate, the body fusiform, and the general appearance not unlike that of *Holoptychius* and *Glyptolepis*.

The peculiar dentition I have described is a point in the structure of *Onychodus* where it differs widely from the fishes with which I have associated it; but I have already shown how much the dentition varies among both recent and fossil fishes which, by other characters, are somewhat closely approximated. It may also be said that while on some large slabs of limestone we have found apparently most of the bony portions of *Onychodus*, among these were no plates, such as belong to the carapaces of the Placoderms; and we have, therefore, no evidence that it has any affinity with *Asterolepis, Coccosteus*, etc. The scales of *Onychodus* are not unlike those which were attributed by Hugh Miller to *Asterolepis*; but we now know that these scales really belong to *Glyptolepis,* and that, so far as known, the body of *Aslerolepis* was without scales.

ONYCHODUS SIGMOIDES, Newb.

Plate 26, Figs. 1 to 5; Plate 27, Figs. 1, 2.

Onychodus sigmoides, N.; Bull. Nat. Inst., 1857, p. 5.

Fishes of large size; head at least one and a half feet long, composed of numerous angular and rounded plates, supported on a cartilaginous brain-box, and so imperfectly united that in the fossil state they are usually disconnected and scattered. Of the head-plates, the opercula are from 3 to 5 inches in diameter, nearly circular, but with a produced anterior angle. The maxillaries are triangular in outline, the anterior and posterior angles much produced, the lower margin nearly straight, and set with a large number of conical, pointed teeth. The dentary bone of the mandibles is often more than a foot in length, curved gently upward at its anterior extremity, which is rounded. Its posterior extremity is thin and flattened, running off to a point and edge, where it is overlaid by the

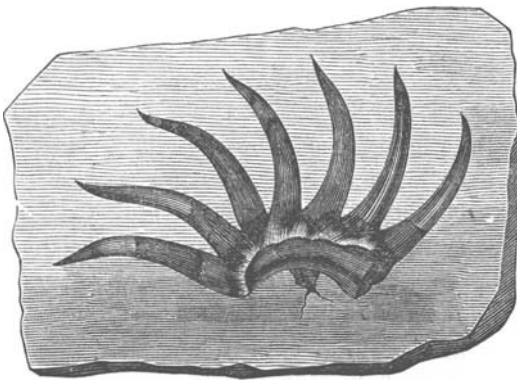
articular portion of the mandible. The upper margin of the dentary bone is thickly set with conical, pointed teeth. Em braced within the anterior extremities of the mandibles is an arch of bone which supports a series of large, conical, sigmoidally curved teeth, seven in number, set vertically and projecting downward, forward and u pward. These teeth show several prominent roots, which partially embrace the bases of the adjacent teeth. The exterior surfaces of the cephalic plates, and the exposed portions of the maxillaries and mandibles, are thickly set with small, enameled tubercles, which have the form of appressed, striated or sulcated cones. The body was covered with relatively thin, highly ornamented scales. These have a circular or elliptical outline; the under surface is smooth, or faintly marked with concentric lines, and often bears a central, elevated tubercle or ridge. The exterior surface shows an anterior semi-lunar space, occupying about half its area, where ad jacent scales were superim posed. This s pace is comparatively smooth, but is delicately ornamented with radiating lines of pits. The posterior and exposed portion of each scale is roughened with appressed, striated tubercles, similar to those on the cephalic plates, and with branching, somewhat foliated ridges of enamel.

The foregoing description will be made more intelligible by referring to the accompanying plates (26 and 27). On Plate 26, Fig. 1, is represented a portion of the bony arch that occupies the symphysis of the under jaw, with three of the large teeth which are set upon it. This specimen was associated with the dentary bone represented on Plate 27, Fig. 1; and they, with a large number of p lates of the head scattered about on the same block of limestone, evidently belonged to one fish. Fig. 2, Pl. 26, represents a single detached tooth of this central series found in another locality; Fig. 3, Pl. 26, a nearly complete series (wanting one) of these terminal teeth, from a small indi- vidual. Figs. 4 and 5, of the same plate, were drawn from a pair of dentary bones of a small individual, and probably the same with Fig. 3. Fig. 4*a* gives a cross-section of Fig. 4. On Plate 27, Fig. 1, is shown the inside of the dentary bone of a mature individual, but by no means the largest yet found. It will be noticed that the anterior extremity of the dentary bone is hollowed on the inside for the reception of the bony arch which carried the series of large teeth. In Fig. 2, of the same plate, is given an accurate representation of a dentary bone found at Delaware, with which the bony arch and its large teeth are seen nearly in the natural position. In this specimen the tuberculated character of the exposed portion of the dentary bone is well shown; and it will be also noticed that on the upper margin many small, pointed teeth are associated with the larger ones already

described— a feature common to many of the fossil Ganoids, and well shown in the living *Lepidosteus.* Fig. 2*a* represents the tuberculation of the jaw enlarged. Figs. l*a*, l*b*, and l*c* show the scales of *Onychodus*; l*a*, the internal surface, l*b*, the external surface of a specimen, not well preserved, but the best at command when the figure was made. In more perfect scales the covered portion is seen to be marked with radiating lines of pits. l*c* represents a portion of the exposed and most highly ornamented surface of a scale, much enlarged.

Figures of the cephalic plates of *Onychodus* are not given in the present volume, as their relationship has been but imperfectly made out; but I hope by the aid of new material to furnish hereafter more complete descriptions and better figures than would now be possible. The homologies of some of these plates have, however, been determined. The Jugulars, for example, are quite unmistakable. They are, in mature individuals, a foot in length by four inches wide, with a spatulate or sandal-shaped outline. The Opercula have been referred to. The Parietals and Supra-temporals have also been identified.

Up to the present time no remains of *Onychodus sigmoides* have been found in any other formation than the Corniferous limestone. Here, however, they are quite abundant, especially in the upper division (the Sandusky limestone), where, both at Sandusky and Delaware, certain layers contain such numbers of bones and teeth that they are designated by the quarrymen as *fish-beds.* The lower or Columbus subdivision of the Corniferous also contains the remains of *Onychodus*, locally, in considerable abundance. In the accompanying wood-cut is represented a complete series of the central teeth of *Onychodus,* intermediate in size between



CENTRAL TEETH OF ONYCHODUS SIGMOIDES, SLENDER FORM.

those represented on the plates. These I formerly supposed to be identical with a species found in the Chemung of New York; but I now have

reason to suppose that we have here only an immature specimen of *O. sigmoides*. In *O. Hopkinsii* of the Chemung, the teeth are apparently smaller than in *O. sigmoides*, and not often, if ever, sigmoidally curved.

It will be noticed that the larger and smaller series of teeth now figured (Figs. 1, 2, 3, Pl. 26, and wood-cut) differ very much, not only in length, but in strength, the larger teeth being relatively more robust. Some of the smaller teeth so frequently met with in the Corniferous limestone are also much more slender than others. These differences may be found to have a specific value, but it has seemed to me that they hardly afforded sufficient ground for a specific distinction.

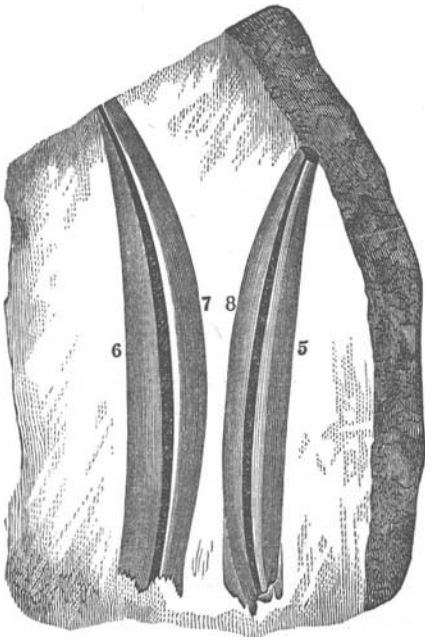
ELASMOBRANCHII.

GENUS MACHÆRACANTHUS, Newb.

Spines often of large size, flattened, curved, ancipital, unsymmetrical (dextral and sinistral); edges and point generally acute; base somewhat narrowed, with a rough and irregular extremity; central cavity reaching nearly to the apex; external surface covered with a thin coating of enamel, in some species smooth, in others punctate and longitudinally striated; microscopic structure that of dense, ivory-like bone.

These spines are very characteristic of the horizon of the Corniferous limestone; having been found at this level in Indiana, various localities in Ohio, in New York, and at Gaspe, Canada. Though presenting some anomalous characters, among which the most remarkable is their want of symmetry (being rights and lefts), it is hardly possible they can be anything else than the defensive spines of fishes. Their dense, bony structure, enameled surface, and rough, irregular bases, would seem to prove that, like the fin-spines of many Sharks and Rays, they had been implanted in the integuments without articulation. Possibly they were the first rays of the pectoral fins, which would account for their being in pairs. In that case, it might be expected that the bases would exhibit some marks of their articulation to the pectoral arch. But as the fishes that bore them were undoubtedly cartilaginous, the insertion of pectoral spines—supposing they possessed them—would naturally somewhat resemble that of the dorsal spines. Many bony fishes, as *Arius*, etc., bear formidable dorsal and pectoral spines; but these always exhibit some indications of an articulation at their proximal extremities. In the Sharks, Chimæras and Rays, however, the dorsal spines are simply implanted in the integuments of the back, and each spine has a roughened and attenuated base, which is surrounded by a larger or smaller mass of

cartilage. Comparatively few cartilaginous fishes of the present epoch are provided with even dorsal spines; and none, so far as known, carry spines on the pectoral fins. In *Chimæra*, however, we have a peculiar spine placed anterior to each abdominal fin; and since, in the Mesozoic and Palæozoic ages, the Elasmobranchiate fishes were much more generally provided with spines, it is not too much to suppose that this tendency to the development of organs of defense should be exhibited in spines appended to the anterior paired fins. The tails of some of the Rays are armed with two closely approximated, serrated spines, and they distinctly show upper and lower surfaces; but both are set on the median line, and are straight. We should naturally expect, therefore, that the defensive spines worn by any cartilaginous fish on the dorso-median line would exhibit similar features. The spines of *Machæracanthus* are, however, distinctly rights and lefts; and in the unique specimen discovered by the late Prof. Hopkins, of Auburn, two spines, which apparently form a pair, are seen lying in the rock, probably nearly in their natural position. A wood-cut of this instructive specimen is given below. It was obtained from the Corniferous limestone at Auburn, New York.



PAIR OF SPINES OF MACHÆRACANTHUS PERACUTUS.

The polished and punctate surface of the spines of *Machæracanthus* gives them very much the appearance of some of the spinous appendages of Crustaceans, such as the telson of *Limulus*, but the dense bony

structure of the spines of *Machæracanthus* is very unlike anything I have seen among the articulates. Beside this, the exo-skeleton of Crustaceans is always jointed together, and the spinous appendages are distinctly articulated with the thoracic or abdominal segments. The spines of *Machæracanthus*, however, show no such articulation; and we are compelled to suppose, from the irregular bases which they present, that they were implanted in the integuments, or sunk in cartilage. From all the facts before me, I am led to conclude, therefore, that we see in *Machæracanthus* paired, defensive spines, which were formerly borne on the pectoral fins of some Elasmobranch fishes, of which all the other portions of the body have disappeared.

That the spines of *Machæracanthus* are homologous with the very peculiar spines which are set anterior to the abdominal fins in *Chimæra* seems scarcely possible, from the very great difference of form and size which they exhibit. When we remember that some of the spines of *Machæracanthus* are more than a foot and a half in length, double-edged and very sharp, we can hardly avoid the conclusion that they were used as weapons of attack or defense, and that they constituted most formidable and efficient ones.

MACHÆRACANTHUS MAJOR, Newb.

Plate 25, Fig. 2.

Machæracanthus major, N.; Bull. Nat. Inst., 1857, p. 6.

Spine large and strong; length, 12 to 20 inches; greatest breadth, 1½ inches; wing of concave border widest; point moderately acute; base narrowed and compressed, with a rough and irregular termination; upper (?) surface lightly striated longitudinally, central axis projecting in an imperfectly rounded ridge, ½ inch wide, elevated 3/16 inch above the wings; under (?) surface of central axis marked by about 10 distinct, longitudinal carinations; axis 5/8 inch wide, flattened, obliquely angled at sides, rising ¼ inch above the wings; base unequally sloped off where it was set obliquely into the integuments. At this point the carinations of the upper part become obsolete; sides of axis, above and below, punctate.

Formation and Locality: Corniferous limestone; Columbus, Delaware and Sandusky, Ohio.

MACHÆRACANTHUS PERACUTUS, Newb.

Plate 29, Fig. 6.

Machæracanthus peracutus, N.; Bull. Nat. Inst., *loco cit.*

Spines 5 to 6 inches in length, 7 to 8 lines wide; point and edges very sharp; wings nearly equal; central axis on the upper surface forming a sharp and narrowed carination; below, a higher but more rounded ridge. This is perhaps the species most common in Ohio. It will be recognized by its small size, the acuteness of its point and edges, and by the angular ridge of the median line above and below. This is the species referred to in the generic description, and that which furnished the figures employed there to show the paired character of the se spines. The average size and appearance are well shown in the illustration cited above.

Formation and Locality: Corniferous limestone; Delaware and Sandusky, Ohio.

MACHÆRACANTHUS SULCATUS, Newb.

Machæracanthus sulcatus, N.; Bull. Nat. Inst., *loco cit.*

Spine 4 to 8 inches in length, 6 to 10 lin es wide; upper surface smooth, with a strong and sharp carination along the axis; wing of convex side widest; opposite wing narrow, and exhibiting a strong marginal sulcus, giving it a double edge; under surface of axis rounded, with several longitudinal sulci and carinæ, and with oblique angles at sides.

At the time of writing this description I have no sufficiently good specimen of this species to furnish a satisfactory figure. There are, however, better specimens in the collection of the late Dr. Mann, and I hope to have it well figured for another volume of the Report. I have little doubt that a spine of this species was the original of the figure published by Prof. Hall in the Geology of New York, Part IV., p. 174, although I have never seen the specimen, and in the figure the distinction between the central axis and the wings is not well preserved. A reduced copy of Prof. Hall's figure is given in Dana's Manual of Geology, p.275. The onl y specimen of *M. sulcatus* which I have is considerably twisted.

Formation and Locality: Corniferous limestone; Milford, Ohio.

GENUS LIOGNATHUS (n. gen.).

A small Placoderm, known as yet only by a jaw, found in the Corniferous limestone. This is spatulate in outline, dentated only at and near its anterior extremity. It has the general form of the dentary bone of *Dinichthys* and *Coccosteus,* and evidently belonged to a fish closely allied to them. It is even possible that it will hereafter be found associated with some small plates which occur in the Corniferous limestone, and which, from their resemblance to some of the plates of the carapace of *Coccosteus,* I have been inclined to refer to that genus.

LIOGNATHUS SPATULATUS (n. sp.).

Plate 29, Fig. 4.

Of this fish we have as yet only the right dentary bone. This is two inches long, by seven lines wide at its broadest part, somewhat triangular or spatulate in outline, its anterior extremity pointed, the posterior broadly rounded. The superior margin is nearly straight, and bears toward the anterior extremity a number of irregularly clustered, conical, blunt (?) teeth. At the extreme point is one (or more) longer, conical, acute tooth. The inner surface only of the jaw is exposed to view. This is flattened and smooth throughout. Probably the anterior portion of the exterior surface, if exposed, would be found to be roughened or tuberculated. As is mentioned in the generic description, the general form of this jaw is similar to that of *Coccosteus,* and it is a miniature copy of the dentary bone of *Dinichthys.* The resemblance is so strong that we must conclude that in this little jaw we have a relic of a hitherto unknown Placoderm which inhabited the Corniferous sea. I have, from the same quarries where this was found, a posterior dorsal plate which closely corresponds, in size and form, with that of *Coccosteus decipiens,* and it is not at all improbable that this plate once belonged to the same fish with the jaw under consideration. The figure given is of the natural size.

Formation and locality: Corniferous limestone; Delaware, Ohio.

GENUS CYRTACANTHUS (n. gen.).

The above generic name is given to a remarkable fish-spine found by Mr. Hertzer at Delaware. It is broken at its superior extremity, and

somewhat exfoliated, but it shows enough of its original form and structure to make it certain that it is quite distinct generically from any fish-spine heretofore described. It is much curved, perhaps abnormally. The exterior surface was once generally tuberculated, except at the rough and expanded base. Its peculiar and diagnostic character is a single row of conical denticles set on the posterior side, limited to the *upper portion*, and *increasing in size from below upward*. Most defensive spines are much less curved, and have the denticles most strongly developed near the base of the exposed portion. They also increase regularly in size from above downward.

Since the specimen upon which this generic description is based is unique, little can be said in regard to its relations. In its curved form, expanded base, and denticulated summit, it recalls the peculiar cephalic spine of *Chimæra*, and hence suggests relationship with the large chimæroid teeth found in the same deposit. And yet the tuberculation of the surface is precisely that of some of the lateral spines of the cephalic buckler of *Aspidichthys armatus*, also found in the Corniferous limestone, and to be more fully described in another volume of this report.

CYRTACANTHUS DENTATUS (n. sp.).

Plate 29, Fig. 5.

Spine 4 inches in length, cylindrical, 3½ lines in diameter at center, larger above and below; base irregularly dilated, and hollowed out below; upper portion covered with small and closely set tubercles. Near the summit is a line of strong, conical, slightly depressed denticles, set on the middle posterior line. These denticles increase in size from below upward; the uppermost being more than a line in diameter and height. The figure given of this spine is of the size of nature.

Formation and locality: Corniferous limestone; Delaware, Ohio.

HOLOCEPHALI.

CHIMÆROIDI.

GENUS RHYNCHODUS (n. gen.).

Teeth somewhat crescent-shaped or semi-circular, much compressed; the exterior margins regularly curved, the interior more nearly straight

and more or less thickened; one of the cornua produced and somewhat acute, the other more or less rounded and obtuse. The straight side of the tooth formed a triturating or cutting edge. In some species it was sharp and played upon the similar edge of the opposite tooth; in others it was broader and fitted for crushing mollusks or other food. Internal structure of teeth cancellated; the triturating surface being roughened by the extremities of calcigerous tubes. The number of teeth and details of dentition are not yet known, but we may infer from their shape that they were placed at the anterior extremities of the head to form a kind of rostrum or beak, much as the dental plates of *Chimæra* are placed. As none of the margins show marks of contact with other teeth, we may conclude there were but four having this form.

The internal structure of these teeth varies somewhat in the different species, adapting each to its functions. In *R. secans* the central portion is cancellated by interwoven calcigerous tubes, while the surfaces are composed of a tissue almost as dense as enamel, so that the cutting edges produced by the friction of opposing teeth on each other were kept constantly sharp and effective. In *R. frangens,* however—in which the upper edge is thick and presents a broad triturating surface to the opposite tooth—the dental tissue is cancellated throughout; affording by use that peculiar roughened surface so constantly seen on the teeth of the Cestracionts (*Psammodus,* etc.).

Among the large number of fish teeth from the Corniferous limestone which I have grouped in the genus *Rhynchodus*, there is considerable variety of form and structure; and yet, when nearly complete, they have so much in common that I have felt compelled to associate them together, and have supposed them to represent three species of a single genus. These species are described and figured in this report, and by reference to Plates 28 and 29 the characteristics of each form will be seen at a glance. In *R. secans* (Pl. 28, Fig. 1, 1*a*) the teeth have cutting edges. In *R. frangens* (Figs. 2, 2*a,* 3, of the same plate), with the same general structure and semicircular form, the edges are flattened and fitted only for crushing or triturating. In *R. crassus* (Pl. 29, Fig. 3) the upper surface is broader and more irregular, the whole tooth more massive and fitted for rougher work. The fundamental structure of all these varieties is, however, the same. They are all somewhat semi-lunar in outline, one of the angles being thickened, forming a kind of crown which was exposed to wear, while the rounded outline of the tooth is composed of comparatively thin walls, which apparently enclosed a process of the jaw on which the tooth was supported. This jaw was evidently cartilaginous, as all traces of it have generally disappeared. Not unfrequently nothing

but the crown of the tooth remains, the thinner walls below having been broken away. Such specimens are shown on Plate 28, Figs. 2*a*, 3. In the more complete specimens, such as are illustrated by Fig. 2, Plate 28, and Figs. 1, 2, Plate 29, although the entire outlines of the teeth are preserved, the thinner portions are crushed in and broken in such a way as to prove that these parts were filled and sustained by some core which has disappeared. The margins of all these teeth, when entire, are thin and rounded in outline, showing that they could not have been matched with others to form a complex dental series, but were solitary, or one set on each ramus of each jaw. Their microscopic structure is that of the teeth of Plagiostomous fishes, and is quite different from that of the teeth of any Ganoid known.

In one specimen which I have before me there are four of the teeth of *Rhynchodus secans* lying on a block of limestone, apparently holding nearly the position they did in life. They are surrounded by obscure traces of other portions of the fish that bore them, but nothing that has any distinct form or character.

In regard to the affinities of *Rhynchodus*, it seems to me that we have no good reason to doubt that they form the dentition of Chimæroid fishes, and that we have in them evidence of the existence on the globe of the *Holocephali* at a period long anterior to that in which their oldest remains have hitherto been found. As has been stated in the general review of our fossil fishes, the Chimæroids of our present seas (*Chimæra* and *Callorynchus*) are the remnants of an order of cartilaginous fishes which once held a much more important place than now in the fauna of the globe. In Europe the remains of the teeth of Chimæroids have been discovered in Tertiary, Cretaceous and Jurassic strata; but none in older formations, if we except the somewhat anomalous *Ptyctodus* found by Pander in the Devonian of Russia,* and of which a single tooth was discovered by Mr. Worthen in the Hamilton group, Calhoun County, Illinois, and described by him and the writer with the name of *Ptyctodus* (*Rinodus*) *calceolus*. (Geol. Surv. Ill., Vol. II., p. 106; Vol. IV., p. 374.) The affinities of *Ptyctodus* may be somewhat doubtful, although I have been inclined to consider the teeth described under this name as probably the dentition of some Chimæroid fish.

Whatever may be thought of the relations of *Ptyctodus*, those who are familiar with the fossil Chimæroids described by Sir Philip Egerton will probably not hesitate to group *Rhynchodus* with them.

* See Pander's monograph "Ueber die Ctenodipterinen des Devonischen Systems," p. 48, Pl. 8.

Although the *Holocephali* have heretofore been supposed to be limited in their downward range by the Jurassic formation, since we have evidence that our living Chimæroids are only the remnants of an expiring fauna, it was to be expected that the life of this fauna would be found to reach far back in time; and it was quite consistent with all the facts before known to find traces of Chimæroids in Palæozoic rocks.

The Rays, on the other hand, are apparently a comparatively modern off-shoot from the original Selachian stock. We have no evidence of their existence at a period anterior to the Jurassic age, and they are evidently now in their epoch of fullest development; with the Chimæroids, in their decadence, should naturally have had an earlier birth.

