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PRELIMINARY NOTES ON THE DISCOVERY OF A VERTEBRATE FAUNA IN SILURIAN (ORDOVICIAN) STRATA

BY

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CONTENTS.

HISTORY OF THE DISCOVERY.

The first discovery known to me of lower Paleozoic fossils in the vicinity of Canyon City, Colorado, was made in 1887 by Mr. S. F. Emmons, of the United States Geological Survey. The collection included two species of lamellibranch shells and one species of gasteropod. After examining the specimens, I requested Mr. Emmons to have a larger collection made from the same horizon, as the species indicated an unrecognized Paleozoic fauna in Colorado. Mr. T. W. Stanton was employed by Mr. Emmons to collect from the sandstones and limestones above the Archean, and a collection was sent in by him accompanied by a sketch of several sections. About the same time Mr. I. C. Russell, of the Geological Survey, while stopping at Canyon City, collected from the lower sandstone a number of specimens of *Lingula* and several portions of the calcified covering of what is now considered to be the chordal sheath of a fish. The preliminary

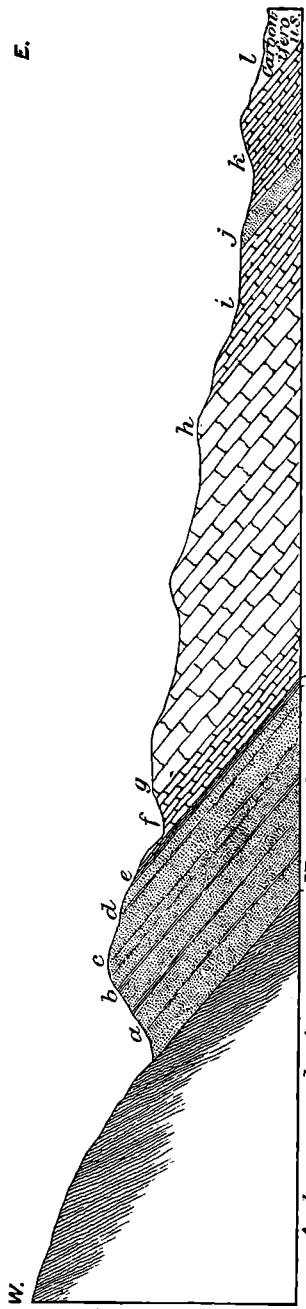

FIGURE 1.—*Diagramatic Section of the Canyon City Silurian (Ordovician) Rocks.*

a = Lowest fossiliferous bed of the Harding sandstone; *b c* = Shaly beds in which fish remains are abundant; *d* = Bed in which the Harding sandstone quarry is located; *e* = Shales above the sandstone; *f* = Limestone at base of Fremont limestone, in which the Trenton fauna is abundantly represented; *g h* = Lower impure limestone; *i* = More or less pure limestone with a few fossils; *j* = Sandstone parting; *k* = Upper horizon of the Trenton fauna; *l* = Carboniferous limestone.

examination of the collection obtained by Mr. Stanton proved the presence of the Trenton fauna in the limestone series above the sandstones. When examining a small fragment of sandstone upon which some lamellibranch shells occurred I discovered upon the lower side what appeared to be fragments of placoderm fish plates. Mr. Stanton was then requested to make a larger collection from the sandstone and to carefully review the stratigraphy of the section. This he did, and from his stratigraphic sections it was evident that the fish remains occurred beneath an invertebrate fauna having a Trenton facies, and an examination of the material disclosed the presence of a large number of plates of placoderm fishes of the types of those of the lower Devonian fauna.

Owing to the great interest of the discovery, and in order to make myself fully acquainted with the succession of the strata and mode of occurrence of the faunas before it was announced, I went to Canyon City in December, 1890, and studied the section in detail and collected largely from the lower sandstone and the immediately superjacent limestone. Mr. Stanton's stratigraphic sections were verified, and the débris was cleared away at critical points so as to photograph the

contact of the sandstone with the subjacent pre-Paleozoic rocks and with the superjacent shales and limestone; views were also obtained of the entire section from this point to the overlying Carboniferous limestone. After my return a brief notice of the presence of an icthyic fauna near Canyon City, Colorado, in association with an Ordovician fauna was read before the Biological Society of Washington on February 7th, 1891.

Description of the Locality.

Canyon City, Colorado, is situated near the southwestern shore of a bay of early Silurian (Ordovician) and probably also of pre-Cambrian time. The outcrop of pre-Cambrian rocks of the Rocky mountain front breaks away south of Pikes peak and sweeps with a broad inward curve to the westward, and thence southeastward past Canyon City before extending eastward to the meridian of Pikes peak. Along the central part of the western shore of this bay sediments were deposited in Silurian (Ordovician) time that at present form massive beds of sandstone and limestone extending several miles northward and southward on the flanks of the pre-Cambrian or Algonkian rocks west and northwest of Canyon City. The valley of the Arkansas river cuts the outcrop a mile west of the town and erosion has removed it in places, but it is practically continuous for ten miles north of the river, and isolated outcrops occur three miles southward toward and into Webster park. The typical section was measured in the immediate vicinity of Harding's quarry, which is about one mile northwest of the state penitentiary at Canyon City.