Up to the present time no teeth of *Rhynchodus* have been discovered outside of the State of Ohio, nor in any other formation than the Corniferous limestone; but here they are not uncommon, though specimens as perfect as those now figured are extremely rare. For twenty years I have had in my possession fossils obtained at Sandusky and on the Islands, similar to that figured on Plate 28 (Fig. 2*a*), of which I could make nothing, until, by the discovery of more complete specimens, they were found to be only the solid anterior angles of teeth which were originally provided with large, semicircular bases. Fragments such as these doubtless exist in many collections, and, with the plates and descriptions now published, they will become intelligible to their possessors.

With the teeth of *Rhynchodus* we not very unfrequently find some peculiar fossils, of which one is represented on Plate 28 (Fig. 4.) They are oblong or imperfectly quadrangular in outline, of no great thickness, one surface flattened, the other concave. The flat surface is commonly marked with low, transverse ridges or lines of growth. The material composing them is dense and hard, more like dentine than bone. What these singular bodies are I am, as yet, quite unable to say; but from their microscopic structure I have been disposed to regard them as some portion of the dental apparatus of an Elasmobranch fish, and from their association with the teeth of *Rhynchodus* I have fancied they might have once belonged together.

RHYNCHODUS SECANS (n. sp.).

Plate 28, Figs. 1, 1*a;* Plate 29, Figs. 1 to 2*a*.

Teeth somewhat semicircular in form, posterior angle rounded or obtuse, the anterior prolonged into a more or less acute point; posterior and inferior margins thin and sharp, anterior and superior margins

thickened; surfaces smooth, almost polished; interior face flattened, exterior sloping from the anterior and upper thickened edges to the thin margins behind and below; upper margins nearly straight; anterior half often worn to a sharp, knife-like edge by contact with the corresponding edge of the opposite and overlapping tooth.

Of these singular teeth I have quite a number, from the upper portion of the Corniferous limestone at Sandusky and Delaware. In outline they form the segment—from one-third to one-half—of a circle, and are from three to four inches in length across the straight side. They were apparently four in number, so set as to form a kind of beak; those of opposite jaws playing on each other like the blades of shears. All the specimens I have are considerably worn, the anterior half of the upper margin being beveled off to form a straight, acute, cutting edge.

In general form and structure these teeth correspond closely with those I have described under the name of *Rhynchodus frangens,* but are smaller, narrower, smoother and much less thick and massive. They are also at once distinguishable by their cutting edges.

On Plate 28, Fig. 1, is represented a tooth of *Rhynchodus secans,* showing a much worn, cutting edge. Fig. 1*a* represents a section of the same. On Plate 21, Figs. 1 and 2, are represented a pair of these teeth placed in their supposed natural positions; while the outlines 1*a,* 1*b,* 1*c,* 2*c*, exhibit different forms of the anterior angle more or less modified by use. All these figures are of natural size. Figs. 1 and 2, Pl. 29, are taken from a group of four found together and forming apparently the dentition of a single fish.

Formation and Locality: Corniferous limestone; Sandusky and Delaware, Ohio.

RHYNCHODUS FRANGENS (n. sp.).

Plate 28, Figs. 2, *2a, 3.*

Teeth semi-lunar in form, one side slightly concave, the opposite margin strongly convex and regularly rounded; type specimen four inches and eight lines in length, depth at the crown of the arch, two inches add nine lines; sides flattened; greatest thickness, six lines; concave side showing a triturating surface on its anterior half and rising upward into a beak like point; lateral surfaces smooth and polished; the lower and rounded portion of the tooth formed by thin walls of bone inclosing a deep pulp-cavity?; crown portion thick and strong.

The above description is based upon a tooth which seems to exhibit

an unusual perfection of preservation, inasmuch as there are several in the collection before me which apparently represent the crown portion—the massive anterior angle with its beak-like point and triturating surface—while the broad and smooth expansion of the side formed by the thin and shelly portion is altogether wanting. It is, however, possible that these are corresponding teeth from opposite jaws of which one form exhibits a crown portion with a broad expansion of marginal wall inclosing, perhaps, a pulp-cavity, while the other is simply concave below for adaptation to the convex surface of a supporting jaw; just such a difference, indeed, as is seen in the teeth of the upper and lower jaws of *Callorhynchus*.

The microscopic structure of these teeth is similar to that of many of the teeth of extinct Selachians, such as *Cochliodus, Psammodus,* etc., viz., a cancellated or reticulated tissue formed by radiating and branching calcigerous tubes completely solidified near the exterior, but wearing in such a manner as to leave a peculiar roughened and punctate grinding surface. The general form of the most perfect of them is very similar to that of those I have designated by the name of *Rhynchodus secans;* but in that species the lower margin is not so strongly arched, and the crown forms a cutting edge which played on that of the opposing tooth. If my view that these are the teeth of Chimæroid fishes is accepted, it will perhaps be thought that the differences between these two species have generic value, as they are quite as striking as those which separate the genera *Edaphodon, Ganodus, Ischiodus, Elasmodus,* etc. Yet, as it seems to me, with so little material before us, and knowing so little of the complete dentition of either species, it would be somewhat premature to attempt now to define more than one genus.

The resemblance presented by these teeth to those described by Buckland under the name of *Chimæra Townsendii* (Proc. Geol. Soc., Lon., II., p. 206) is so striking, that to anyone who will make the comparison the question will seem to be not so much whether the teeth under consideration are those of a Chimæroid fish, as whether the present species and that of Buckland do not belong to the same genus.

RHYNCHODUS CRASSUS (n. sp.).

Plate 29, Fig. 3.

Teeth large and strong, 3 to 5 inches in length, 1½ to 2 inches in breadth. Base expanded with a somewhat semicircular outline, from which the sides converge upward to an irregularly flattened and rough-

ened crown, which rises at the anterior extremity into a pointed prominence. Base excavated. Crown thick and strong, upper surface showing attrition from use.

In the tooth described above, we have a form of which a number of examples have been taken from the Corniferous limestone, none of which, however, are sufficiently complete to enable us to give all desirable details of their normal outlines and structure. So far as we can judge from this material, the original form of these teeth was not unlike that of the one I have described under the name of *Rhynchodus secans,* but they were evidently much broader and stronger, and fitted rather for crushing than cutting. For the reasons already given, I have been led to group these with the other teeth now described under the same generic title, and to regard them as the remains of fishes having more affinity with *Chimæra* and *Callorhynchus* than with any others now living. Probably the accumulation of more material will enable future palæontologists to determine more accurately the relations of this group of fishes with each other and with our living fauna; and it is possible their researches will modify in some degree the views now advanced. I have thought, however, that the publication of figures and descriptions of this singular group of fossils would at least serve a useful purpose in stimulating collections and researches by which their structure and relations would be more fully ascertained.

Formation and locality: Corniferous limestone; Sandusky, Delaware and Kelley's Island.

PLACODERMI.

GENUS DINICHTHYS (n. gen.).

This was a very large Placoderm allied to *Asterolepis, Coccosteus*, etc., but apparently far exceeding them in dimensions. The cranium was composed of thick, bony plates, strengthened with massive internal arches, all firmly anchylosed together, forming a bony box, not yet found disarticulated, which was at least two feet in length and breadth. Within the osseous cranium there was doubtless a cartilaginous brain-case, but the solid bone of the occipital portion was three inches in thickness.

The dentary apparatus consisted, First, of relatively small and thin, somewhat triangular maxillaries, which bear on their margins a number of conical, acute, anchylosed teeth, formed by the prolongation of the bony tissue of the jaw. These teeth interlocked with a similar series on the mandibles. Second, in advance of the maxillaries, the premaxillaries

are developed into large and strong triangular dental plates or teeth. Third, the mandibles consist of a dental bone, in some species, two feet or more in length, flattened and spatulate behind, turning up anteriorly to form a strong triangular tooth, which, with its fellow of the opposite mandible, interlocked with the great divergent premaxillary teeth. Midway of the dentary bone, in some species, the upper margin was prolonged into a series of conical teeth which matched with those of the maxillaries, and between this series of relatively small teeth and the upturned extremity of the mandible, a single large triangular tooth was formed by the prolonged jaw tissue. The articular extremity of the mandible, which was probably cartilaginous, and was spliced on to the dentary bone, has not yet been discovered. The union between the mandibles at the symphysis was apparently very slight, as the approximated surfaces are smooth, and the jaws are always found disconnected. The tissue of those portions of the mandibles, maxillaries and premaxillaries which served the purposes of teeth, is exceedingly dense, resembling enamel in this respect. The surfaces are also smooth and highly polished. Along the inner face of the triangular tooth formed by the upturned end of the mandible, in some species, a single line of pitted tubercles form an evident and even striking ornamentation. A similar row of tubercles is seen on the outer surface of some of the great premaxillary teeth, as shown in Plate 31, Figs. 1 and 2.

The external surface of the cranial bones and mandibles shows a peculiar, fine, vermicular or reticulated marking, quite different from that of the surface bones in the allied genera. The cranial surface is also seen to be marked with a series of narrow, simple furrows, which form an ichthyic arabesque that has no relation to the sutures which unite the cranial plates.

The body of *Dinichthys* would seem to have been protected by plates which formed a carapace, as in *Coccosteus, Pterichthys* and *Asterolepis*. Not all the plates composing this armor have yet been found, but we have enough of them to know that it enclosed the body less completely than in *Pterichthys* and *Coccosteus,* but more so than in *Asterolepis* and *Heterostius*. The plates which protected the under side of the body were large, but relatively thin, and were perhaps partly covered with integument, as they show little of the peculiar vermicular ornamentation of the upper surface. The plates of the back were very large and thick, and must have covered all the vital parts of the body. Of these, the dorso-median shield, which occupied the middle portion of the back, was sometimes fully two feet in length and breadth. In outline it approaches the same bone in *Asterolepis,* but is fully twice as large. It bears on its

under surface a strong median crest which in its highest portion projects more than four inches from the concave arch of the plate. It is also prolonged into a neck-like extremity, which extends several inches beyond the outline of the dorsal shield. The form of this remarkable bone will be best understood by reference to the figures on Plate 32, of which the largest is one-fourth, the others one-eighth natural size, linear.

On either side of the dorso-median shield was located a large and flat Supra-scapular (*os articulare corporis* of Pander). These bones had in *Dinichthys* much the same form and position as in *Coccosteus*, though very much larger, as will be seen by a comparison of the figures now published (Plate 34, Figs. 1 and 2) with those given by Pander (*Ueber die Placodermen des Devonischen Systems,* Taf. 3, Figs. 10*a* and 10*b,* Taf. 7, Figs. 2*b* and 2*b*'). As in *Coccosteus,* this bone has a strong and prominent condyle which moved in a socket in the plate which formed the posterior lateral angle of the cranium (*os articulare capitis* of Pander), Plate 34, Figs. 3, 3*a,* 3*b* and 4.

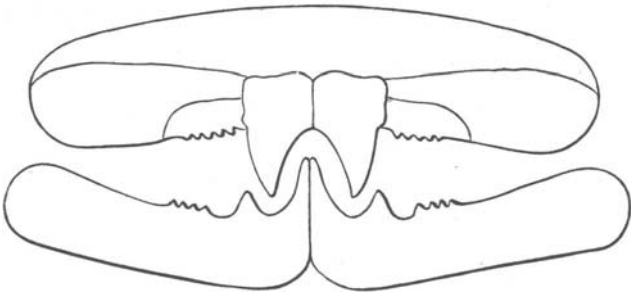
No scales have yet been found with the remains of *Dinichthys;* and from their absence we may infer that, as in *Coccosteus,* the posterior portion of the body was covered simply with a tough skin. We are unable to say, from any evidence yet before us, what the form of the body was; whether it was short and massive, as in *Pterichthys* and *Coccosteus,* or more elongated, as in *Asterolepis* and *Heterostius*. We may infer, however, from its affinities, which are closer with *Coccosteus* than with *Asterolepis,* that the body was relatively short and massive. We know that it could not have been less than 2½ to 3 feet in diameter, but it is impossible to say whether the fish was 10 or 15 feet in length, and we do not yet know what was the number and form of the fins.

Though presenting some striking peculiarities, the structure of *Dinichthys* exhibits so many points of resemblance to that of the group of Placoderms already described—*Asterolepis, Coccosteus,* etc.—that there can be no doubt that it was a member of this order, and apparently the most gigantic of all. The dental apparatus of *Dinichthys* is its most remarkable feature, and at first sight it would seem entirely without parallel among living or fossil fishes. The huge triangular teeth formed by the modified premaxillaries are certainly very different from the teeth borne by any other member of the Placoderm group, and yet they are not very unlike the dental plates of the *Chimæroids,* and are less heteroclite than the dentition of some modern fishes, as, for instance, that of *Scarus.*

Among the old Devonian fishes the dentition was scarcely less varied than in those of the present day; and in those which have been obtained from the Devonian rocks of Ohio, and are described in this report, there

are some of the most extraordinary modifications of dentition known. For example, *Macropetalichthys* was probably, like the Sturgeon, edentulous. *Onychodus* carried a crest of relatively large teeth upon an arch of bone set between the extremities of the mandibles. These teeth seem not to have matched with any in the upper jaw. The teeth of *Rhynchodus* form a parrot-like beak, as do those of *Chimæra*, one species having teeth with sharp edges which played upon each other like the blades of shears. In another the heavy semicircular teeth, four to five inches in diameter, were fitted for crushing rather than cutting. In *Dinichthys* the massive jaws are themselves transformed into teeth more singular in their structure, and more formidable than those of any living fish. Although so peculiar, the dentition of *Dinichthys* is not so different from that of *Coccosteus* and *Pterichthys* as might at first sight appear. In all these we have the same consolidated, spatulate mandible, with a series of anchylosed teeth occupying the middle of its upper margin. These teeth are formed by the condensation and prolongation of the tissue of the jaw, while in many fishes the teeth are implanted in sockets, or have a ligamentous attachment to a cartilaginous support.

In the accompanying diagram I have attempted to give a plan of the dentition of *Dinichthys*.



DENTITION OF DINICHTHYS, ONE-TWELFTH NATURAL SIZE, LINEAR.

It will be understood that in this figure the jaws are represented as spread so as to be fully seen from the front. In life the posterior ends of the mandibles were brought so near together that their form could not be distinctly seen in a front view. To obtain a just idea of the formidable nature of this dentition, it should be remembered that each of the mandibles is *two feet* in length.

DINICHTHYS HERTZERI (n. sp.).

Plates 30 to 34.

As the remains of this great fish have served as a basis for the generic description of *Dinichthys*, they have already been so fully described that

little more is required to give a clear idea of its size and structure. The bones of *Dinichthys* collected at Delaware, Monroeville and Sheffield, have been provisionally referred to *D. Hertzeri*, but it is by no means certain that all should be referred to one species, as they show differences in structure which indicate sexual or other varieties, or distinct species. These points of difference will best appear in the detailed descriptions of the different bones.

Cranium. The form of the posterior portion of the cranium is well shown in the two figures given on Plate 33. Of these, one represents the outside, the other gives an inside view of a specimen obtained from the Huron shale, in Sheffield, Lorain County, by Mr. J. Terrell. Another cranium, found by Mr. A. W. Wheat at the same locality, presents essentially the same features, though on a larger scale, inasmuch as the diameter of the posterior portion of the larger cranium is 24 inches, of the smaller, 16 inches. It will be seen, by reference to the figures, that the various plates which compose the skull in *Dinichthys* are firmly soldered together, so that their outlines cannot be fully and accurately determined. The posterior margin of the cranium is formed by the representatives of the Supra-occipital, the Squamosal and Epiotic plates. These coalesce to form a massive arch which presents in some portions a thickness of over three inches of solid bone. The posterior margin of the Supra-occipital, which forms the summit of the crescent of the posterior outline of the skull, shows almost precisely the form and structure of the corresponding bone in *Heterostius*, viz., in the crown of the arch is seen a pyramidal tubercle projecting posteriorly, while immediately anterior to this, and not well shown in the figure, is a deep pit, which is sometimes single in *Dinichthys,* but oftener is composed of two depressions, as in *Heterostius, Asterotepis* and *Coccosteus.* The posterior lateral angles of the head are formed by the articular margin of the Epiotic (*os articulare capitis*), better shown on Plate 34, Figs, 3, 3*a*, 3*b* and 4, than in the general view, Plate 33. The projecting point shown in all these figures is a rest or guard which strengthened the articulation. The joint itself is formed by a deep cylindrical socket, into which fits the condyle of the Supra-scapular in such a way as to form one of the strongest and most complete articulations in the whole animal kingdom. In the specimen figured on Plate 33, only the posterior and central portions of the cranium are shown. The bones of the anterior and lateral portions seem to have been united by cartilaginous attachments, so that they are generally disconnected. Two very massive; somewhat triangular bones were found by Mr. Wheat occupying the position of the bones numbered F. in Hugh Miller's diagram, and called by him Posterior-frontals. Of

these, the under sides are roughened and deeply pitted, apparently to afford firm bases for the great premaxillary teeth.

In one specimen discovered by Mr. Hertzer the entire cranium was present, and not very much distorted. This afforded very precious information regarding the aspects and structure of the anterior portion of the head. Unfortunately, the upper surface was so firmly attached to the rock that the plates were considerably exfoliated in its removal. The maxillaries are, however, seen in position, and the premaxillary teeth holding their proper place, with the exception that one is somewhat twisted laterally. Under the cranium, in this specimen, the mandibles were found lying together, and though detached, their ends were pointing up between the premaxillaries. The position of the bones in this head has revealed to us all the generalities of the structure of the jaws and teeth in *Dinichthys,* and forms the basis of the restoration given in the diagram on a preceding page.

Mandibles. The form and structure of the mandibles have been given in a general way in the generic description. To that I would add, however, that the polished and ornamented interior faces of the triangular tooth formed by the upturned end of the mandible seem to me to render it at least probable that, instead of uniting to form *one* tooth, the pointed extremities of the mandibles were slightly divergent, so as to form *two* teeth; both of which, however, passed between the extremities of the premaxillaries in the closure of the mouth. Among the mandibles found at Delaware, I have noticed an interesting difference of form. In some—like that figured on Plate 30—a conspicuous triangular point or tooth is raised between the anterior extremity and the series of small teeth set near the middle of the dentary bone. In other specimens this seems to be entirely wanting; a variation which may, however, be only dependent on age or sex. The smaller teeth, to which I have referred, are represented, natural size, on Plate 31 (Fig. 3.)

Premaxillary teeth. From the center of a concretion found at Delaware was taken the absolutely perfect tooth figured, natural size, on Plate 31. It will be seen that the outline of this tooth is triangular, that it occupied the anterior lateral angle of the muzzle and arched around from the front to the side. Above, it is broadly expanded, flattened, and more or less rough, for co-adaptation with the associated bones. Below, it is composed of dense and polished tissue, which indicates great hardness and strength in this portion of the tooth. From its size, form, and jet-black color, as it lay partially exposed in the rock, it suggested the half of the hoof of the elk or moose. This tooth has evidently seen much service, for the shoulder which it presents on Plate 31, Fig. 1, is evidently, for the most

part, made by co ntact with the tu bercle or s ubordinate tooth of the mandible. A tooth found by Prof. Allen, on the Lake shore at Sheffield, and which evi dently corresponds to that now figured, shows a remarkable deviation from it in form. With equal or greater length, it is scarcely more than half as wide; and, instead of terminating above in a squamosal margin, shows here a massive ovoid tuberosity, such as has evidently been impacted in some cavity of the cranial bones. This tooth is also without the ornamentation formed by the line of tubercles shown in the figure. These differences are s o marked that it would not be surprising if it proved that we had here the rem ains of two distinct species. Additional material, illustrative of the structure of *Dinichthys,* will doubtless be obtained before the completion of the Geol ogical Survey, and when another volume shall be published we may have t he means of definitely settling this question.

Dorsal Shields. Of the plate-armor which enclosed the central portion of the body of *Dinichthys,* the most interesting portions are figured on Plates 32 and 34, and have been already described. The dorso-median shield is sufficiently well shown in the figures now published, to enable anyone to form a clear i dea of its structure. They will very likely, however, fail to get from the reduced figures an adequate appreciation of its magnitude, and realize that it is more than two feet in diameter in both directions. Those who have access to the monograph of Prof. Pander on the Placoderm fishes of Russia, wil l see that the dorsal shield o f *Dinichthys* presents considerable resemblance to th ose of both *Asterolepis* and *Heterostius,* and yet is sufficiently distinct from both. In general outline it more closely resembles the dorsal plate of *Asterolepis,* while in the neck-like projection of the inferior crest, it is much more like that of *Heterostius.* In its fine, inconspicuous ornamentation, its outer surface differs widely from the tuberculated exterior of the bones of all its congeners, *Heterostius, Asterolepis, Coccosteus,* etc.

Supra-scapular. The Supra-scapular of *Dinichthys* (*os articulare corporis* of Pander) is represented in our collections by a number of more or less complete specimens. From these we learn that it was so mewhat oblong or rudely triangular in outline, terminating on either margin with broad, squamosal surfaces, where it was overlapped by other plates. Its anterior margin bears a remarkably formed articular condyle, which is a wonder of adap tation. It was so inserted into t he socket of the *os articulare capitis* as to form a strong and perfect joint—one which gave considerable motion to the parts j oined, and yet that locked them together so firmly that they could not be separated without the fracture of either the condyle or socket, both of which were very strong.

Our first knowledge of *Dinichthys Hertzeri* we owe to the industry and acuteness of observation of Rev. H. Hertzer, a clergyman stationed for two years at Delaware, Ohio; and who, while performing his ministerial duties, and receiving a very small salary, still found time to make many important collections and observations in geology. The town of Delaware is located upon the line of junction of the Huron shale and the Hamilton and Corniferous limestones. The Corniferous abounds in fossils, and Mr. Hertzer collected a splendid suite of the ichthyolites which characterize this formation; but the Huron shale had, up to this time, been regarded by all geologists as barren ground—nothing but a few *Lingulæ* and *Discinæ* having been obtained from it. Near its base the Black shale contains, both at Delaware and elsewhere, a great number of concretions composed of impure limestone. These are often quite spherical, and ten feet or more in diameter. In examining some of these septaria which had been split, apparently by the frost, Mr. Hertzer discovered that they not unfrequently contained masses of silicified wood (*Dadoxylon Newberryi*, Dawson,) or fragments of bones that had served as nuclei around which they had formed. Of these bones several were taken by Mr. Hertzer to the meeting of the American Association at Buffalo, in 1866. There they were submitted to me, and I recognized them as the bones of huge Ganoid fishes, altogether new to science. With enthusiasm fired anew by the interest these specimens excited, Mr. Hertzer devoted all the time possible to further examinations of the concretions which contained them. The results of his efforts were communicated to me from time to time, in letters, in which each of the discoveries that resulted in the almost complete restoration of the head of *Dinichthys* is graphically described. The rock which contains these fossils is one of the toughest and most intractable known, and Mr. Hertzer deserves great credit for the care and skill with which hundreds of fragments were carefully gathered, and each cemented in its proper place. In one of these concretions Mr. Hertzer found a head of *Dinichthys,* of which the component parts, though somewhat dislocated, were all present. In another was a complete mandible, and in still another, one of the great teeth of the upper jaw. Though much broken, both of these latter specimens were restored by Mr. Hertzer nearly to their former integrity, and they now constitute the pride of the collection of the School of Mines of Columbia College.

The specimens which occur in the cliffs on the Lake shore at Sheffield, Lorain County, are not found in concretions, but simply imbedded in the shale. Generally a thin coating of "cone-in-cone" covers all their surfaces; and doubtless if there had been more lime in the carbonaceous

mud which now forms the Huron shale, the bones would have been more completely enveloped with calcareous material. From the circumstances in which they occur, the bones found at Sheffield are much more easily detached from their matrix than those which are included in the concretions at Delaware and Monroeville; hence we must look to the former locality for the most numerous and satisfactory specimens of this gigantic fish. At Sheffield the cliff is constantly worn away by the waves, and the fragments of bone may from time to time be noticed projecting from the weathered face. These fragments attracted the attention of Mr. Terrell some years since, and we now owe to his intelligent interest in them some of the most complete and instructive specimens known.*

In consequence of the compression suffered by the shale from the weight of the overlying rock, the Sheffield specimens are found very much crushed and broken. Great care is therefore necessary in getting them out, freeing the fragments from their calcareous crust, and reuniting them each in its proper place. Much patience and skill has been expended by Mr. Wheat in the restoration of the specimens obtained by him at Sheffield. All the more important ones have passed through his hands, and they owe much of their completeness and symmetry to his care and skill. It is a somewhat remarkable fact that among some hundreds of fragments of the bones of *Dinichthys* obtained at Sheffield, only a single premaxillary tooth has yet been discovered, and no portion of the maxillaries or mandibles. We are therefore wanting in materials for comparing satisfactorily these specimens with those obtained at Delaware. The difference in form of the great tooth obtained by Prof. Allen at Sheffield, from those collected at Delaware by Mr. Hertzer, has been remarked upon, and it will not be surprising if two

* I regret to be compelled to report that, since the above paragraph was written, the finest specimens discovered by Mr. Terrell, and those represented on Plates 32 and 33, have been destroyed by the fire which consumed Ely's block, in Elyria. It is to be hoped that this sad misfortune will prompt those who may hereafter secure fine and unique specimens illustrating our palæontology, to place them at once in some repository where they will be safe from the all-devouring element; for it seems that fate has decreed that, without such a precaution, their destruction is simply a question of time.

Another suggestion is scarcely of less practical importance, and that is, that all remarkably fine specimens should be carefully photographed as soon as convenient after their discovery. We may congratulate ourselves that Mr. Terrell's thoughtfulness in this respect has saved his specimens from being utterly lost to science; for the photographs which he had taken have supplied the material for the plates to which I have referred, and have thus made the more important features of his specimens immortal.

or more species of *Dinichthys* should be found to be represented in the two localities. This probability is somewhat strengthened by the fact that the bones obtained at Sheffield are from the extreme upper layers of the Huron shale, while the Delaware specimens are from th e base of th e formation.*

Sections of the bones and teeth of *Dinichthys* have been made by Mr. John E. Gavitt, of New Y ork. These, when examined under the m icroscope, reveal some interesting and instructive phases of bone tissue. It has not been possible, ho wever, to have figures made from these sections in time for introduction into this vo lume, but it is h oped that they will be illustrated in the future publications of the Geological Survey.

GENUS ASPIDICHTHYS (n. gen.).

A Placoderm fish of la rge size, ha ving a carapace composed of massive, bony plates, of which the mid dle plate of the back—"dorso-median"—is similar in form to that of *Pterichthys,* but many times larger, and is covered with large, hem ispherical, smooth, enameled tubercles.

Up to the present time one entire dorso-median plate and a few fragments of others are all th at we have o btained of this remarkable fish. When other portions of his plate armor shall be found, t hey will probably be seen to correspond most nearly with that of *Pterichthys.* The tuberculation of the surfa ce is, however, very different from that of *Pterichthys,* and, as the dermal ornam entation is very characteristic in these old fishes, it is undoubtedly indicative of differences which have generic value.

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* Since the above description was written, a mandible of *Dinichthys* has been obtained from the summit of the Huron shale, at Sheffield, Lorain County, by Prof. A. A. Wright, which gives us some new light on the dentition of this remarkable fish. This mandible is smaller than those from Delaware, being only eighteen inches long, and shows several points of difference in form; but its most striking feature is a sharp cutting edge along the anterior third of its length—an edge formed by the friction upon it of the maxillary and premaxillary which shut over it, their edges playing upon its edge precisely as scissor blades play on each other. In this specimen the denticles seen on the upper margin of the mandible now figured (Plate 30) are obsolete, the margin of the jaw being raised into a thin edge, evidently for cutting only.

These specimens will be fully described and figured in another volume of our Report. They will doubtless form a second species of the genus, for which I propose the name of *Dinichthys Terrelli*, to comme morate the zeal and intelligence shown by Mr. Jay Terrell in the collection of this interesting fossil at Sheffield, Lorain County Ohio.

By Pander, *Pterichthys*—of Agassiz and Hugh Miller—is called *Asterolepis,* as he identifies it with *Asterolepis* of Eichwald. But Eichwald's description and name were based on a fragment so uncharacteristic that it is quite impossible to be certain what it is; while the names *Asterolepis* and *Pterichthys* have been so thoroughly identified with the fishes to which Agassiz and Hugh Miller assigned them, that it would produce great confusion to attempt to change them. Pander called *Asterolepis* of Agassiz *Homostius,* but his example has not been followed by others.

ASPIDICHTHYS CLAVATUS (n. sp.).

Plate 35, Figs. 1 and 2.

Of this huge and remarkable fish very little is known, as only some portions of the dorsal plates have yet been found. These are, however, so peculiar and so different from anything else known to palæontologists that they will serve to identify unmistakably one of the largest and most singular of the great Placoderm fishes that inhabited the Devonian seas.

The most significant fragment of *Aspidichthys* yet discovered is a nearly entire median dorsal plate, obtained by Mr. Hertzer from the Huron shale at Delaware, Ohio. This plate is an elongated hexagon, or short, coffin-shaped, having, indeed, almost exactly the form of the dorso-median plate of *Pterichthys,* but a hundred times as large; for, while the largest plate of *Pterichthys* is 12 by 18 lines in dimension, the corresponding plate of *Aspidichthys* is as many inches in each direction, or, more exactly, is 13 by 17 inches, and a portion of it is wanting. It is more than an inch in thickness in the central portion, and is keeled below as is the same plate in *Dinichthys* and *Asterolepis.* The most striking feature in this plate is, however, its external ornamentation. This consists of knobs or bosses of smooth, shining enamel, of the size and form of split peas.

In its general aspect this tuberculation resembles that of *Pterichthys* and *Coccosteus,* but differs strikingly in this, that the tubercles are perfectly smooth and polished, and show nothing of the stellate ornamentation which is to be seen on the plates of nearly all the great mailed fishes of the Old World. This character has, doubtless, generic value, but the form of the dorso-median plate is so nearly that of the same plate in *Pterichthys Milleri,* that, if it were not for this peculiar tuberculation, we might conclude that we had in this fish nothing more than a huge monster of a *Pterichthys.*

The margins of the plate under consideration are beveled oft and

straightened in such a way as to prove that it articulated with others, and there is no reason to doubt that it formed part of a carapace similar to that of *Pterichthys*.

Plate 35, Fig. 1, represents the dorso-median plate of *Aspidichthys*, very much reduced; Fig. 2, a portion of the same, natural size.

Formation and Locality: Huron Shale; Delaware, Ohio.

DESCRIPTIONS OF

FISHES OF THE CARBONIFEROUS SYSTEM.

ELASMOBRANCHII.

SQUALI.

GENUS CTENACANTHUS, Agass.

Fin-spines of moderate or large size, compressed, gradually tapering, moderately arched backwards; anterior face narrow, rounded; posterior face concave, with a modera te cavity, the lateral edges bordered by two rows of curved denticles, inclining downwards; exposed surface marked with strong, longitudinal ridges and furrows, pectinated by transverse ridges, scales or tubercles; base of moderate size, rapidly tapering, finely striated or roughened.

Defensive spines belonging to this genus are, perhaps, more widely distributed than any others known. Numerous species have been found in the Old World and the New. Most of these have been obtained from the Carboniferous rocks, and it is evident that the fullest development of the family of sharks which bore these spines took place in the Carboniferous age. But several species are now known which were obtained from Devonian strata, and of these, by far the finest, *Ct. vetustus,* is figured and described in this volume. Barrande carries the date of the beginning of *Ctenacanthus* much farther back, as he describes a species (*Ct. Bohemicus*) which occurs in the Upper Silurian and Lower Devonian strata. There is, however, some question whether this species should be included in the genus *Ctenacanthus.* It is not yet cer tainly known w hat teeth were associated with the spines of *Ctenacanthus,* but there is little doubt that they have been described under different names. From the association of teeth of *Orodus* and spines of *Ctenacanthus* in the Waverly Shale at Vanceburg, Ky., I have been led to suppose that they were originally parts of the same fi sh. We may confidently expect, however, that in th e formation and locality where the specimens to which I allude were

obtained, we shall before long procure material that will enable us to settle this question, just as a similar question has been set at rest in regard to the relationship of the teeth and spines of *Hybodus* and *Acrodus* in the Jurassic.

Another inquiry is suggested by the results of the study of the Jurassic sharks, and that is, whether there were one or two spines on the back of *Ctenacanthus*. It has been proved that in *Hybodus* there were two, differing somewhat in form and markings. These questions will be referred to again in the descriptions, to be published in another volume, of *Orodus variabilis* and *Ctenacanthus furcicarinatus* found at Vanceburg, Ky.

Ctenacanthus is exclusively Palæozoic in its range, and the sharks which bore these spines must have been sometimes of formidable dimensions. Some specimens of *Ct. major*, from the Coal Measures of England, are considerably more than a foot in length, and very strong. A specimen of *Ct. formosus*, Newb., found in the Waverly, at Warren, Ohio, is fourteen inches in length. This will be figured in another volume of this Report.

CTENACANTHUS VETUSTUS (n. sp.).

Plate 35, Figs. 3, 3*a*, 3*b*, 3*c*, 3*d*.

Spine of medium size—6 to 8 inches long—robust, gently arched backward, rapidly tapering to the point; buried portion conical, nearly smooth; exposed portion ornamented with 16 or more nearly equal ridges—those on the sides for the most part simple, but sometimes forked at base and nearly smooth; those on the anterior margin pectinated so strongly as to afford a marked specific character; section conical; posterior surface flattened, with a strong, rounded, longitudinal mesial ridge; medullary cavity small, opening backward at the base of the ornamented portion.

This beautiful spine is the first well marked species of *Ctenacanthus* found in the Devonian rocks of Ohio. Its most striking peculiarity is the smoothness of the lateral carinæ and the strong pectination of the anterior margin.

Formation and locality: The specimen on which this description is based, was obtained from the Huron shale at Avon Point, Lorain County, by Mr. J. W. Hulbert, of Elyria, to whom I owe the opportunity of describing it.

CTENACANTHUS MARSHI (n. sp.).

Plate 36, Figs. 3, 3*a*, 3*b*.

Spine short and robust, much compressed, broad at base, rapidly tapering to a sub-acute point; anterior margin straight or gently arched;

posterior border very oblique; buried base broader than superior portion, rounded below, laterally flattened, finely striated; pulp cavity very broad, opening posteriorly below the ornamented portion; line of demarcation between plain and ornamented surfaces curved; exposed portion of spine much flattened below, more rounded above; anterior margin acute; posterior face concave, forming a broad longitudinal groove, on the margins of which are set a few tubercular denticles; lateral surfaces marked with relatively few, strong, nearly plain, enameled ridges, those near anterior border strongest and most continuous, nearly straight, and parallel with the margin; toward the posterior edge they are shorter, more numerous and oblique; the summits of these ridges in places faintly beaded, but no where pectinated; width of spine at base, 18 lines; length, 7 inches; thickness, 7 lines.

Two specimens of this spine are before me, one of which I owe to the kindness of Col. J. W. Foster, of Chicago, the other to Prof. O. C. Marsh, of Yale College. Both want the superior extremity, but show the middle and basal portions nearly equally well. They indicate a short, robust, compressed and strongly carinated species, very unlike any other yet found in America.

In the general character of the surface markings, these spines closely resemble those figured and described by Agassiz under the name of *Ctenacanthus major*; and they agree also with Agassiz's description so far as regards the ornamentation, but not in regard to form or the "acute posterior margin" —the latter being a most anomalous feature in the spines of *Ctenacanthus,* all of which, so far as I know, have a flattened posterior surface. The spines under consideration are much shorter and relatively thicker than those of *Ctenacanthus major,* and are also distinguished from those described by Prof. Agassiz, by the obliquity of the short ridges which cover the posterior half of the sides near the base.

It is possible, however, that both the specimens which have come into my hands are from the posterior dorsal fins, where the spines (if there were two in *Ctenacanthus*) would almost necessarily be shorter than those of the first dorsal. This is strikingly true of the spines of *Hybodus* and *Acrodus*, as shown by Mr. Day in his paper published in the first volume of the Geological Magazine; and if I am correct in the suggestion I have made, that the spines forming the genus *Ctenacanthus* belonged with the teeth known as *Orodus,* there was a close relation between these genera, *Orodus* and *Ctenacanthus* forming the Carboniferous representatives of the Jurassic *Acrodus.*

I have some large and massive spines from the Coal Measures of Scotland, which, with nearly identical surface markings, are twice as long

as these, and they have the posterior margins, not acute, as Prof. Agassiz represents his specimens of *Ctenacanthus major*, but broadly concave, as in the specimens before us. These spines come to me as those of *Ctenacanthus major,* and suggest the probability that Prof. Agassiz was misled by the imperfect exposure of the specimen he figures, and that if this were properly developed it would show a flattened, striated posterior surface, as do the other species of the genus.

If Prof. Agassiz is correct in representing the section of *Ctenacanthus major* as lenticular, and both margins acute, our specimens must be considered distinct. If, however, his description is erroneous, and the spines of *Ctenacanthus major* are posteriorly flattened, we have no well marked characters with which to distinguish our specimens from the European, except the smaller size and more robust figure of ours. It is possible, as has been remarked, that this striking difference may depend on the different positions of the spines, and that all the European specimens of which I have any knowledge are anterior, and that both our specimens are posterior dorsals; but this is hardly probable. Until such time, therefore, as we shall have obtained more material bearing on the question, we shall be compelled to consider our Zanesville spines as representing a new species. To this species I have given the name of Prof. O. C. Marsh, of Yale College, who has kindly loaned to me for examination the best specimen yet found.

Among the *Ctenacanthus* spines described abroad, there are none so short and thick as these, unless it be those of *Ctenacanthus tenuistriatus*, Ag., in which the carinations are much finer and more numerous.

Formation and locality: Coal Measures, near Zanesville, Ohio.

CTENACANTHUS FORMOSUS (n. sp.).

Plate 36, Figs. 2, 2*a*, 2*b*.

Spine very long (14 inches), slender, curved, broadest at base (1 inch), narrowing to a long acute point; much compressed laterally; basal portion relatively short, rounded below, flattened laterally, surface covered with a fine, longitudinal striation; exposed portion marked with numerous, sharp, continuous, pectinated carinæ (about 25 at base, 15 in the middle), those occupying the middle portion of each side being finest; posterior face flattened and slightly concave, the angle on either side set with small, crowded, hooked denticles; pulp cavity relatively small, opening to posterior surface at the junction of the ornamentation with the base.

The size of this spine, its graceful curve, and elegant ornamentation, combine to render it the most beautiful of all the species known to me of the genus. The basal portion is unusually short, broad and compressed. The angle formed by the line of junction of the ornamented and plain surfaces with the axis of the spine is of about 45°. The enameled ridges on the sides are more numerous, sharper, and more continuous than in any other known species. These characters, with its compressed section and curvature, will serve to identify it at a glance.

Formation and locality: This species of *Ctenacanthus* is a characteristic fossil of the Waverly. I have fine specimens obtained from the Cuyahoga Shale by M. C. Read, at Warren, Trumbull County; from the Berea Grit, at Chagrin Falls, by C. T. Blakesley, Esq.; and from the "Waverly Black Shale," at Vanceburg, Kentucky, by Capt. Patterson.

CTENACANTHUS TRIANGULARIS (n. sp.).

Plate 36, Figs. 1, 1*a*, 1*b*.

Spine of medium or small size, 4 to 6 inches in length, straight or slightly curved, robust; section triangular; pulp cavity large, opening to posterior surface above the base; basal portion broadest, oblong in outline, irregularly rounded at the extremity, marked with a fine, longitudinal, vermicular striation; exterior portion broadest below, tapering regularly to the triangular point; lateral faces marked at the base with about twelve longitudinal, pectinated carinæ, which are largest near the anterior margin, and diminish in number and strength toward the nearly smooth summit; posterior face flattened or slightly concave, with an obscure ridge along the median line, the whole covered with fine vermicular, longitudinal markings; the posterior angles of the upper half of the spine set with hooked denticles.

The section of this spine—nearly an equilateral triangle—is its most striking feature. It is also more nearly straight than any other species with which I am acquainted.

More than two dozen of these spines were found by Mr. G. K. Gilbert on a slab of sandstone detached from a cliff below the Conglomerate on the banks of Oil Creek. They were mingled with the impressions of many large, flattened and rounded teeth, most of which had been replaced by carbonate of iron, and had lost all definiteness of form and markings. Such a concentration of spines and teeth of Selachians I have nowhere seen; and we may hope that the same bed will hereafter furnish some material of great palæontological interest. It is to be re-

gretted that the teeth which accompany the spines are not better preserved, as they would give us important light on the affinities of at least one of the fishes of which the spines are grouped in the genus *Ctenacanthus*. The obscure impressions left by the teeth indicate a dental series unlike any hitherto known; and if, as seems probable, they belonged to the same fishes that bore the spines, they prove that the genus *Ctenacanthus* includes fishes very different, if not generically distinct.

One of these teeth has somewhat the form of those of *Acrodus*, and might be considered as the tooth of *Orodus*; but the others are more like those of *Psammodus*.

Formation and locality: Waverly group; Oil Creek, Pennsylvania.

GENUS GYRACANTHUS, Agass.

Defensive spines of large Selachians, found not unfrequently in the Coal Measures of Europe, and first described by Prof. Agassiz in his "*Poissons Fossiles*." They are usually straight, and are marked by oblique ridges, which converge ascending, and meet on the anterior margin. These ridges are often broken into tubercles which form a rasp-like surface. Two fine species are described by Prof. Dawson—*G. duplicatus*, D., and *G. magnificus*, D. (Acadian Geology, p. 210, figs. 55 and 55*a*)—from the Coal Measures of Nova Scotia. Of these, one is 22 inches long. The dentition of the sharks which bore these spines is unknown.

GYRACANTHUS COMPRESSUS (n. sp.).

Plate 37, Figs. 1, 1*a*, 1*b*, 2, 2*a*, 2*b*.

Spines of large size—12 inches or more in length, 1¼ inches in greatest diameter—laterally much compressed; anterior margin sub-acute; posterior flattened; ornamented portion covered with very numerous, fine, oblique, parallel, pectinated or beaded ridges.

This species of *Gyracanthus* is associated with *G. Alleni*, but is very distinct from that. Its most striking and characteristic features are its flattened, compressed section, and the fine, somewhat reticulated, oblique carination, which covers *all the exposed portion*. *G. Alleni* is more slender, is much more nearly cylindrical, and the oblique ornamentation of the sides is much coarser and is limited to a smaller portion of the surface than in *G. compressus*.

From the foreign species *G. formosus* and *G. tuberculatus* of Agassiz-

probably only varieties of one species—*G. compressus* will be at once distinguished by its flattened section and much finer markings.

Formation and locality: Cuyahoga Shale, Medina, Ohio; and from the Drift (doubtless Waverly), Dearborn County, Indiana.

GYRACANTHUS ALLENI (n. sp.).

Plate 37, Figs. 3, 3*a*, 3*b*, 3*c*, 3*d*.

Spine 6 to 8 inches long, straight, cylindrical below, compressed laterally above; basal portion conical, finely striated longitudinally; line of insertion very oblique, 12°-15°; posterior canal reaching to middle of spine; half of basal portion of exposed surface highly ornamented with oblique, parallel lines of tubercles, which converge and meet on the anterior border; above, these lines of tubercles coalesce, and near the summit form beaded ridges which cover the entire lateral surfaces; posterior half of lateral faces below and posterior face above nearly smooth, but showing fine, oblique striations.

These spines are smaller and straighter than the European species, but exhibit the same generic characters. The distinguishing peculiarity of our species is the great breadth of the nearly smooth posterior belt. In the Old World species this smooth space is altogether posterior, and does not reach the summit of the spine. In our species it occupies half the circumference below, and, gradually narrowing, apparently reaches the summit as a smooth, posterior face.

These specimens are of special interest as being the first of the genus found in the United States; and since *Gyracanthus* is found exclusively in the Coal Measures abroad, they give a decided Carboniferous character to the rock in which they occur.

This species is named in honor of Prof. G. N. Allen, of Oberlin, Ohio, who first met with it. The type specimen is in his cabinet.

Formation and Locality: Cuyahoga Shale (Waverly); Bagdad, and Lodi, Medina County, Ohio.

GENUS COMPSACANTHUS, Newb.

Spines of small size, gently curved backward; exposed portion smooth and polished; section at all points circular; a single row of relatively large, remote, depressed hooks set along the posterior median line.

The spines of this genus will be at once recognized and distinguished from all others known by the *single* row of large hooks which they bear along the posterior median line.

COMPSACANTHUS LÆVIS, Newb.

Plate 40, Figs. 5, 5*a*.

Compsacanthus lævis, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Spines small, 3 to 4 inches in length, slender, curved, acuminate, smooth, having a circular section at all points; upper two-thirds furnished with a single row of relatively large, depressed, acuminate hooks, set along the median line of posterior surface, diminishing in size to the summit.

Of this neat little defensive spine quite a number of specimens have been found at Linton, though it is not known to occur in any other locality. The figure now given represents the superior two-thirds of one of these, of the natural size. The basal extremity has not yet been distinctly seen, but it apparently extends considerably below the hooks, and its surface is nearly or quite smooth.

GENUS ORTHACANTHUS, Agass.

ORTHACANTHUS ARCUATUS, Newb.

Plate 40, Fig. 4.

Pleuracanthus arcuatus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Spines 3 to 6 inches in length, 3 to 5 lines in diameter at base, base, gently curved backward, tapering to an acute point; anterior surface rounded, finely striated longitudinally; posterior face flattened, or raised into a low ridge along the median line. This flattened surface occupies about one-third of the circumference, and at the angle formed by the junction of the lateral surfaces with this is, on each side, a row of closely set, acuminate, depressed hooks.

Spines similar to that described above are not uncommon in the cannel coal at Linton, Ohio. They seem to be composed of dense, bony tissue, have a nearly circular section, and show, in the center, traces of a medullary cavity which reaches two-thirds of the way from base to point. At the basal end the opening is apparently terminal. In all essential particulars these spines show a great resemblance to that figured by Agassiz (*Poissons Fossiles,* Vol. 3, Atlas, Tab. 45, Figs. 8, 9), under the name of *Orthacanthus cylindricus.* The specimen so named by Agassiz is not described, but is simply referred to in the text (Vol. 3, p. 330). It is

much larger than any found in Ohio; the two rows of denticles on the posterior face are much more closely approximated than they are in our fossils, and the spine is straight, while ours are gently curved. The latter character exhibited by the specimen in the hands of Prof. Agassiz suggested the name given to it, and there is a certain discrepancy in referring a curved spine to the genus *Orthacanthus*; but the resemblance in the general structure exhibited by the specimens from Linton and that figured by Prof. Agassiz is so close that it seems to me plain they should be united in one genus. If they are generically identical, it simply proves that the discovery of new material has thrown some additional light on the characteristics of the genus, and has shown that the generic name was not fortunately chosen. Among the many spines found at Linton, which are at least generically identical with the one now described, are several which, when they sunk to the bottom of the water inhabited by the fishes which bore them, chanced to fall with the posterior face turned either directly down or up. In such cases, by the vertical pressure to which they have been subjected in the consolidation of the cannel coal, they have been rendered nearly straight; and as the specimen figured by Prof. Agassiz shows many transverse fractures, it is possible that this also was once curved, and, like most dorsal spines of sharks, curved backward. Much more complete and beautiful specimens have been obtained of *O. arcuatus* since the figures now given were made, and one or more of these will be drawn for publication in another volume. In these better specimens the denticulation of the posterior face is most perfectly preserved, and is more regular and beautiful than that of any other spines with which I am acquainted.

At Linton these spines lie in the black coal, and, being coated with sulphide of iron, they have the appearance of beautifully finished and formidable metallic stilettoes. Since they were composed of the densest tissue, they must have formed very effective defensive or offensive weapons.

As we look over the remains of fishes found at Linton to see what other appendages of Selachians exist in corresponding abundance, in order, if possible, to associate them with these spines, we find none but the teeth of *Diplodus,* which, by their numbers, seem to correspond in the slightest degree. The teeth of *Diplodus* are very numerous; and as I have proof from several imperfectly preserved jaws that each fish was provided with several hundred of them, the numbers of the teeth and spines found are perhaps not disproportionate. This relationship is mentioned, not as teaching anything new, but as confirming the conclusions arrived at in the Old World by Sir Philip Egerton and Prof. Kner, viz.: that the spines

called *Orthacanthus* were worn by a Selachian of which the teeth were *Diplodus*.

I should also say that I h ave recently obtained several specimens in which the spines of *Orthacanthus arcuatus* are buried in the ill-defined mass of granular material which represents in the cannel coal the partly ossified cartilage that composed the hard parts of the head of *Diplodus*. With them are also groups of *Diplodus* teeth still attached to the jaws. These specimens not only confirm the statements made tha t *Diplodus* and *Orthacanthus* belong together, but also shows that the spines were worn on or near the head.

The specimen now figured (Pl. 40, Fi g. 4) is the middle portion of a spine of average size. It i s seen from the side, and shows one row o f denticles.

GENUS DIPLODUS, Agass.

The fish-teeth called by Agassiz *Diplodus* are not unfrequently met with in the Coal Measures of Europe and North America. Two species were described by Agassiz many years ago; *D. gibbosus* and *D. minutus* (*Poiss. Foss.*, Vol. 3, p. 204; Atlas, Vol. 3, Tab. 22*b*, Figs. 4 and 7). Two others are in dicated by Prof. Dawson (*D. acinaces* and *D. penetrans*) derived from the roof shales of the coal seams of Nova Scotia (Acadian Geology, p. 211). Three species have been described by myself (Proc. Acad. Nat. Sci., Phila., 1856), *D. latus, D. compressus* and *D. gracilis*. These were obtained from the cannel coal at Linton. Two other species were described by Mr. Worthen and myself, *D. duplicatus* and *D. incurvus*, both fro m the Keokuk limestone of Nauvoo, Ill. Fig ures and descriptions of the last-mentioned species will be found in the Report of the Geological Survey of Illinois, Vol. II., p. 60, Pl. IV. Descriptions of the two Ohio species which occur in Illinois, *D. latus* and *D. compressus*, and that of another and the most co mmon species found at Lin ton, are given below. They will be figured in another volume of our Report.

The teeth of *Diplodus* will be at once recognized, wherever found, by their peculiar form. They consist of a rounded or flattened bony base, from which spring two lateral, and sometimes a small central, denticle; the whole being not unlike a miniature representation of the horns of an ox springing from a portion of the skull. They were considered by Agassiz to be the teeth of a Plagiostomous fish, but others have regarded them as dermal spines.* This question has, however, been set at rest by Prof. Kner

* See the paper of Messrs. Hancock and Atthey, in Ann. and Mag. Nat. Hist., May, 1868.

and Sir Philip Egerton, who have shown that they formed the dentition of the sharks of which the spines have been described under the names of *Orthacanthus* and *Xenacanthus*. My own observations confirm those of the last-mentioned authors, as I have several more or less perfect jaws thickly set with the teeth of *Diplodus*. These show that each jaw bore several hundred teeth, arranged in radiating rows, the points projecting inward, precisely as in many modern sharks, and as in the extinct genus *Cladodus*.

As the spines of *Orthacanthus* found at Linton are distinct from the European species, they furnish additional evidence that our species of *Diplodus* are different from those described by Prof. Agassiz.

DIPLODUS COMPRESSUS, Newb.

Diplodus compressus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*
Diplodus compressus, N.; Geol. Surv. Ill., Vol. II., p. 60, Pl. IV., Fig. 2.

Teeth from 3 to 6 lines in length; base small; lateral denticles unequally spreading, compressed, with acute points and sharp, strongly crenulated edges; central denticle very small, acute, compressed, finely crenulated on margins.

This is by far the most common species at Linton, where it occurs literally in thousands. It may be recognized by its flattened cornua, of which the edges are salient and conspicuously crenulated. In form these teeth resemble those of *D. latus*, but they are much smaller, and have a flattened, crenulated median denticle which is wanting in that species. From *D. gracilis* they differ in their broader and more flattened cornua, but it is possible these species will be found to run into each other.

Formation and locality: Coal Measures; Linton, New Lisbon and Straitsville, Ohio.

DIPLODUS GRACILIS, Newb.

Diplodus gracilis, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Teeth varying in size from 2 to 6 lines in length; base very small; lateral denticles long, curved, slender, divergent toward the points, very slightly compressed, the crenulation of the lateral edges slight or obsolete; median denticle small, subulate, scarcely crenulate.

This is perhaps only a variety of *D. compressus*. It is, however, noticeably more slender, the cornua more rounded, and less distinctly crenulate. They are also less divergent and more curved.

We shall be able to determine the relations of these different forms, only when we shall have found jaws of *Diplodus* which carry all the dental series. On these we may perhaps see that the teeth of the central and lateral rows differ in size and form, as they do in many modern sharks. The specimens which I have already obtained do not, however indicate any such differences, but they are too incomplete to be decisive of this question.

Formation and locality: Coal Measures; Linton and New Lisbon, Ohio.

DIPLODUS LATUS, Newb.

Diplodus latus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*
Diplodus latus, N.; Geol. Surv. Ill., Vol. II., p. 59, Pl. IV., Figs. 1 to 1*e.*

Teeth from 10 to 16 lines long, from 6 to 12 lines broad; lateral denticles ovoid or lance-form, divergent on the same plane, of nearly equal length, acute, compressed, with sharp and strongly crenulated margins; middle denticle obsolete or reduced to a simple knob; bony base tuberous, large, sometimes with a prominent tubercle.

This is a large and strong species of *Diplodus,* not uncommon in the Coal Measures of Illinois, but rather rare in Ohio. It may be recognized by its large size, its broad, flattened, lance-head cornua, divergent in the same plane, and by the absence of a middle denticle.

Formation and locality: Coal Measures; Linton, Ohio.

GENUS LISTRACANTHUS, N. and W.

Spines small, gently arched, flattened, thin; sides marked by numerous sharp, longitudinal carinæ; edges set with many divergent, slender, acute teeth, those on the convex margin most numerous and largest; base abruptly expanded and obliquely truncated.

The above name was given by Mr. Worthen and myself to certain small, flattened, strongly striated spines found in the Coal Measures of Illinois. A description of the genus and one species is contained in the Report of the Geological Survey of Illinois, Vol. IV., p. 371. Since the organization of the Geological Survey of Ohio, two or three small specimens of the species found in Illinois (*L. hystrix*) have been obtained from the bituminous shales overlying one of the lower coals in Coshocton County.

LISTRACANTHUS HYSTRIX, N. and W.

Listracanthus hystrix, N. and W.; Geol. Survey of Illinois, Vol. IV., p.372, Pl. II., Figs. 3, 3*a*.

Spines small, thin, delicate, flattened, gently arched in outline, rapidly narrowed above, truncate, and slightly expanded at base; both edges set with sharp, spiny teeth, directed upward; the sides marked with fine, longitudinal ridges, which successively terminate above in the margin.

A few specimens of this small, highly ornamented spine have been procured from the bituminous shales of the Coal Measures of central Ohio, and a much larger specimen was found many years ago, by Dr. S. P. Hildreth, in the Upper Coal Measures near Marietta. Figures of these will be prepared for another volume of the Report. Meantime this peculiar fossil may be readily identified by the description now given.

As I have shown in the Report of the Illinois Geological Survey, these spines are apparently modified scales, and were evidently set *upon the surface* of the body or head, and attached by the broad, trumpet-mouthed bases.

GANOIDEI.

CROSSOPTERYGIDÆ.

GENUS CŒLACANTHUS, Agassiz.

The name *Cœlacanthus* was first proposed by Agassiz for certain equal-tailed, hollow-spined fishes from the Magnesian limestone of Durham, England. He subsequently briefly characterized several species of the genus coming from the Carboniferous and Mesozoic rocks of the British Islands and the continent of Europe. He also grouped these with *Holoptychius, Undina, Macropoma* and several other genera into the family *Cœlacanthi.* These fishes have been since more fully illustrated by Prof. Huxley in the Decades of the Geological Survey of the United Kingdom, so that we have now before us, in the three last-mentioned genera and *Holophagus,* one of the most remarkable and well-defined families of fossil fishes.

Prof. Huxley has shown that *Holoptychius* and several other genera included by Agassiz among his "Cœlacanths," differ somewhat widely in structure from *Cœlacanthus*; and though placed by Huxley in the same sub-order, they are excluded from his family *Cœlacanthini.*

The most noticeable points in the structure of *Cœlacanthus* are very briefly as follows. The fossil fishes of the family *Cœlacanthini* are included by Prof. Huxley in his sub-order *Crossopterygidæ,* or those in which the paired fins are lobed, *i. e.,* have fleshy and scaled bases and centers. In all the Cœlacanths, however, the fins are but slightly lobed, and it is even doubtful whether this character can be said to belong to them. Hence, if included among the *Crossopterygidæ,* the fishes which compose this family constitute a remarkably distinct section, of which the relations to the typical Crossopterygians can only be accurately determined when we shall be in possession of more material than we now have. In *Cœlacanthus,* as in the other genera of the family to which it belongs, the fishes are covered with imbricated, ornamented scales. The head-plates are also ornamented. They have two dorsal fins supported on palmated interspinous bones, and the vertebral column is prolonged centrally through the equi-lobate caudal fin, and bears at its extremity a minute supplemental caudal. The vertebral column was cartilaginous; but the neural arches and the fin-rays were bony. The under side of the head was protected by a pair of long-elliptical jugular plates. The teeth are rarely discoverable, but in the largest specimens of *Cœlacanthus* they are of considerable size, are conical and acute. Prof. Huxley states that in *Cœlacanthus,* as in *Undina* and *Macropoma,* the air-bladder was ossified; but I have not yet discovered any trace of this in the specimens of *Cœlacanthus* which have passed through my hands.*

Until recently, *Cœlacanthus* was without representative in the collections of American fossil fishes; but when the remarkable fish-deposit of Linton was discovered, species of this genus were found to be more abundant there than in any other known locality. The finding of *Cœlacanthus* at Linton, a place so far removed from those in which it occurs abroad, is not only a fact of much geological interest, but, since the most common species found there is scarcely distinguishable from *C. lepturus* of the Coal Measures of England, it affords another and interesting illustration of the homogeneity and wide distribution of the Coal Measure fauna, and the remarkable persistence in space, as well as time, of even minute characters in the organization of *Cœlacanthus.*

Prof. Huxley has called attention to the very great resemblance, and almost generic identity, of *Cœlacanthus, Undina* and *Macropoma*; and cites this succession of fishes—the inhabitants of ages to our compre-

* A very interesting and instructive review of the relations of the genus *Cœlacanthus* will be found in Decade XII. of British Fossils, published among the Memoirs of the Geological Survey of the United Kingdom.

hension infinitely removed from each other—as affording a striking example of what he terms a persistent type. In this case we have a form of organization showing an elaborate and complicated structure, which has continued almost unchanged throughout the inconceivable duration of successive geological ages, while all the world of physical circumstance was revolutionized again and again. The extension of *Cœlacanthus* into America affords another instance of the wide diffusion of forms which have great vertical range.

CŒLACANTHUS ELEGANS, Newb.

Plate 40, Figs. 1, 1*a*, 1*b*, 1*c*, 1*d*.

Cœlacanthus elegans, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body fusiform, robust, 6 to 8 inches in length; cranial surface covered with closely approximated tubercles; surfaces of opercula, mandibles and jugular plates ornamented with raised lines, generally continuous, but sometimes broken into detached tubercles. On the opercula these lines radiate from the superior angle. On the mandibles and jugulars they are imperfectly parallel with the margins of these plates. Scales nearly circular, exposed portion ornamented with converging raised lines; anterior dorsal fin slightly in advance of ventrals; posterior dorsal as much forward of anal fin. Radial formula, A. D. 10; P. D. 12; C. 22; A. 6; V. 11.

Among several hundred specimens of *Cœlacanthus* which I have obtained from Linton, it has not been easy to decide whether there was more than one species. Nearly all of these specimens are of about the same size, *i. e.,* from six to eight inches in length; the operculum having the longest diameter of about half an inch; the jugular plates, one inch. I have obtained, however, many fragments of very much larger individuals, some of which must have attained a length of a foot and a half. I also have one small and slender specimen which presents some characters which, I have supposed, might be of specific value. I have, therefore, described three species, giving to the more common one the name of *C. elegans;* to the largest, *C. robustus*; and to the smallest, *C. ornatus.* Future observation will alone determine how constant the distinctions are upon which the species have been founded. Another question not yet cleared of doubt is, whether our most common species, *C. elegans,* is distinct from *C. lepturus* of Agassiz, from the Coal Measures of Europe. The differences between them are certainly not great, and I shall not be

surprised if they should ultimately prove to be inseparable. Unfortunately, no specimens of the foreign species are before me; but on comparing our fishes with the excellent figures given by Prof. Huxley, I notice that in *C. lepturus* the ornamentation of the jugular plates is much more transverse than in any American specimen I have seen. In size, form, and general character of ornamentation of the body, no well-marked differences are discoverable. A careful comparison of specimen with specimen will alone enable us to decide this question; and yet it probably has no practical importance. The resemblance between the American and foreign fossils is so close that we are compelled to ascribe to them a common origin; and if slight differences shall be found to exist between them, it will be doubtless wiser to consider the two forms as varieties of the same species rather than as specifically distinct.

The figures now given of *C. elegans* are very imperfect, but they will suffice for the identification of any specimens which may be in the possession of the readers of this Report. In another volume some additional illustrations of this species will be published, and such as will afford better means of comparing the American and European fishes.

Formation and Locality: Coal Measures; Linton, Ohio.

CŒLACANTHUS ORNATUS, Newb.

Cœlacanthus ornatus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Fishes of small size, not exceeding 4 to 5 inches in length; body fusiform, slender, scarcely wider than head; cranial plates ornamented with relatively large and remote tubercles; opercula, mandibles and jugular plates marked with elevated lines, which, like those on the scales, are stronger than in the associated species.

More material will be required before we can decide whether the specimens described above constitute a distinct species of *Cœlacanthus.* They present, however, some features which have led me to separate them from all others found in the same locality, viz.: a more slender and cylindrical form of body, and stronger ornamentation of the scales and cephalic bones. This ornamentation is not only relatively, but absolutely, coarser than that of *C. robustus,* in individuals ten times as large. No illustrations of this species are given in the present volume, but figures will be published hereafter.

Judging from the representations of *Cœlacanthus elongatus,* Hux. (Mem. Geol. Surv. Unit. King., Dec. XII., Pl. V., Figs. 6, 7), it seems to me

probable that Prof. Huxley had before him specimens of this species when his description was written. Further comparisons, however, will be necessary before this question can be decided.

Formation and Locality: Coal Measures; Linton, Ohio.

CŒLACANTHUS ROBUSTUS, Newb.

Plate 40, Figs. 2, 2*a*.

Cœlacanthus robustus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body robust, 1 foot to 1 foot 6 inches in length; upper surface of cranium covered with small, closely approximated tubercles; opercula, mandibles and jugular plates threaded with fine, parallel, sometimes interrupted lines; opercula 1 inch 6 lines in longest diameter; jugular plates 2 to 2½ inches in length, 6 to 8 lines wide; extremities pointed, sometimes acute; teeth conical, acute, smooth, longest 2 lines in length; scales elliptical in outline, exposed portion ornamented with fine, converging, raised lines.

Of the great number of specimens of *Cœlacanthus* which are before me, nearly all are less than eight inches in length, and these are so uniform in size that I have supposed that their dimensions were those of mature individuals of one species, *C. elegans*. We have occasionally, however, met with fragments, and in one case an entire, though decomposed, individual of a much larger *Cœlacanthus*. Of these larger fishes no specimen has been obtained sufficiently well preserved to furnish the materials for a detailed description. All the generalities of structure and ornament are apparently the same in the larger and the smaller individuals; but in the strength of ornamentation on the scales and bones there are no differences corresponding to the difference in size; the thread lines and tubercles of the largest species being, indeed, less strongly marked than in some of the smaller ones. I have, therefore, been led to conclude that the large individuals belong to a distinct species, which I have designated by the name given above. In this conclusion I am strengthened by the uniformity of size which prevails among the specimens of *C. lepturus* of Europe, which is so closely allied to our *C. elegans*. Not having any specimens of *C. robustus* sufficiently complete to furnish a good drawing, I now publish figures of only a jugular plate and a scale, natural size.

Formation and Locality: Coal Measures; Linton, Ohio.

RHIZODUS LANCIFER, Newb.

Plate 39, Fig. 9.

Rhizodus lancifer, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Teeth striated below, section elliptical, smooth toward the summit, where they are very much compressed, with a lenticular section and cutting edges; summit of tooth like a lance head; near the apex the cutting edge of one side is often slightly gibbous, an apparent tendency toward a barbing of the point, as is seen in the teeth of *Lepidosteus.* As usually found, the plicated base of the tooth has mostly disappeared, the solid point alone remaining; this is about an inch long. The entire tooth was more than twice that length.

Teeth similar to that now described are not unfrequently met with in the Coal Measures in different parts of our country; but so far as I know, always detached from their connections with the jaw. Large fish-scales, such as are usually referred to the genus *Rhizodus,* often occur with them, and both are usually supposed to belong to the same animal. It has been suggested, however, that these so-called *Rhizodus* teeth are really the teeth of Amphibians; and it is not improbable that this may be true of some of them. The large scales, however, with which they are associated (such as *R. quadratus,* Pl. 39. Fig. 8), are unquestionably the scales of fishes; and Ganoids of sufficient size to wear such scales, probably had jaws furnished with teeth as large as these. Future discoveries will doubtless give us the information we so much desire in regard to these interesting fossils; and the researches necessary to answer the questions suggested will perhaps be stimulated and aided by the publication of the material we now have, fragmentary though it be.

Formation and locality: Coal Measures; Linton, Ohio.

RHIZODUS ANGUSTUS, Newb.

Plate 39, Fig. 6.

Rhizodus angustus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Laniary teeth elongated, slender, finely striated at base, smooth above, with cutting edges, length one inch; subordinate teeth less than half the length of the larger ones, with a circular section throughout, slender, acute, striated; surfaces of jaw coarsely tubercled.

In the diversity of form in the teeth, this species differs from *R. gra-*

cilis, McCoy, as well as from other species found in Ohio. As has been remarked in regard to the other large flattened teeth associated with these at Linton, it is by no means certain that they represent the dentition of fishes. Some of the Amphibians, of which the remains are found in the same deposit, are so like the Ganoid fishes in structure, that it is impossible to say, without having more complete material, to which group these teeth belong.

RHIZODUS QUADRATUS (n. sp.).

Plate 39, Fig. 8.

Scales large and thin, largest 2 inches long by 1¾ wide, imperfectly quadrangular in outline; surface nearly smooth, but margins marked by fine radiating striæ and concentric lines of growth; central and posterior portions marked by fine thread-like reticulations.

I have given the above name to certain large and thin scales which are found in the cannel coal at Linton, and which belong to some large fish that may be supposed provisionally to be a species of *Rhizodus.* They resemble in their general character those found by Dr. Hibbert in the Burdie House limestone, but are undoubtedly specifically distinct. These may be the scales of the fish of which the teeth are named *Rhizodus lancifer,* but they have never been found in connection.

GENUS MEGALICHTHYS, Agassiz.

Rhombiferous Ganoids of large size; head defended by strong, bony, highly polished plates; jaws furnished with numerous small conical teeth and a few large laniary teeth striated at base, and resembling those of Saurians; the vertebræ are ossified, the paired fins are supposed to be lobate, and the body is covered with rhomboidal enameled scales, of which the surface is punctate and brilliantly polished.

The remains of *Megalichthys* are frequently met with in Europe, where, from its great size, its powerful dentition, and its coat of mail, it must have been the tyrant of the bays and lagoons of the Coal Measure epoch. No traces of *Megalichthys* are reported to have been hitherto found in America, but I have for some years had in my possession scales and vertebræ obtained from the Coal Measures of Ohio, which must have belonged to fishes of this genus. Two of these scales are represented on Plate 40, Figs. 3, 3*a.* They are generally rhomboidal in form, each side 6 to 9 lines in length, are thick and strong, and are covered with a bril-

liant coating of brown punctate enamel. The under surface of these scales is elliptical in outline, about 10 lines in diameter, and exhibits the concentric lines and sub-central umbilicus, which are so characteristic of the under side of large Ganoid scales. These scales were found in the black shale overlying Coal No. 5, at Mineral Point, Tuscarawas County, Ohio. From the cannel coal of Linton I have obtained a number of short, massive, bony, amphicœlous vertebræ from 6 to 8 lines in diameter, scarcely distinguishable from the vertebræ of *Megalichthys* sent me by Mr. Barkas, and obtained from the shales of the Northumberland coal field, England. These, so far as I know, are the first traces of this great Carboniferous Ganoid met with in this country.

The material before me is too meager to enable me to say with certainty whether ours is a new species of *Megalichthys,* and it is probably best to leave that question to be decided by future discoveries.

I should perhaps mention in this connection, that the large, *thin* scales—sometimes 4 or 5 inches in diameter—found in the Coal Measures of England and Scotland, and formerly attributed to *Megalichthys,* are now known to belong to *Rhizodus.*

LEPIDOSTEIDÆ.

GENUS PALÆONISCUS, De Blainville.

A genus of rhombiferous Ganoids included in Owen's order *Lepidoganoidei* and family *Palæoniscidæ,* and a type genus of Huxley's family of *Lepidosteidæ,* of which *Palæoniscus, Amblypterus, Eurylepis,* etc., are Carboniferous genera. *Palæoniscus* includes twenty or more species, ranging from the Sub-Carboniferous limestone to the Trias. They have fusiform bodies, rhomboidal scales, heterocercal tails, a single dorsal fin, fulcral spines on the anterior margins of all the fins. Their teeth are numerous, conical, and acute. In some species the scales are highly ornamented, in others plain and polished. It was formerly supposed that the Carboniferous species generally had plain scales, while those of the Permian were striated. This is now known to be incorrect, as most of the Carboniferous species have ornamented scales and head-plates. In Europe several species of *Palæoniscus* are quite common in the Carboniferous and Permian strata, and most cabinets contain specimens of *P. Frieslebeni,* which occurs so abundantly in the Permian copper schists of Mansfeld. In America several species have been described from the Carboniferous rocks of New Brunswick, and one, *P. fultus,* from the Trias of the Con-

necticut valley. In Ohio two species only have been found in such a degree of preservation as to admit of description, *P. peltigerus* and *P. Brainerdi,* both of which are noticed in this volume. In the iron-stone nodules of Mazon Creek, Illinois, a very small species (*P. gracilis,* N. and W.) has been obtained by Mr. Worthen. Fragments of larger species, not yet described, have been met with in the same locality, in the Waverly at Knob Lick, Ky., and in the Cleveland shale—the base of the Waverly—in many parts of Ohio, and at Vanceburg, Ky. In the Cleveland shale the smooth, shining, rhombic scales of *Palæoniscus* are found wherever the stratum is opened; but, up to the present time, no entire individual has been seen. In the fish-bed at Linton *Palæoniscus* is far outnumbered by *Cœlacanthus* and *Eurylepis,* but the species found there is the most highly ornamented known; in this respect vieing with any of its associates, though they all exhibit a profusion and delicacy of ornament quite unknown among the fishes of the present day. Perhaps the taste for color was not developed in these ancient fishes; but if sexual selection created all the elaborate ornamentation of their polished armor, they certainly had a highly cultivated sense of beauty in form. Since, however, sexual selection so little controls the propagation of fishes, the elaborate system of ornament exhibited in the adornment of our palæozoic fishes becomes somewhat difficult of explanation by the Darwinian hypothesis.

PALÆONISCUS PELTIGERUS, Newb.

Plate 38, Figs. 1, 1*a,* 1*b.*

Palæoniscus peltigerus, N.; Geol. Surv. Ill., Vol. II., p. 17.
Elonichthys peltigerus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body short, compressed; length, 5 inches; height, 1 inch 4 lines; surface of cranial bones covered with small, thickly-set tubercles; maxillaries and mandibles ornamented by parallel convolutions of thread lines; scales all covered with similar raised lines, which cross them diagonally downward and backward, terminating in serrations of the posterior margins. About the middle of the space between the occiput and dorsal fin, on the median line, begins a row of large, oval, ornamented scales, extending to the dorsal fin. Behind the dorsal is a similar row, which become transformed into large, striated fulcra, which overlie the prolongation of the vertebral column to its termination. Fins large; dorsal triangular, nearly an inch in height and the same in breadth, composed of about 26 rays; ventrals lower, but as broad, and contain-

ing nearly the same number of rays; pectorals oblong, rounded at extremity, composed of about 10 rays; anal fin extending from ventrals to caudal, containing 40 or more rays; caudal broad as anal, and apparently composed of an equal number of rays.

This is a highly ornamented, and must have been a beautiful species of *Palæoniscus*. It was apparently an inhabitant of many of the lagoons of the coal marshes of North America, as I have received it from several places in Ohio, Indiana and Illinois. It is possible, also, that it will prove to be identical with some one of the species described by Dr. C. T. Jackson, and obtained from the Albert mine in New Brunswick. I have some imperfect specimens from that locality of a species very closely allied to this, in which, however, the ornamentation of the scales is coarser. Judging from Dr. Jackson's descriptions and figures, it would seem that *P. peltigerus* differs from the smaller species found at the Albert mine, in having the scales on the sides relatively higher, the markings finer and more oblique, and in the larger size of the fins. From his larger species it differs in its higher scales and finer and more oblique markings. The ornamentation is apparently more general and elaborate in our species than in any of the Albert mine fishes. It resembles them, however, in many respects, and belongs to the same group of species with them and *P. decorus* of Sir Philip Egerton.

Formation and locality: In Cannel Coal, at Linton, Jefferson county, and Canfield, Mahoning county, Ohio; Coal Measures of Fulton county, Illinois, etc.

PALÆONISCUS BRAINERDI, Thomas.

Palæoniscum Brainerdi, Thomas; Cleveland Times, Sept. 14th, 1853.

Fish 12 inches in length, fusiform, slender; body covered with relatively small, rhomboidal scales, which are finely and diagonally striated; dorsal fin set opposite the anterior margin of anal; both these fins triangular, 1 inch 3 lines in height and breadth; caudal fin 3 inches in length, superior lobe very much produced.

A short, popular description of this fish was given by Mr. W. H. B. Thomas in a Cleveland newspaper, and subsequently in the Report of the Polytechnic Institute of Philadelphia. I have since received numerous specimens of it from Mr. Hannibal Goodale, of Chagrin Falls, Ohio, in whose quarries in the upper layers of the Berea grit it occurs. Mr. Goodale has been careful to preserve all that have been found in working his quarries, but most of these have been given away and scattered, so

that no good ones have been accessible for figuring in time for this volume. It is hoped that material will be obtained from which better illustrations and a more complete description can be given, in another volume, than it is now possible to furnish.

The species was named by Mr. Thomas in honor of Prof. J. Brainerd, of Cleveland, who obtained the first specimens, and called the attention of geologists to the interesting locality where it is found.

Formation and locality: The only locality where *P. Brainerdi* is known to occur is in the upper layers of the Berea grit at Chagrin Falls, Ohio.

GENUS EURYLEPIS, Newb.

Heterocercal Lepidoganoids of small size; body fusiform; head obtuse; tail elongated, lobes very unequal; fins small and provided with delicate fulcra; dorsal fin opposite anal or nearly so, both set far back on body; ventrals near middle of abdomen; cranial surface ornamented by corrugations, tubercles or granulations; maxillary, mandibular and jugular plates ornamented with convoluted corrugations of the surface in various patterns; scales smooth or ornamented, posterior margins of lateral scales all or in part serrated, scales of median line above and below characteristically angled or toothed, two or more rows of scales on sides extending back to near anal fin, remarkably high, vertical 2 to 5 times longitudinal diameter; lateral line nearly straight, passing through the upper part of the lower row of the high lateral scales; teeth numerous, conical, short.

The peculiar group of fishes to which I have given the name of *Eurylepis,* mainly replace *Palæoniscus* in the ichthyic fauna of the locality where they occur. From *Amblypterus* and *Elonichthys* they may be readily distinguished by their small fins, all bearing fulcra. With *Palæoniscus* their affinities are closer, but the *ensemble* of characters presented by the large number of specimens which I have examined, seems to separate them from that genus. Among these diagnostic characters, the most conspicuous are their small size, posterior position of dorsal fin, and especially the high lateral scales. The large median scales of the back, so common in *Palæoniscus,* are wanting in all the species of *Eurylepis* which have come under my observation.

In the lagoon that existed at Linton in the peat-marsh where Coal-seam No. 6 was forming, these little fishes must have been exceedingly numerous. In some parts of a mine opened there, this coal-seam shows a thin stratum of cannel at its base; and hardly a fragment of this can-

nel can be found which does not contain the detached scales of *Eurylepis*. Sometimes, indeed, several individuals, in a more or less perfect state of preservation, will be seen in a block a few inches square. It is evident also that they formed a large part of the subsistence of the many carnivorous fishes and salamanders which inhabited the same water. This is indicated by the great number of coprolitic masses found in the cannel, and which are sometimes almost entirely composed of the scales of *Eurylepis*.

As I was the first to discover the fossiliferous character of the cannel at Linton, and have been collecting during twenty years from this locality, a large number of good specimens of *Eurylepis* have came into my possession. Among these I have found marked differences in the size and form of the body, in the shape of the scales, and in the degree and kind of ornamentation of the scales and cranial plates. These differences have led to the creation of several species, but their distinctive characters can only be clearly seen where there is much good material in hand for comparison, and when that material is carefully scrutinized. In such circumstances, however, it will not be difficult to show that the differences I have indicated are quite as real as those which have been considered sufficient to separate the species of *Palæoniscus* from each other. Whether some of these distinctions are not dependent upon age or sex we have not yet ascertained; but, since the characters that have served to distinguish the species are such as are usually regarded as having specific value, there has seemed to be no other way than to give them this value until such time as they may be found to shade into each other, and thus obliterate specific lines.

In the most complete specimens of *Eurylepis* found, the exoskeleton may be said to be perfect. The ornamented cephalic bones, the scales, and the fin-rays, are all in position, without a fracture or displacement. In all cases, however, the scaly armor of the fish alone remains. The cartilaginous portion of the cranium, the vertebral column, and the neural and hæmal spines, have entirely disappeared.

It may be regarded as somewhat remarkable that such a group of fishes as is formed by the several species of *Eurylepis* should be found in abundance in one locality, and no one of them have been met with elsewhere. It will be remembered, however, that over the immense area occupied by Carboniferous rocks in the United States, careful search for the remains of fishes has been made in but few of the places where such fossils would be likely to occur. Doubtless as the working of our coal mines progresses, and as the local geology of our Carboniferous districts is more thoroughly worked up, very great additions will be made to our

knowledge of the fishes which lived on our continent in that far-off age. As yet only five localities have yielded any considerable number of Carboniferous fishes in this country, viz. : the Albert mine, New Brunswick; the banks of Mazon Creek, Grundy County, Illinois; the quarries of the Berea grit at Chagrin Falls, the Cleveland shale at Vanceburg, Ky., and the Niesly mine at Linton, Ohio. In each of these localities fishes are found which have not been collected elsewhere. For example, none of the species of *Palæoniscus* of the Albert mine, of Chagrin Falls or Mazon Creek have been obtained in any other places than those I have enumerated, and none are common to two of these. The same may be said of *Eurylepis* and *Cœlacanthus*, and also of the various Amphibians found at Linton. At Mazon Creek we have procured *Platysomus* and *Amblypterus,* but they have been obtained in no other American locality. And yet these are genera so characteristic of the Coal Measures of Europe, that now, since we have found them in one place, we may expect them to be met with in many others. The species of *Cœlacanthus* most common at Linton (*C. elegans*) is as abundant as any species of *Eurylepis,* but not an individual of the genus has been found any where else in this country.

These instances of the recurrence, even in single localities in America, of the Carboniferous fishes of Europe, prove so general a distribution of both genera and species, that we shall be sure to meet with them again and again.

It should be remembered, also, that the little fishes found in the Coal Measures were inhabitants of circumscribed bodies of water—rivers, lagoons, lakes and bays—and therefore their distribution could not have been so general as that of marine, and especially of pelagic fishes. We can only hope to find such groups of lagoon-inhabiting fishes as those of Linton when we chance to come upon the sediments of the perhaps few and remotely-set pools of open water in the coal marshes. Since, however, we have learned that our cannel coals and the bituminous shales associated with our coal seams are the sediments which accumulated in the bottoms of these lagoons, our search need not be entirely at random. Such localities as Linton—where the cannel coal is *crowded* with animal remains—must necessarily be rare; but I am led by my own experience to expect that similar fossils, though, perhaps, in less numbers, will be discovered in various parts of our country. In Europe the bituminous shales of the Coal Series, the beds of cannel and the concretions of nodular iron ore have yielded most of the scaled fishes of the Coal Measure epoch, and we may expect that our experience in America will be the same.

EURYLEPIS TUBERCULATUS, Newb.

Plate 38, Figs. 2, 2*a*, 2*b*, 2*c*, 3, 3*a*.

Eurylepis tuberculatus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body fusiform; entire length 3 inches; head 6 lines; tail 8 lines; cranial plates strongly tuberculated; tubercles rounded, elongated or reniform; surfaces of opercular, maxillary and jugular bones covered with linear, parallel corrugations; scales of the body smooth, except a few on the anterior dorsal and ventral surfaces, which are sometimes punctate; lateral scales nearly 5 timesas high as long, posterior margins bearing a few serrations; anal fin opposite dorsal.

This is perhaps the most common species of *Eurylepis* at Linton. It may be recognized by its tuberculated cranium (much more distinctly tuberculated in the figure 2*c*) and by its high, smooth, polished scales, conspicuously serrated on their posterior margins.

EURYLEPIS CORRUGATUS, Newb.

Plate 38, Figs. 4, 4*a*.

Eurylepis corrugatus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body fusiform, robust; length 3 inches 4 lines; breadth 10 lines; length of head 8 lines; anterior lateral scales 2½ times as high as long; cranial plates ornamented by convolutions of fine, thread-like corrugations; maxillary bones, opercular and hyoid plates corrugated much as superior surface of head; scales smooth, except a few on the anterior dorsal surface, which are finely striate and punctate; posterior margins of lateral scales as far back as anal and dorsal fins serrated; scales of tail, like most of those of the dorsal and ventral surfaces, plain on surface and margins; anterior margin of anal fin opposite center of dorsal; longest rays of anal when collapsed just reaching base of caudal.

This is the largest and most robust species of the genus yet known. It may be identified by the relative vertical shortness of the lateral scales, which are smooth, and especially by the convolutions of thread lines which cover all the cephalic bones.

Formation and locality: Coal Measures; Linton, Ohio.

EURYLEPIS OVOIDEUS, Newb.

Plate 39, Fig. 1.

Eurylepis ovoideus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Fish small, robust; body ovoid; length 1 inch 6 lines; breadth 6 lines; length of head 4½ lines; cranial surface corrugated and finely granulated; sides and lower parts of head ornamented by thread-like corrugations; scales of anterior portion of abdomen granulated, of sides serrated; lateral scales 3½ times as high as long.

Of this small species I have obtained a large number of specimens. It is usually broader and more ovate in outline than would be inferred from the figure. Its distinguishing characteristics are the mingling of tubercles and thread lines in the cephalic ornamentation, and the relative height of the lateral scales. In form and marking it approaches nearest to *E. corrugatus*, but in that the head is not tubercled and the lateral scales are relatively shorter.

Formation and locality: Coal Measures; Linton, Ohio.

EURYLEPIS INSCULPTUS, Newb.

Plate 39, Fig. 2, 2*a*.

Eurylepis insculptus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body fusiform, slender; length 2 inches 6 lines; breadth 5 lines; cranial plates ornamented with elongated tubercles, spaces between tubercles granulated; sides and under surface of head marked by raised lines and fine granulations; scales on anterior half of the body highly ornamented; lateral scales 3½ times as high as long, and having a double waved line along anterior margin, with acicular denticulations of posterior border; scales of abdomen having entire surface covered with appressed denticles; scales of tail and posterior portion of body plain; dorsal fin opposite anal.

This highly ornamented species approaches in its markings that next described, *E. ornatissimus,* and they may prove to be merely varieties of the same. The distinction visible in the specimens before me is this: that in *E. insculptus* only those scales which are on the abdomen and anterior portion of the body are ornamented, while in *E. ornatissimus* the surface of every scale is roughened with salient points.

Formation and locality: Coal Measures; Linton, Ohio.

EURYLEPIS ORNATISSIMUS, Newb.

Plate 39, Figs. 4, 4*a*.

Eurylepis ornatissimus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Fish small, fusiform, slender; length 2 inches; breadth 5 lines; cranial surface sparsely tubercled, tubercles somewhat radiated; spaces between tubercles finely granulated; lateral and inferior bones of head granulated and corrugated; all the scales of the body and tail ornamented with granulations, striæ or denticles; lateral scales 4 times as high as long, with a double line of appressed denticles on anterior borders and acute serrations of posterior margins; fins all relatively longer than in other species; dorsal fin nearly opposite anal.

This little fish is elaborately ornamented in every part, and presents the extreme form of the tendency to adornment which runs through all the genus. I have felt compelled by the differences noted in the descriptions of *E. insculptus, E. granulatus,* and *E. ornatissimus,* to consider them as specifically distinct. But their great general resemblance suggests the possibility that they may prove to be varieties only.

Formation and locality: Coal Measures; Linton, Ohio.

EURYLEPIS GRANULATUS, Newb.

Plate 39, Figs. 5, 5*a*.

Eurylepis granulatus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body fusiform, robust; length 3 inches, breadth 7 lines; head 6 lines long; tail 9 lines; head tubercled above, tubercles elongated, with granulations between; lateral and inferior bones of the head threaded; scales apparently thinner and more delicate than those of any other species; those on the anterior portion of the body granulated, and having a faint, double waved line along anterior margin; posterior border serrated; lateral scales 4 times as high as long. Radial formula, D. 6; C. 14; A. 8; V. 5?; P. 9?

As has been remarked, this species considerably resembles the two preceding, but in a large number of well-marked specimens which I have before me, the characters are so constant that I am inclined to regard the species as a good one. This is one of the more common forms.

Formation and locality: Coal Measures; Linton, Ohio.

EURYLEPIS LINEATUS, Newb.

Plate 39, Figs. 7, 7*a*.

Eurylepis lineatus, N.; Proc. Acad. Nat. Sci., Phila., *loc. cit.*

Body fusiform, robust; length 3 inches, breadth 8 l ines; cephalic bones all ornamented wi th thread-like lines, as in *E. corrugatus,* and without tubercles; scales of anteri or portion of abdomen covered with concentric thread lines; margins of lateral scales ornamented in the same manner; lateral scales lower than in any o ther species yet di scovered, greatest vertical d iameter scarcely twice longit udinal; scales of abdomen very numerous and twice as long as high.

In this well marked species we find an absence of the high scales of the sides which form so striking a feature in most species of the genus. It would, therefore, if considered separately, be generally regarded as a *Palæoniscus*; but the peculiar ornamentation of the head-plates, the posterior position of the dorsal fi n, and the ab sence of the large nuchal scales of *Palæoniscus,* seem to require that it should be made generically distinct and united with the other species of *Eurylepis.* This is the rarest of all the forms found at Linton.

Formation and locality: Coal Measures; Linton, Ohio.

EURYLEPIS MINIMUS (n. sp.).

Plate 39, Fig. 3.

Fishes very small, 8 to 12 lines long, 2 to 4 lines wide; cranial surface corrugated with short, curved, obtuse ridges, with a few tubercles at the nasal extremity; maxillaries, lateral and inferior head-plates ornamented with relatively co arse, parallel, raised lines; scales on inner surface nearly smooth; exteriorly, somewhat roughened by obtuse k nobs or arches; lateral scales 3½ to 4 tim es as high as wide; posterior margin delicately serrate.

The cannel coal at Linton contains immense numbers of minute fishes, from ¾ of an inch to 1 inch in length, which I, for a long time, supposed to be the young of the different species of *Eurylepis* with which they are associated. I have been led, however, to doubt whether this is the case, as they exhibit such a remarkable uniformity of size, and t heir markings seem to be somewhat different from those of any of the larger species. I have now in my possession several hundred specimens which vary but

little in dimensions and markings, and there is no such gradation in size between these and the individuals of the species of *Eurylepis* that have been described, such as we might expect to find if one were the fry of the other. It is true, also, that a few individuals of the most common species of *Eurylepis* (*E. tuberculalus*) have been found at Linton, which are much smaller than the average, and which evidently represent the earlier stages of growth of that species; but they are distinguishable from even the largest of *E. minimus* by their thicker, smoother scales, and the broader and rounder tuberculation of the cranial surface.

It may seem surprising, if we consider the species now described as distinct from all the larger ones, that so few young individuals of those should be found where the mature forms are so abundant. But the same thing is true in regard to *Cœlacanthus*. The more common species of this genus, *C. elegans*, is, perhaps, as frequently met with at Linton as any species of *Eurylepis*; and yet, out of the great number which I have obtained there, only two specimens were very much below the average size. It seems probable, therefore, that the young of both *Cœlacanthus* and *Eurylepis*—as is the case with so many of our living fishes—had different feeding grounds from those of the mature individuals.

Among the hundreds of specimens of *E. minimus* which are before me as I write, a very considerable number are smaller and narrower than the others; and in these the head-plates and scales seem to have been exceedingly thin and delicate, so that they are now warped and corrugated, giving the impression, at first sight, that they are highly ornamented. I am inclined to believe, however, that these are only younger individuals of *E. minimus* in which the plates and scales were so very thin that they have been corrugated simply by pressure.

The figure now given of *E. minimus* presents only the general aspect of the fish, and no effort has been made to copy the markings of the cranial plates. The specimen drawn was also somewhat imperfect, and the nasal extremity of the head is not represented. In more complete specimens the head is seen to be obtuse, the eye orbit relatively large, and almost always distinctly visible. Highly magnified views of the different plates and scales are required in this, as in the other species of the genus, to give a clear idea of the character and beauty of their ornamentation. Perhaps these anatomical details will be given in a future volume of the Report. The mission of the figures now published will be fully accomplished, however, if through them, the more conspicuous features of this new and interesting group of fishes are made known, and they afford the means for identifying the species described.

Formation and Locality: Coal Measures; Linton, Ohio.

EURYLEPIS STRIOLATUS (n. sp.).

Fishes of small size, from 1 to 2 inches in length by 3 to 5 lines in width; form robust; head rounded and obtuse; cranial surface tuberculated; lateral and inferior head-plates ornamented with parallel, raised, interrupted, sometimes beaded or granulated lines; lateral scales 5 times as high as wide; all the scales of the anterior portion of the body ornamented with fine, straight, thread-lines, which run from front to rear, and cover the posterior two-thirds—probably all the exposed portion—of each scale. These lines are parallel among themselves; about nine on the highest scales.

Of this little fish I have but few specimens, but these are so clearly marked as to leave no doubt that they are specifically distinct from any others yet described. In general form they resemble the larger individuals of *E. minimus,* and some of them are scarcely larger. They are, however, somewhat more robust, the posterior portion of the body broader, the upper lobe of the tail shorter; but none of these characters would alone serve to distinguish these from the hundreds of other little fishes with which they are associated. The markings of the scales, however, are altogether different from those of any other species of *Eurylepis,* and the fine, widely spread, straight, thread-lines that traverse them from front to rear will arrest the attention at the first glance at the fish with a lens. The posterior margins of the scales seem not to be serrated, but they are perhaps slightly crenulated by shallow scallops between the raised lines. No figure of this species is given in the present volume, as the specimens described were not obtained in time. It will probably be figured hereafter.

Formation and locality: Coal Measures; Linton, Ohio.

PLATE XXIV.

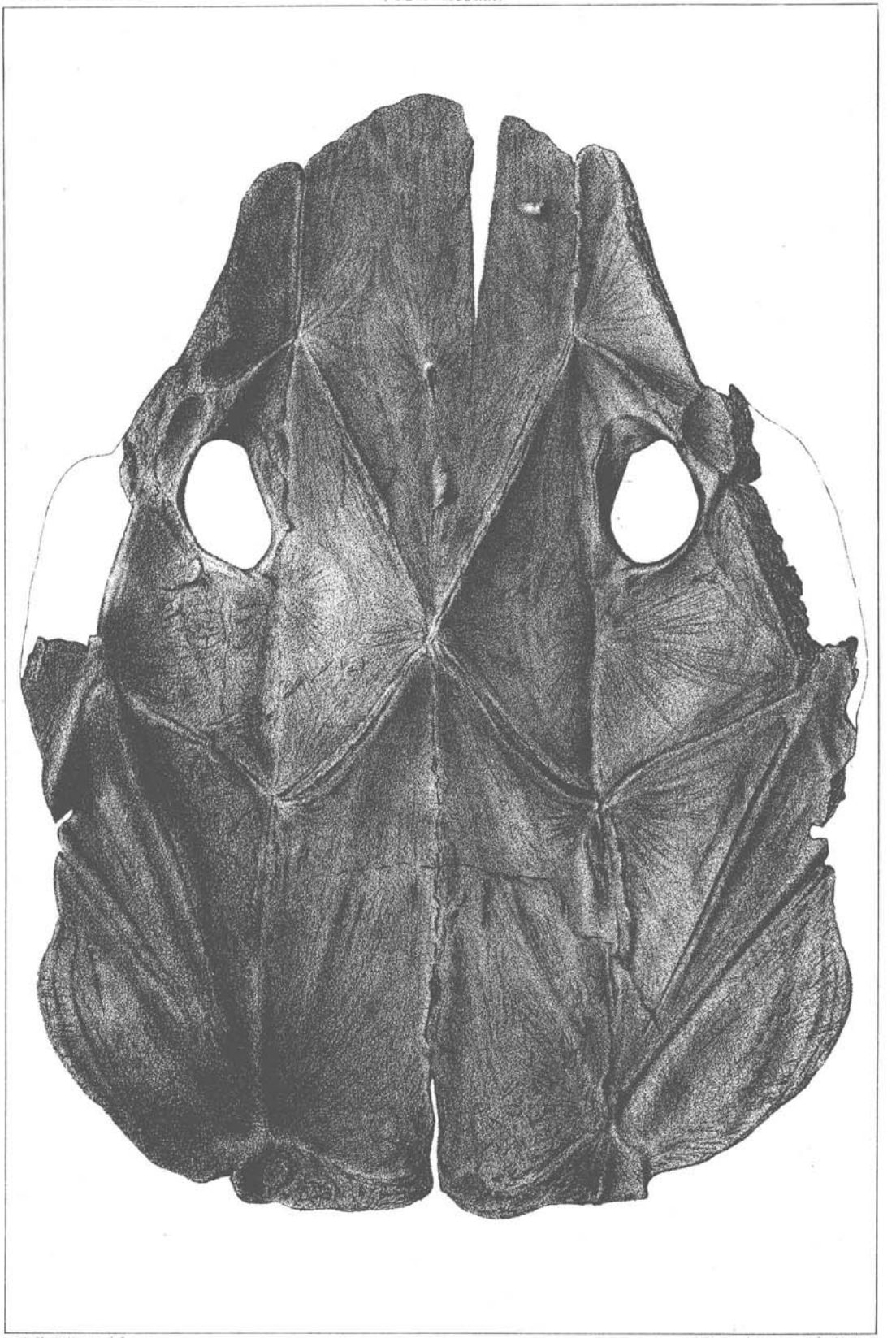
PAGE.

Fig. 1. MACROPETALICHTHYS SULLIVANTI. Newb..... 294

View of under side of cranial plates. Natural size.

Corniferous limestone, Sandusky, Ohio.

The specimen from which this drawing was made belongs to Dr. A. H. Agard, of Sandusky.



G.K. Gilbert, del. Thos Sinclair & Son, lith. Phila

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PLATE XXV.

PAGE.

Fig. 1. MACROPETALICHTHYS SULLIVANTI. Newb..... 294

Side view of cranium, external surface.

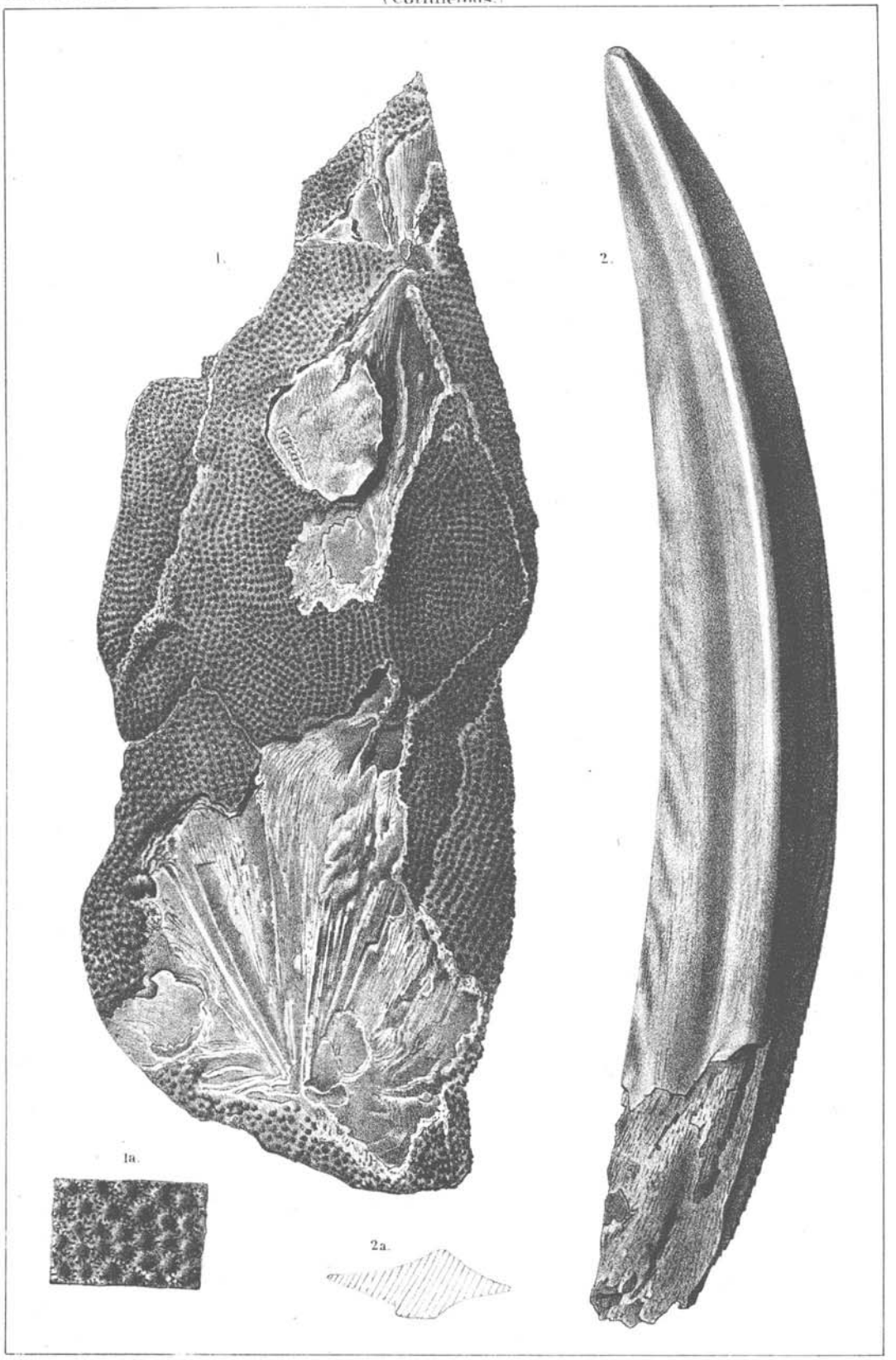
1 *a*. Group of dermal tubercles enlarged to twice natural size.

Fig. 2. MACHÆRACANTHUS MAJOR. Newb..... 304

Natural size.

2 *a*. Section of same.

All from the Cornifervus limestone, Sandusky, Ohio.



Tan Sinclair & Son lith. Phila. G. K. Gilbert del.

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PLATE XXVI.

Fig. 1. Inter-mandibular crest with three teeth, natural size, from same individual as mandible, Plate XXVII., Fig. 1.

Fig. 2. Detached tooth of mandibular crest. Natural size.

Fig. 3. Inter-mandibular crest with six of the seven teeth in position. This crest belongs with mandibles 4 and 5.

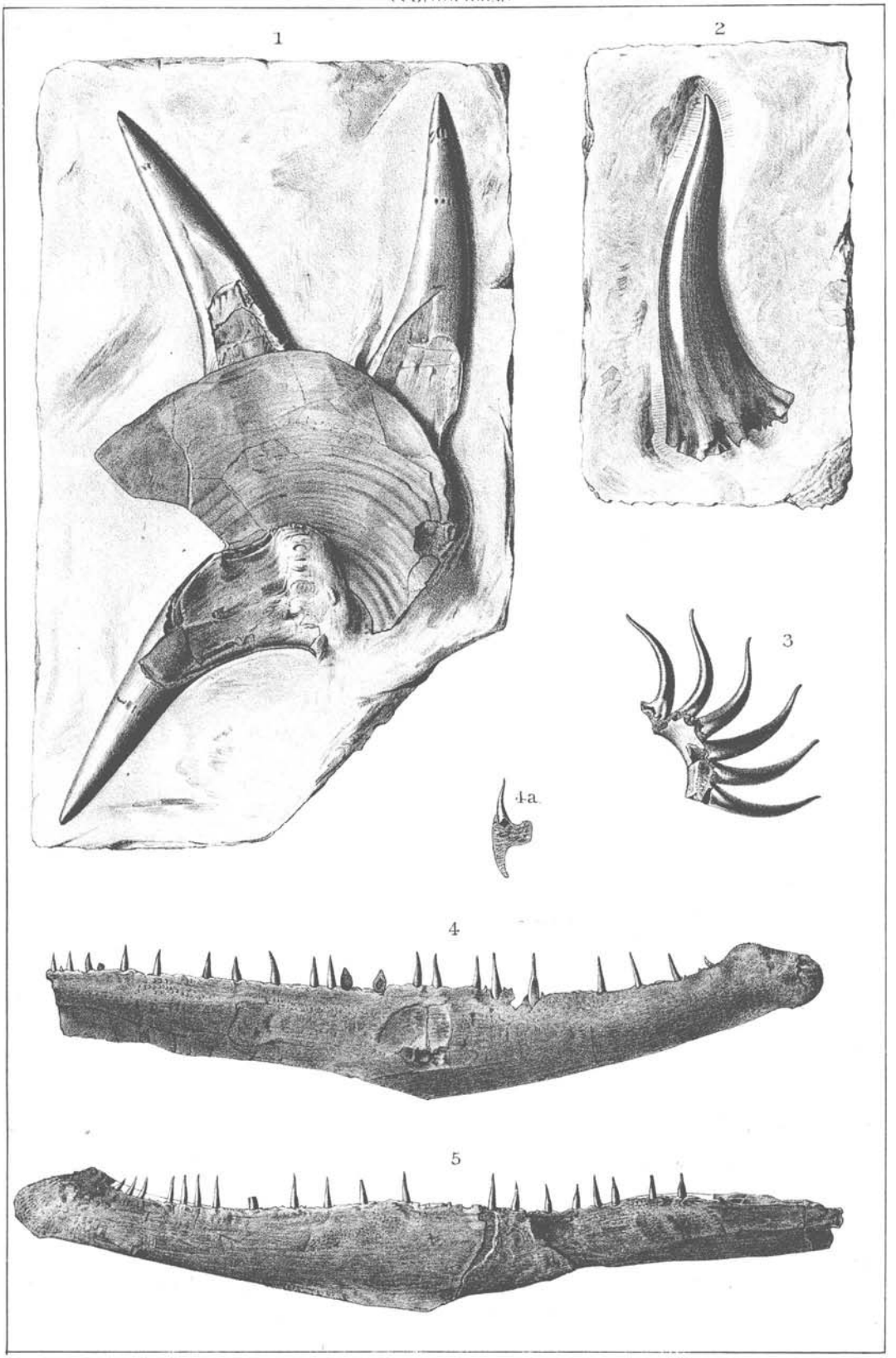
Fig. 4. Exterior face of right mandible of a small individual.
4 *a*. Transverse section of the same.

Fig. 5. Exterior face of left mandible belonging with Fig. 4.

All from the Corniferous limestone, Delaware, Ohio.

Geological Survey of Ohio.

(Carniferous.)



G. K. Gilbert, del.

Thos Sinclair & Son, lith., Phila.

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PLATE XXVII.

Fig. 1. Mandible, inside view.
1 *a*. Scale, inside.
1 *b*. Scale, outside, showing exposed and covered portions of surface; outline restored.
1 *c*. Surface of scale enlarged to show ornamentation.

Fig. 2. Mandible, outside view, showing ornamented surface and three of the series of large teeth embraced in the symphysis of the jaw nearly in position.
2 *a*. Dermal surface of mandible enlarged.

All except 1 *c* and 2 *a* natural size. Corniferous limestone, Delaware, Ohio.

Geological Survey of Ohio.

(Corniferous Limestone.)

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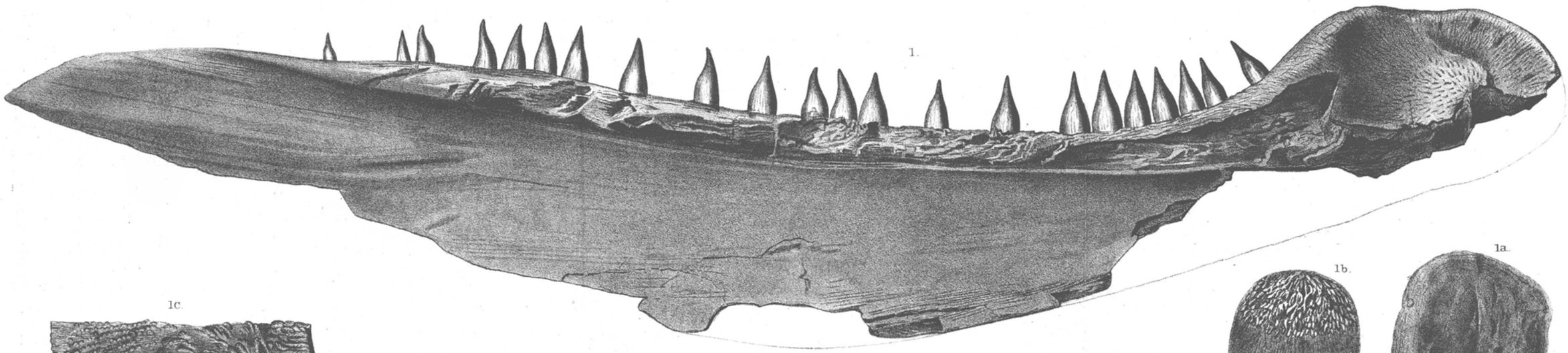
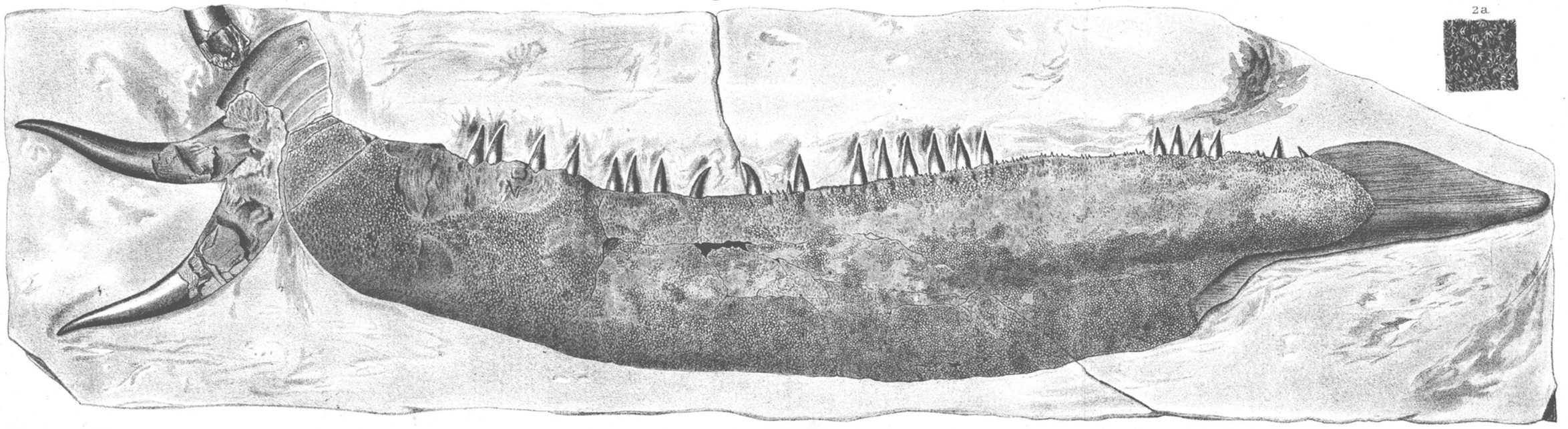


1a.

1b.

1c.

2



2a.

C. K. Gilbert, del.

Th^s Sinclair & Son, lith. Phila

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PLATE XXVIII.

PAGE.

Fig. 1. RHYNCHODUS SECANS. Newb. 310

Upper ? tooth, showing worn cutting edge. Natural size.

1 *a*. Vertical section of Fig. 1, one-third the distance from front.

Fig. 2. RHYNCHODUS FRANGENS. Newb. 311

External face of left ? lower ? mandibular tooth. Natural size.

2 *a*. Triturating surface of Fig. 2.

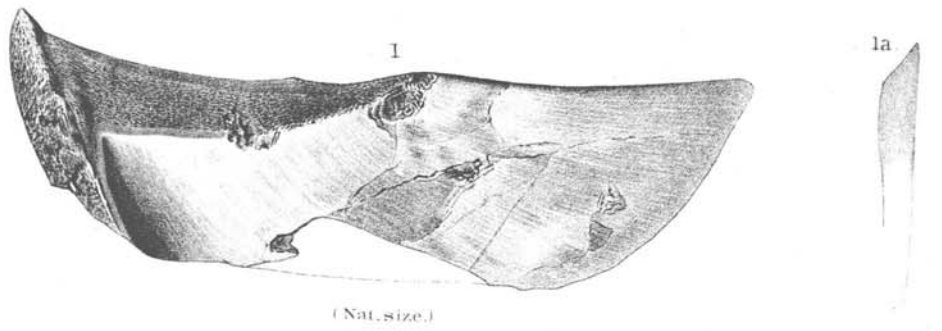
Fig. 3. RHYNCHODUS FRANGENS. Newb. 311

Interior face of anterior crown portion of tooth similar to Fig. 2.

Fig. 4. RHYNCHODUS SECANS. Newb 310

Tooth ?

All from Corniferous limestone, Delaware, Ohio.



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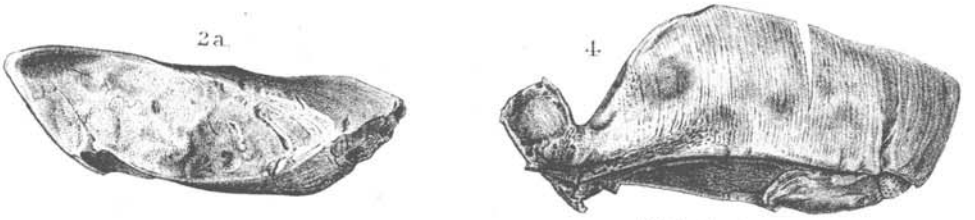

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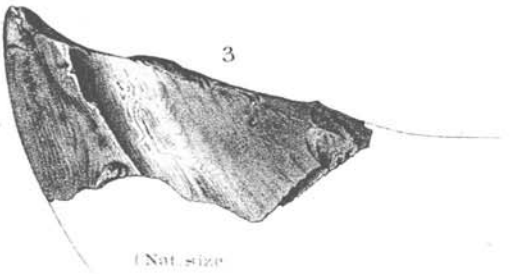

(Nat. size

G.K. Gilbert, del. Thos Sinclair & Son, lith. Phila.

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PLATE XXIX.

PAGE.

Fig. 1. RHYNCHODUS SECANS. Newb 310

Upper mandibular tooth.
1 *a*. Outline of anterior angle of upper mandibular tooth worn by use.
1 *b*. Another form of the same.
1 *c*. Another form of the same.

Fig. 2. RHYNCHODUS SECANS. Newb 310

Lower mandibular tooth.
2 *a*. Outline of anterior angle of another tooth, somewhat worn.

Fig. 3. RHYNCHODUS CRASSUS. Newb 312

Lower ? mandibular tooth considerably worn, seen from the inside, showing triturating surface.

Fig. 4. LIOGNATHUS SPATULATUS. Newb 306

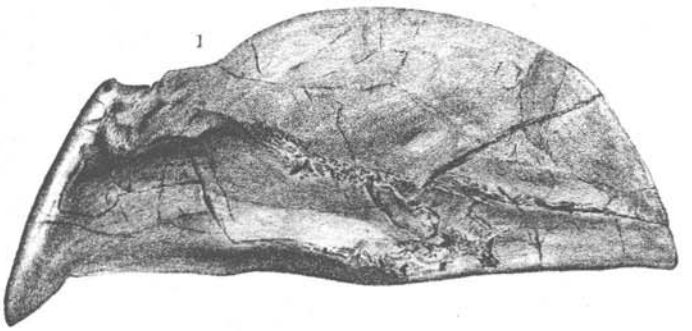
Mandible, interior face.

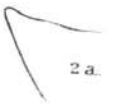
Fig. 5. CYRTACANTHUS DENTATUS. Newb 307

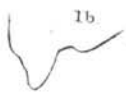
Fig. 6. MACHÆRACANTHUS PERACUTUS. Newb 305

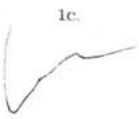
6 *a*. Section of the same.

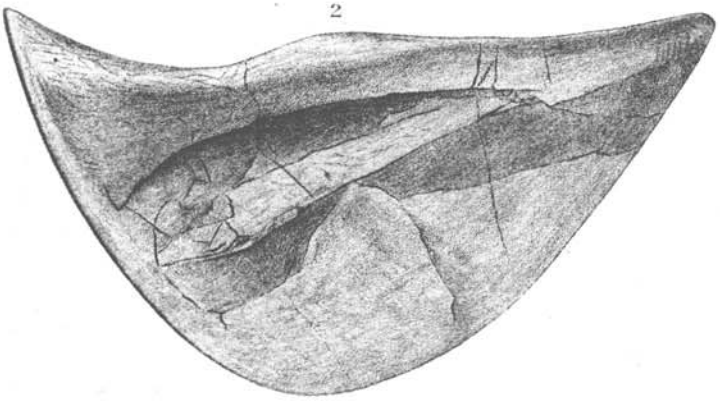
All natural size. Originals from Corniferous limestone, Sandusky and Delaware, Ohio.

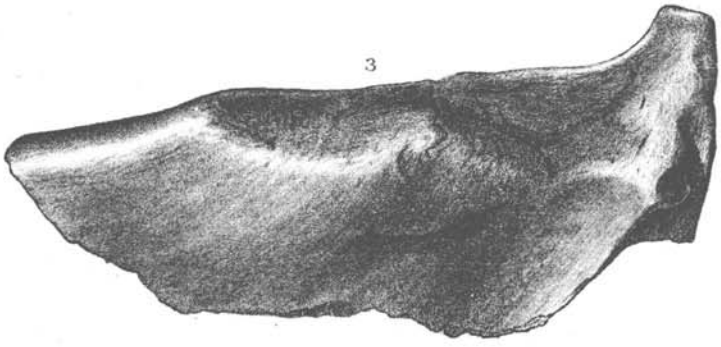


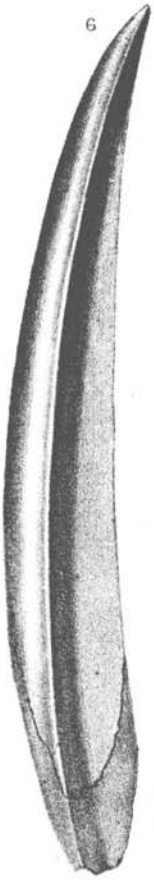


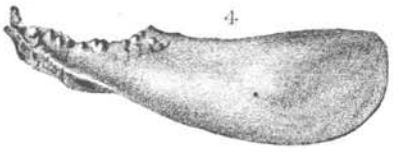












C. K. Gilbert, del. Th^s Sinclair & Son, lith., Phila

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PLATE XXX.

PAGE

DINICHTHYS HERTZERI. Newb. 316

Fig 1. Mandible showing interior face, one-third natural size, linear. Original two feet in length.

Fig. 2. External face of Fig. 1, one-third natural size.

From concretions in Huron Shale, Delaware, Ohio.

Geological Survey of Ohio.

DEVONIAN. (Huron Shale.) PLATE 30.

C. K. Gilbert, del. Thos Sinclair & Son, lith., Phila.

1.

PLATE XXXI.

PAGE.

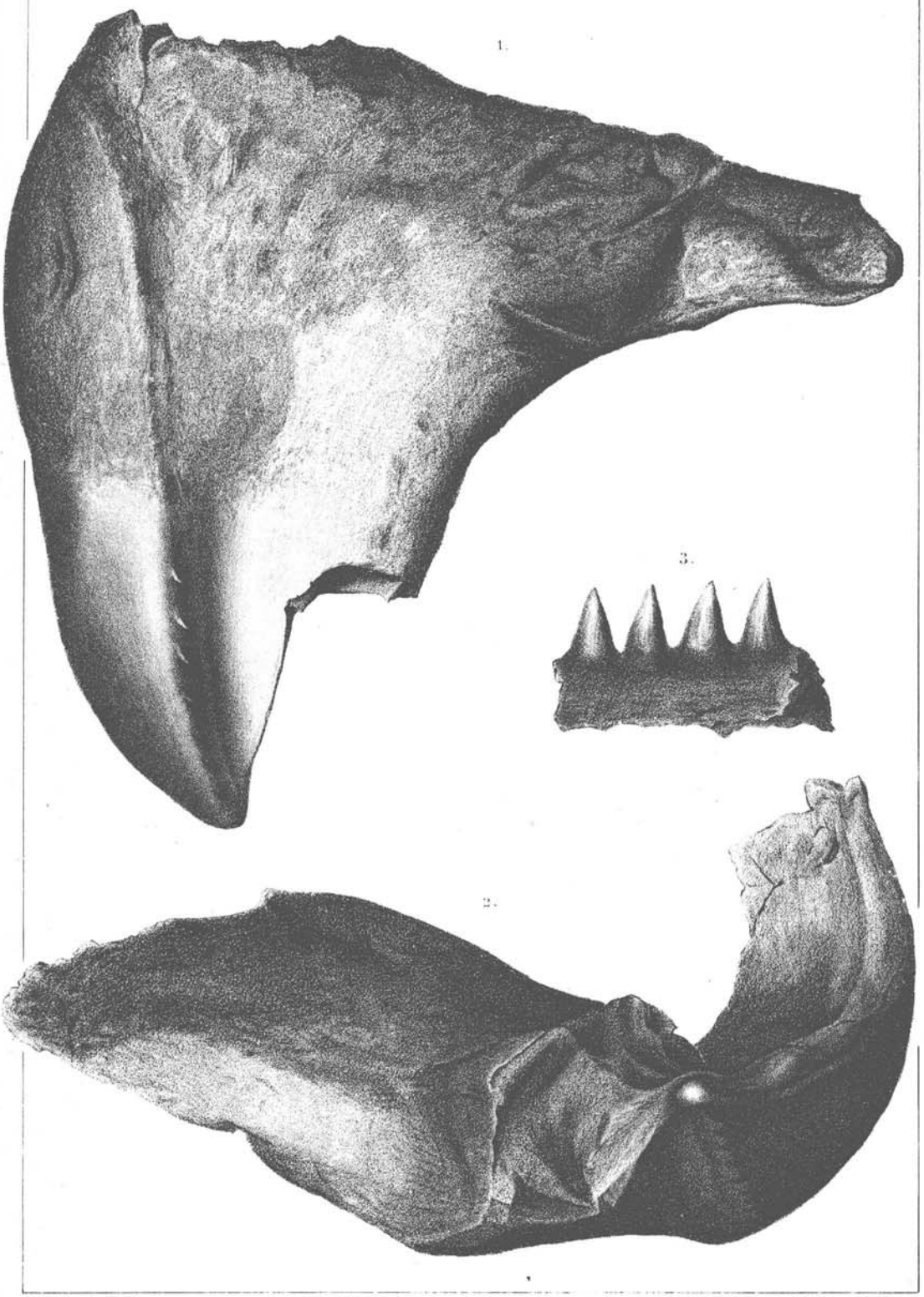
DINICHTHYS HERTZERI. Newb. 316

Fig. 1. Premaxillary tooth of left side; lateral view.

Fig. 2. Vertical view of Fig. 1.

Fig. 3. Teeth from central portion of mandible.

All natural size. Huron Shale, Delaware and Monroeville, Ohio.



Thos Sinclair & Son. ath. Phila

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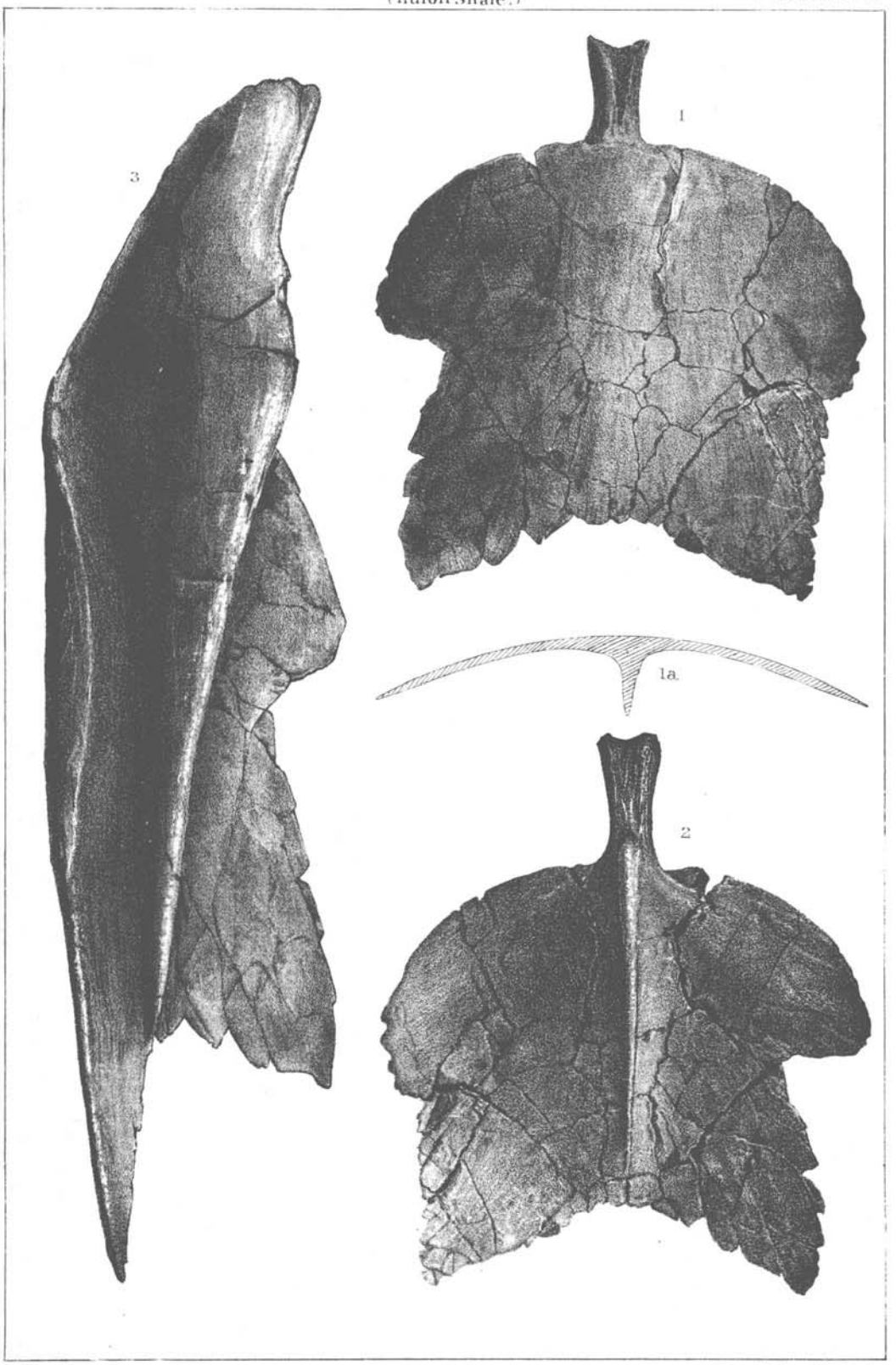
PLATE XXXII.

Fig. 1. Dorso-median plate, external surface.
1 *a*. Transverse section through middle of plate, one-eighth natural size. Original twenty-three inches broad.

Fig. 2. Internal face of dorso-median plate showing strong median keel, one-eighth natural size.

Fig. 3. Perspective view of interior surface of dorso-median plate, one-fourth natural size, linear.

From Huron Shale, near Avon Point, Lorain County, Ohio.



J.S. Newberry. del

Thos Sinclair & Son. lith. Phila.

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PLATE XXXIII.

PAGE.

DINICHTHYS HERTZERI. Newb..... 316

Fig. 1. Posterior portion of cranium, exterior surface, about one-third natural size, linear.

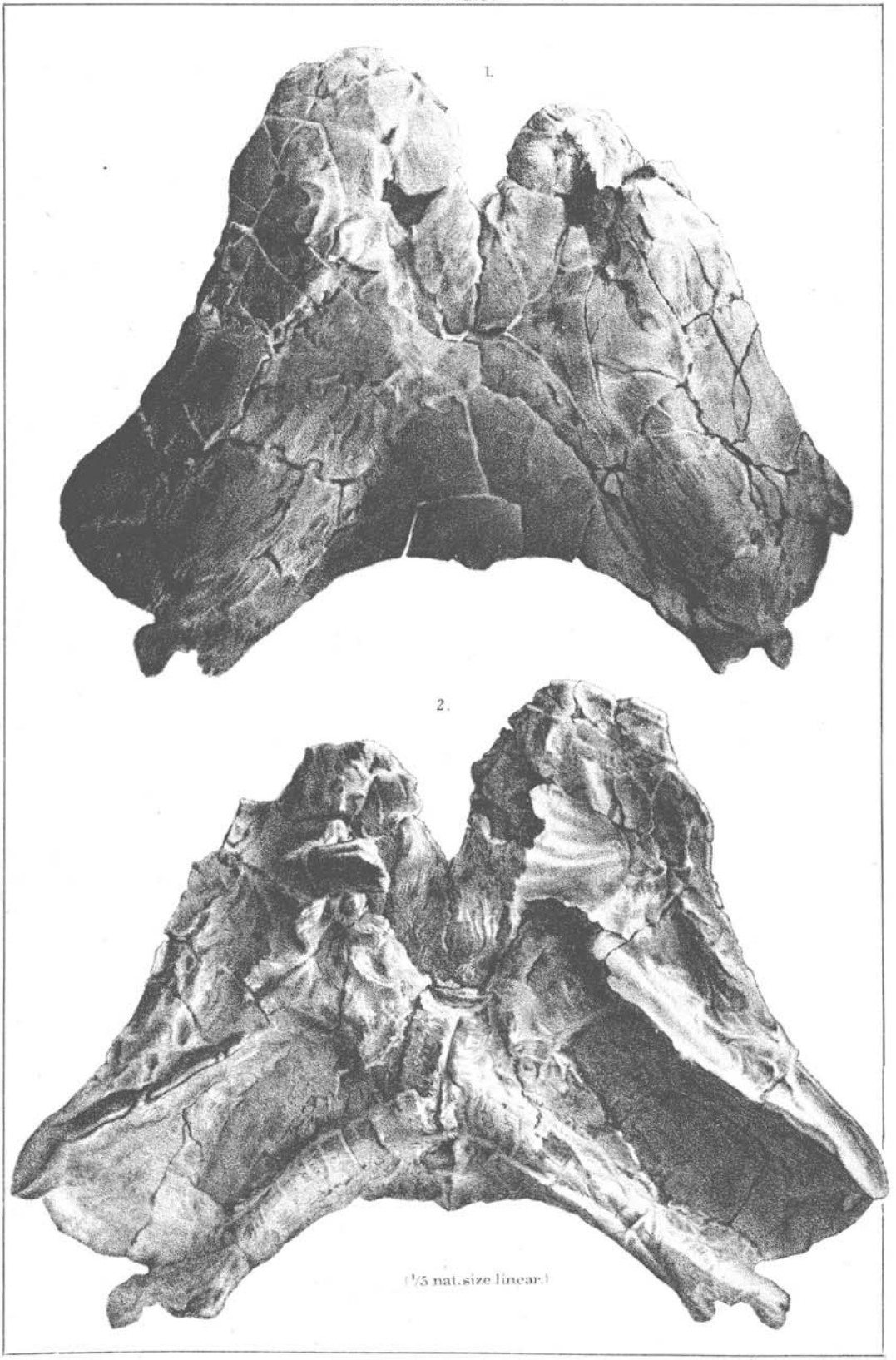
Fig. 2. Posterior portion of cranium, interior view, one-third natural size, linear.

The largest specimen found of the cranium of *Dinichthys Hertzeri* is twenty-four inches wide near its posterior extremity.

Huron Shale, Sheffield, Lorain County, Ohio.

Geological Survey of Ohio.

(Huron Shale.)



Thos Sinclair & Son lith. Phila.

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PLATE XXXIV.

Fig 1. Supra-scapular of right side, interior face, one-fifth natural size, linear.
1 *a*. Anterior edge of Fig. 1.

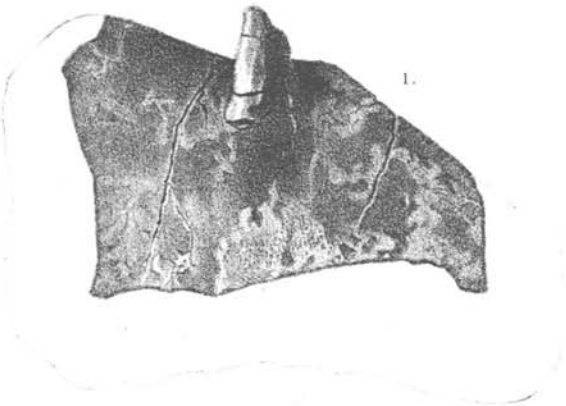
Fig. 2. Supra-scapular of left side, interior face, one-fifth natural size, linear.
2 *a*. Exterior face of Fig. 2.

Fig. 3. *Os articulare capitis* of right side (right posterior angle of head), exterior face, one-fifth natural size.
3 *a*. Interior face of Fig. 3.
3 *b*. Posterior edge of Fig. 3, profile view, showing articulation with Fig. 1 *a*.

Fig. 4. *Os articulare capitis* of left side, interior face, one-fifth natural size, from same individual as Figs. 2 and 3.

All from Huron Shale, Sheffield, Lorain County, Ohio.

(Huron Shale.)



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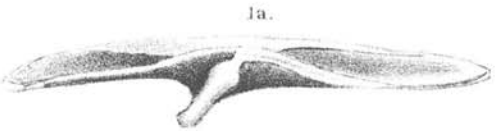

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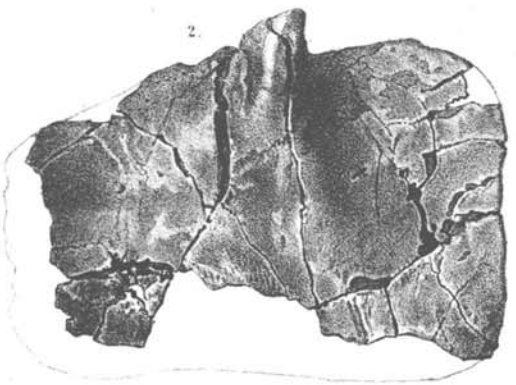

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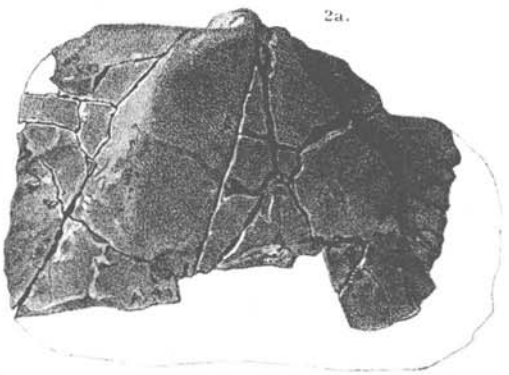

2a.

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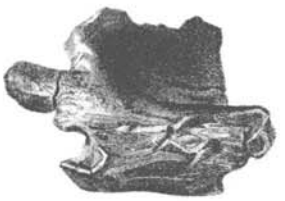

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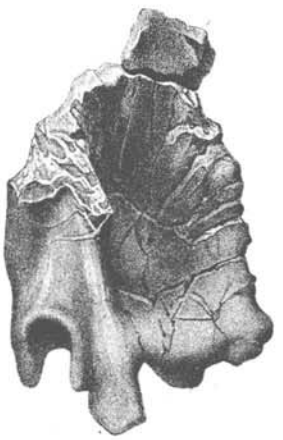

1/5 nat. size. Linear.

Bettendorf & Son lith. Phila.

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PLATE XXXV.

PAGE.

Fig. 1. ASPIDICHTHYS CLAVATUS. Newb 323

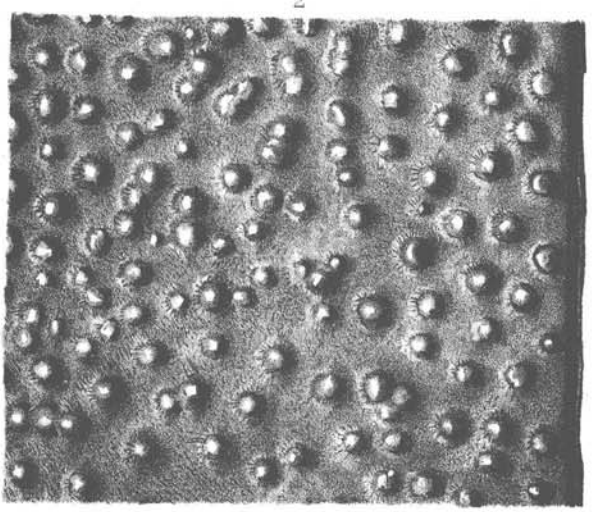
Dorso-median shield, one-fourth natural size, linear. (Size of incomplete plate, seventeen by thirteen inches.)
Huron Shale, Delaware, Ohio.

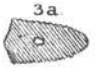
Fig. 2. ASPIDICHTHYS CLAVATUS. Newb 323

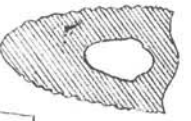
Portion of dorsal shield drawn natural size, to show tuberculation.
Huron Shale, Delaware, Ohio.

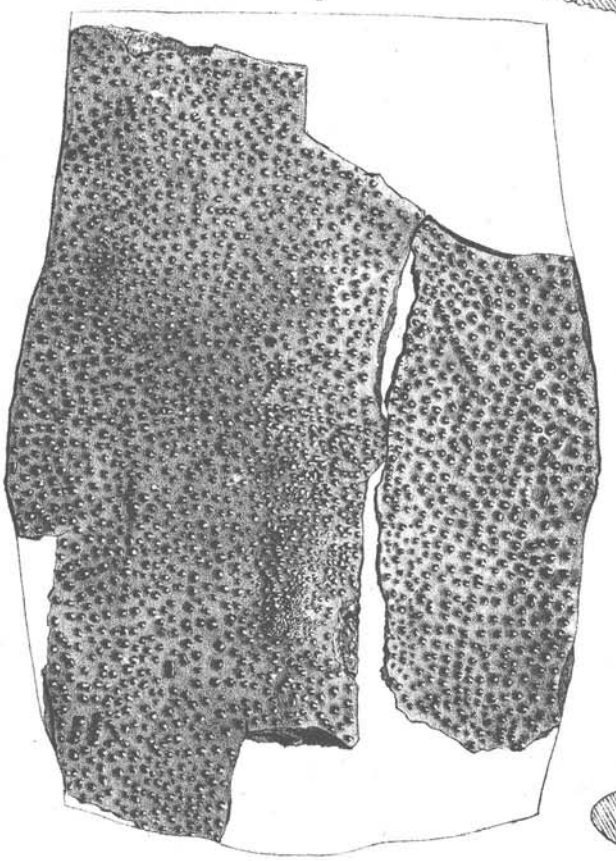
Fig. 3. CTENACANTHUS VETUSTUS. Newb 326

Side view, natural size.
3 *a* to 3 *d*. Sections of same.
Huron Shale, Sheffield, Lorain County, Ohio.









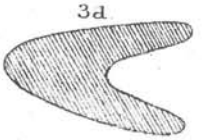


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PLATE XXXVI.

PAGE.

Fig. 1. CTENACANTHUS TRIANGULARIS. Newb..... 329

Lateral surface.
1 *a*. Posterior face.
1 *b*. Section.
All natural size.
Waverly, Oil Creek, Penn.

Fig. 2. CTENACANTHUS FORMOSUS. Newb..... 328

Lateral surface, natural size.
2 *a*. Posterior face, showing denticles magnified.
2 *b*. Lateral surface magnified.
Waverly, Vanceburgh, Ky.

Fig. 3. CTENACANTHUS MARSHI. Newb..... 326

Lateral surface.
3 *a*. Posterior face, natural size.
3 *b*. Section.
Coal Measures, Zanesville, Ohio.

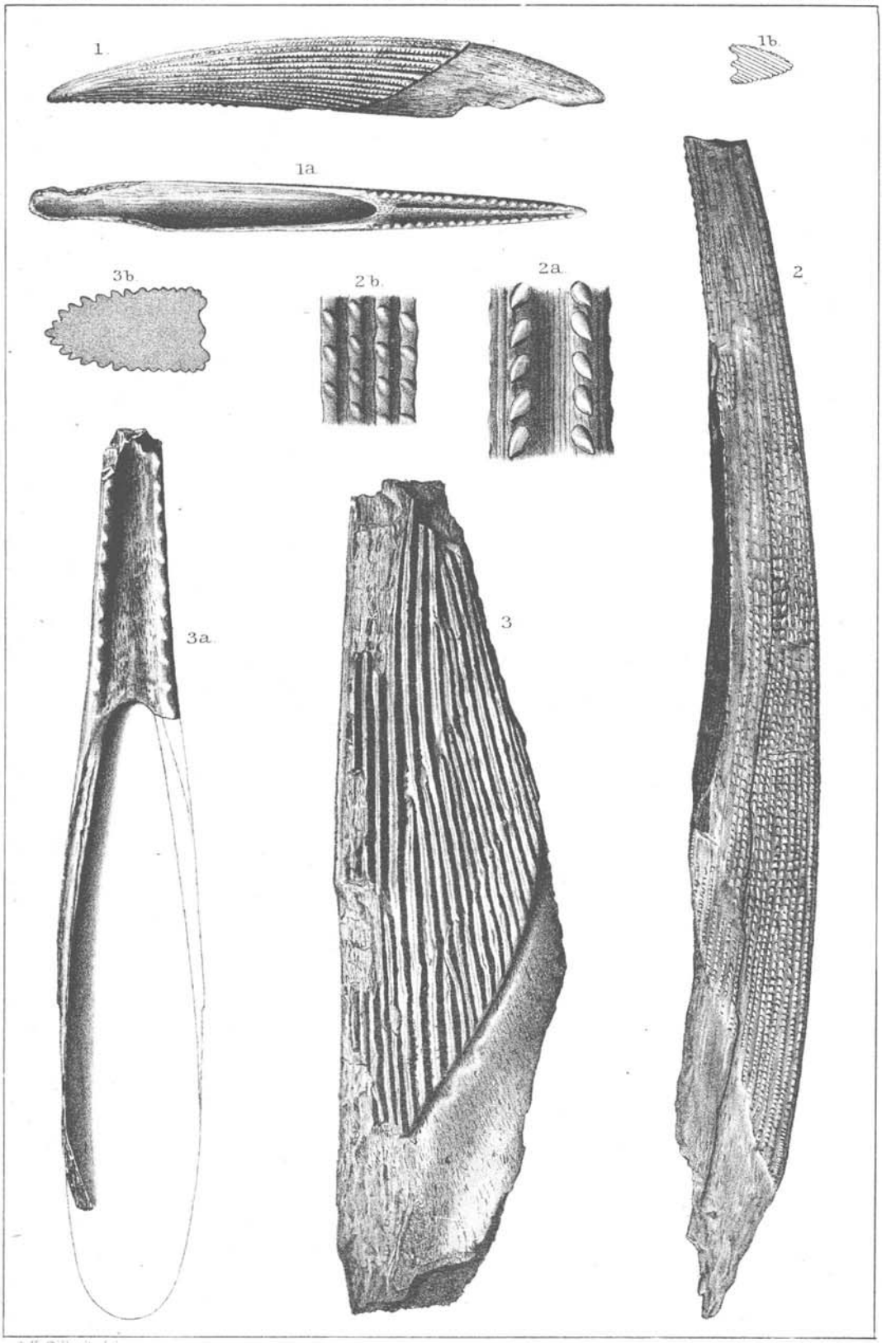

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PLATE XXXVII.

PAGE.

Fig. 1. GYRACANTHUS COMPRESSUS. Newb..... 330

Lateral surface.
1 *a*, 1 *b*. Sections of the same.

Fig. 2. GYRACANTHUS COMPRESSUS. Newb..... 330

Fragment of a large specimen from Dearborn, Indiana, lateral surface.
2 *a*. Posterior face of same.
2 *b*. Section of same.

Fig. 3. GYRACANTHUS ALLENI. Newb..... 331

Lateral surface.
3 *a*. Posterior face.
3 *b*. Anterior face, showing exposed and inserted portions.
3 *c*, 3 *d*. Sections of same.

Figs. 1 and 3 from Cuyahoga Shale (Waverly), Bagdad, Medina County, Ohio.

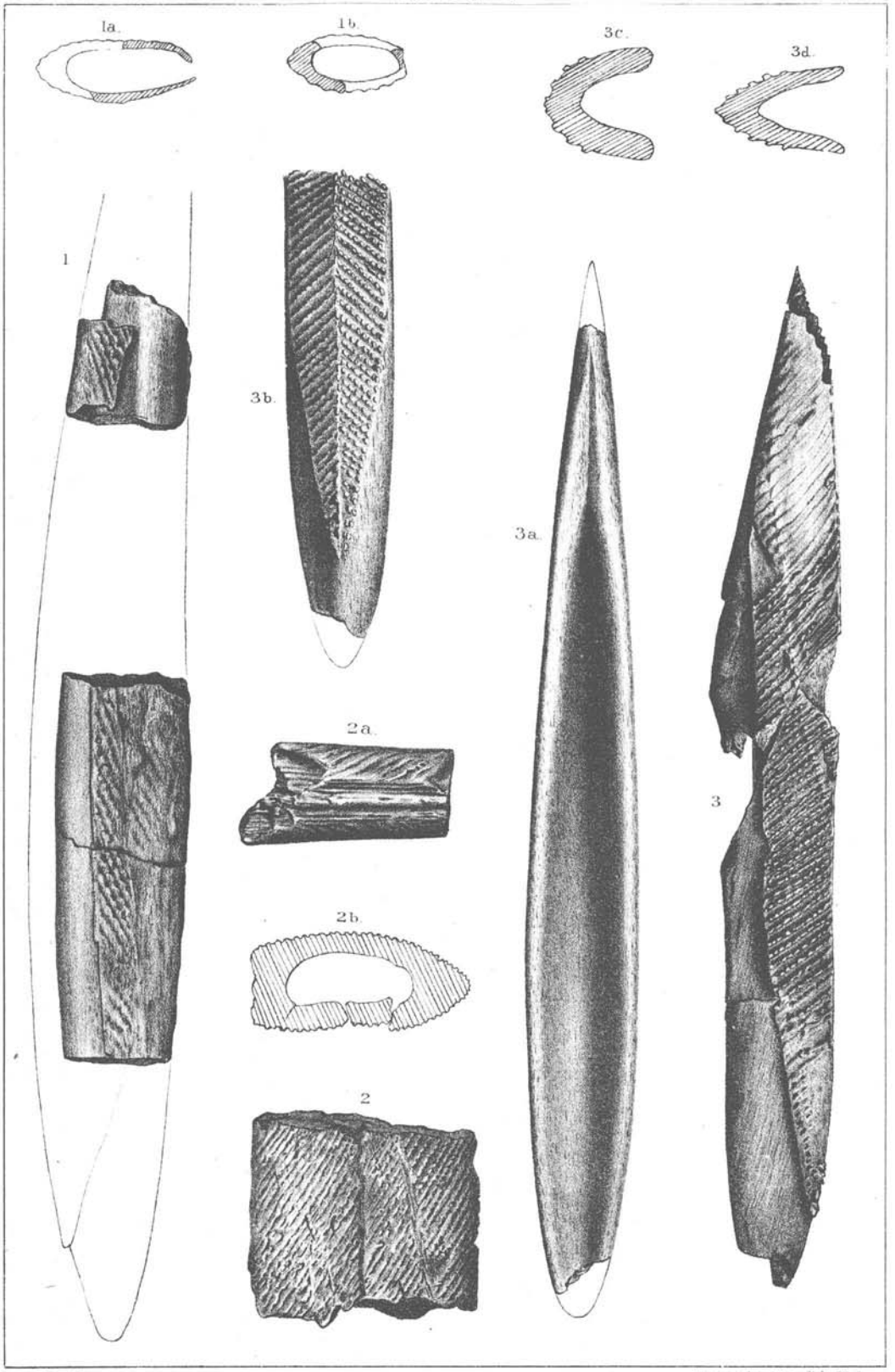

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PLATE XXXVIII.

PAGE.

Fig. 1. PALÆONISCUS PELTIGERUS. Newb. 345

1 *a*, 1 *b*. Scales of same.

Fig. 2. EURYLEPIS TUBERCULATUS. Newb. 350

2 *a*, 2 *b*. Scales of same, enlarged.
2 *c*. Cranial plates of same, enlarged to show ornamentation.

Fig. 3. EURYLEPIS TUBERCULATUS. Newb. 350

Another individual.
3 *a*. Scale, enlarged.

Fig. 4. EURYLEPIS CORRUGATUS. Newb. 350

4 *a*. Scale of same.

Fig. 5. Tail of a Crustacean.

All from Cannel Coal forming bottom of Coal Seam No. 6, Linton, Jefferson County, Ohio.

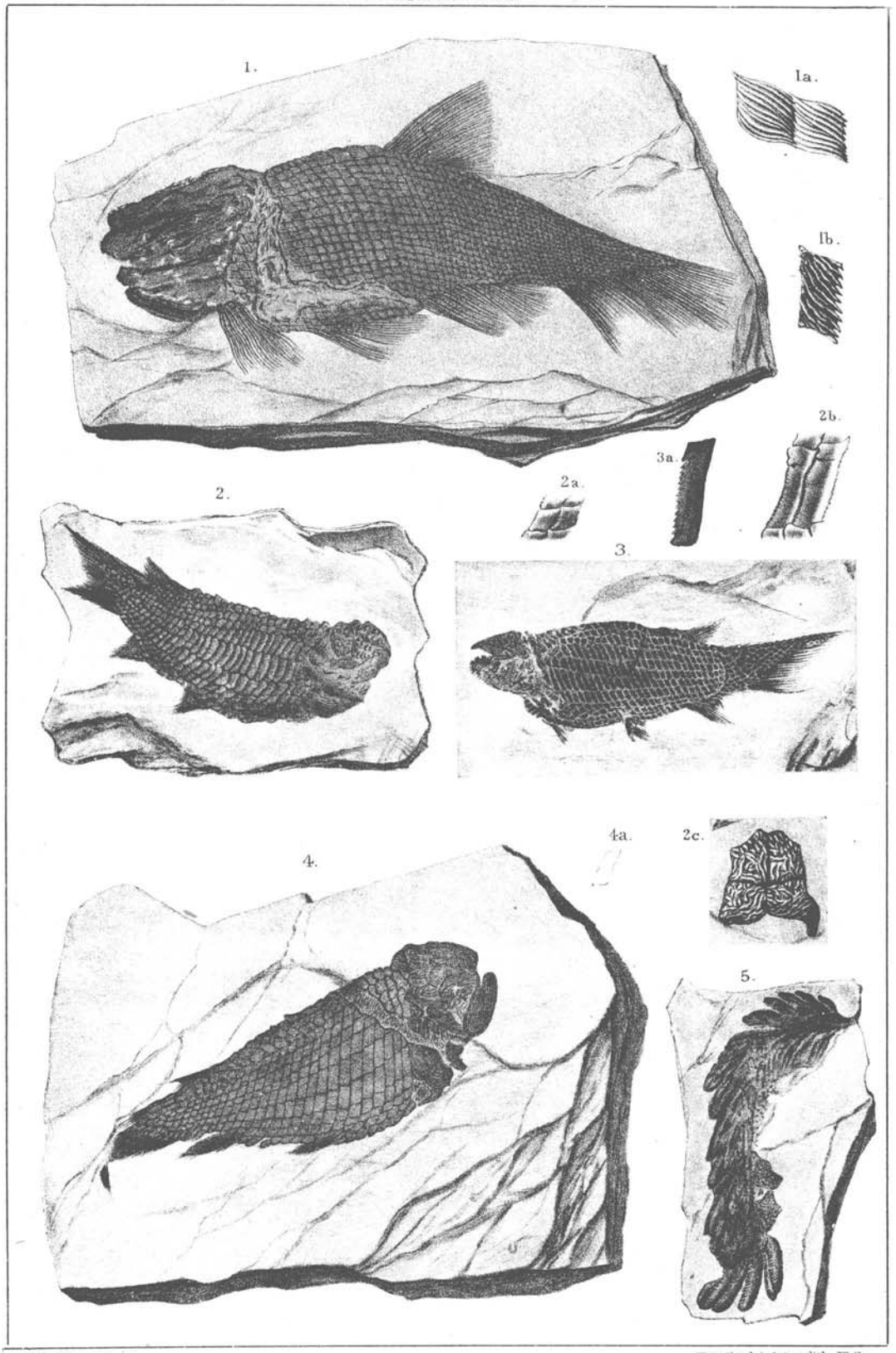

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PLATE XXXIX.

PAGE

Fig. 1. EURYLEPIS OVOIDEUS. Newb..... 351
Natural size.

Fig. 2. EURYLEPIS INSCULPTUS. Newb..... 351
Natural size.
2 *a*. Scale of same, enlarged to show ornamentation.

Fig. 3. EURYLEPIS MINIMUS. Newb..... 353
Natural size.

Fig. 4. EURYLEPIS ORNATISSIMUS. Newb..... 352
Natural size.
4 *a*. Scale of same, enlarged.

Fig. 5. EURYLEPIS GRANULATUS. Newb..... 352
Natural size.
5 *a*. Scale of same, enlarged.

Fig. 6. RHIZODUS ANGUSTUS. Newb..... 342
Portion of jaw with attached teeth, natural size.

Fig. 7. EURYLEPIS LINEATUS. Newb..... 353
Natural size.
7 *a*. Scale of same, enlarged.

Fig. 8. RHIZODUS QUADRATUS. Newb..... 343
Scale, natural size.

Fig. 9. RHIZODUS LANCIFER. ewb..... 342
Tooth, natural size.

All from Cannel Coal forming base of Coal Seam No. 6, Linton, Jefferson County, Ohio.

Geological Survey of Ohio.

CARBONIFERDUS, (Coal Measures.) PLATE 39.

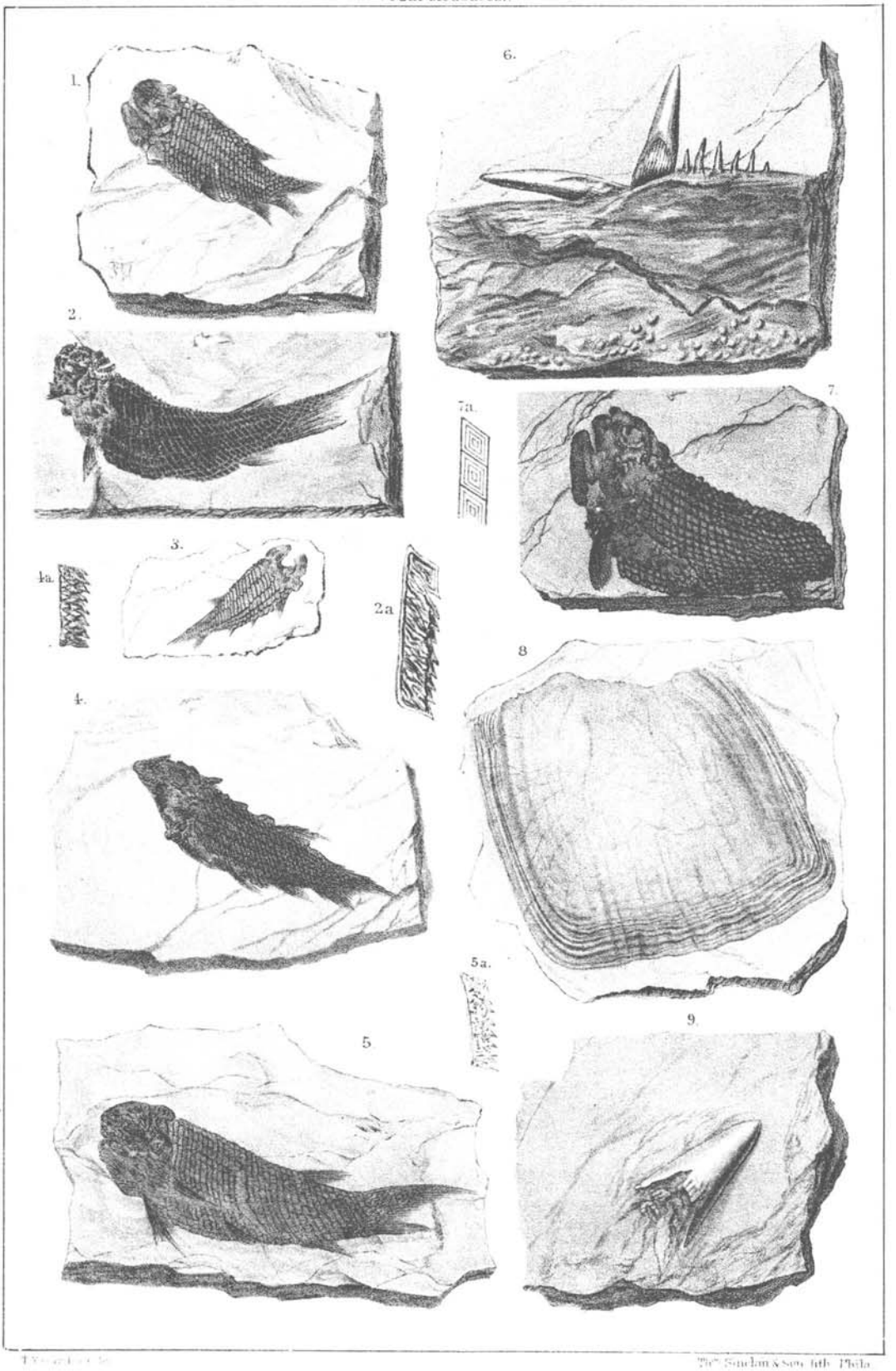

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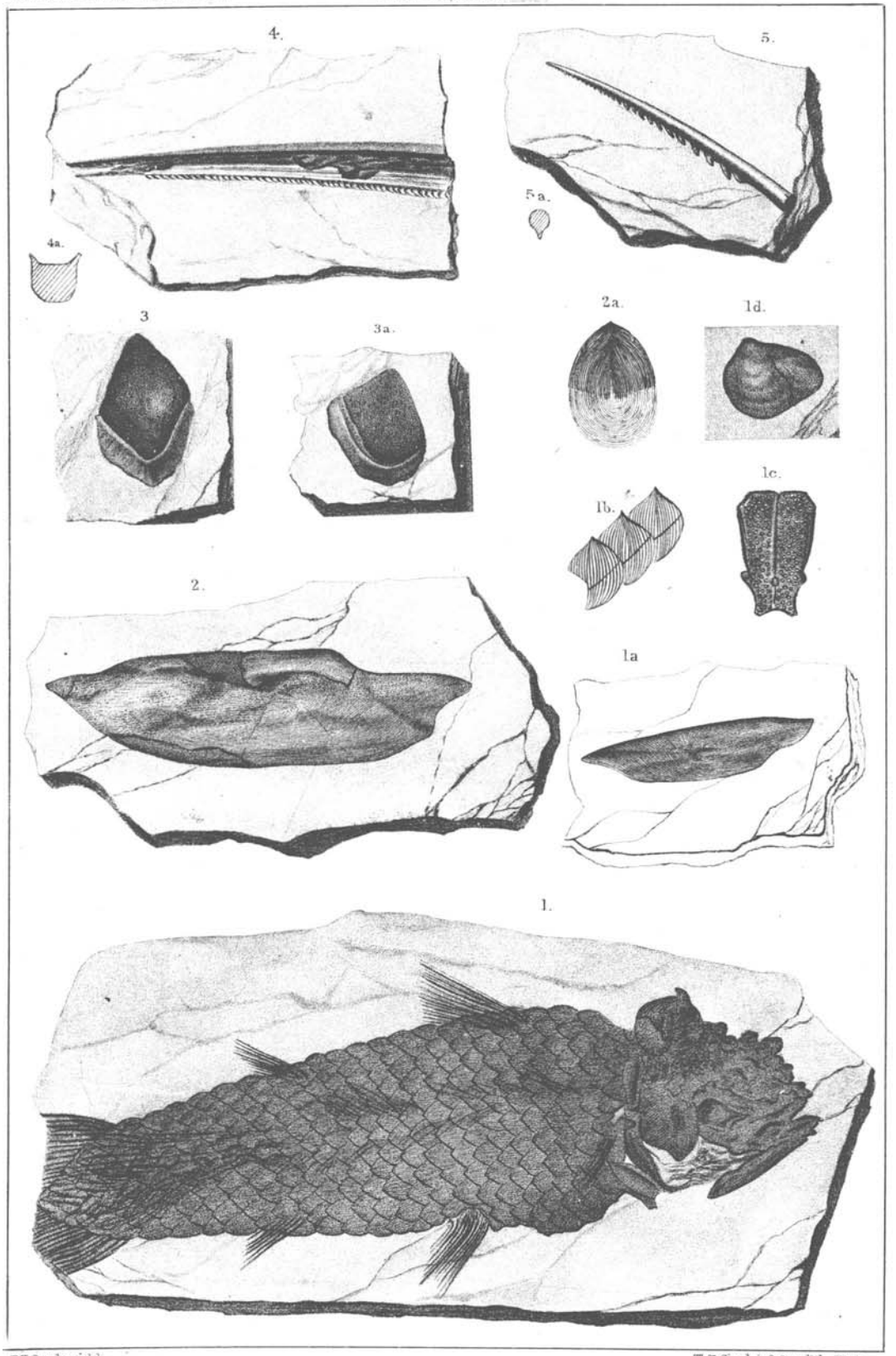
PLATE XL.

All from Coal No. 6, Linton, Jefferson county, Ohio,



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