The Harding Quarry Section.

The section begins near a spring a little way west of the Harding sandstone quarry, and is carried on the strike of the beds so that it terminates nearly a mile north of the quarry. This is done in order to secure contacts from layer to layer all the way from the base to the summit. The basal bed of sandstone rests unconformably upon Algonkian bedded gneiss and micaceous schists that dip to the eastward at high angles, 60°–75°. The succession is as follows:

	Feet.
1. *a*—Coarse, light gray sandstone	5
b—Compact thinly bedded reddish and gray sandstone passing into a gray and more massively bedded somewhat friable sandstone that changes, at 25 feet up, into a purplish-tinted somewhat coarse friable sandstone (strike, N. 10° E. (mag.); dip, 40° E.)	33
Fossils.—A few scattered fish scales were noticed in the purple beds and *Lingula attenuata*, Salter (?), 20 feet from the base. The beds are penetrated by an immense number of annelid borings, and the surfaces of the purplish-tinted layers are often	

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a network of the casts of the borings. On the southern side of the Arkansas river, two miles south of the section, there were found in a stratum 20 feet above the Algonkian rocks numerous lamellibranchs, a few gasteropods, and numerous fragments of the plates and scales of placo-ganoid fishes.

c—Reddish-brown sandy shales that are partially calcareous in some layers 7

Fossils.—Fish plates in great abundance and, in the calcareous layers, *Orthoceras multicameratum*, Hall (?), *Beyrichia* (like *B. fabulites*, Conrad), and several species of lamellibranchs (see list, page 158).

d—Massively bedded gray and reddish sandstone, with thin irregular beds of reddish-brown sandy shale in the lower portion 20

Fossils.—Fish plates and scales of fish are numerous in the lower portion and also in a reddish-brown capping of the massive bed in which the Harding quarry is located. The supposed chordal sheaths occur scattered through this bed and also more rarely in *b*, *c* and *e*.

e—Fine-grained argillaceo-arenaceous shale 3
Gray and buff sandstone 7
— 10

f—Coarse purplish-tinted sandstone in several layers, with gray layers above 11

Fossils.—Plates and scales of fish.

Total sandstone 86

Observations on the Harding Sandstone Series.—The lower bed is a shoreline deposit following the advance of the sea upon the land; it is formed of coarse grains of quartz and small quartz pebbles imbedded in a fine arenaceous matrix. The succeeding layers of sandstone have more or less calcareous matter in the matrix. Their contained acephalous shells, drift-worn plates and scales of fishes, and the vast number of casts of annelid borings, all prove the littoral origin of the sediments. The fish plates and scales are scattered more or less throughout the beds, but they are very abundant in four principal zones, viz, *c* of the section; near the base, and again near the summit of *d;* and at the summit of *e*. In *c* they are commingled with remains of *Orthoceras* and with acephalous mollusks and gasteropods. The closing deposit of the sandstone series is formed of a coarse drifted sand, containing numerous fragments of larger fish plates than those below. The change to the succeeding shaly beds is abrupt, and apparently due to the deepening of the water and the cessation of arenaceous deposits.

2. Red and purple fine-grained argillaceo-arenaceous shale 2–4

Fossils.—Rolled and worn fragments of fish plates occur in the lower portion.

3. Gray silicious magnesian limestone, somewhat ferruginous in the lower portion. Locally, this decomposes to a reddish, friable rock and soil; the entire mass above 25 feet from the base weathers into rough, irregular cliffs with numerous shallow caverns and holes of various sizes and forms 170

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Fossils.—The lower layers are, in places, made up largely of the casts of corals and mollusks, but well preserved specimens are rare. Corals were observed in abundance in the lower 10 feet of the limestone on the northern side of the road leading from Canyon City to Parkdale, a little east of where it enters on the pre-Paleozoic rocks. In the lower three feet at the Harding quarry and immediately toward the north there have been collected the species mentioned in the list, pages 159, 160.

4. *a*—The upper portion of 3 passes into a hard, compact, light-colored limestone..... 45

Fossils.—*Zaphrentis* and fragmentary casts of gasteropods.

b—Dark reddish-brown sandstone..... 10

c—Compact, hard light gray limestone breaking into angular fragments and with a band of purple and gray calcareo-arenaceous shale at the base..... 45

Fossils.—A large and varied fauna occurs of a Trenton type (see list, pages 161, 162).

5. Impure variegated banded limestone with interbedded sandstones and argillaceous beds..... 15–30

Fossils.—*Spirifera rockymontana, Athyris subtilita.*

Observations on the Fremont Limestone Series.—The line of demarkation between the upper beds of the Silurian (Ordovician) and the superjacent limestones in which Carboniferous fossils occur is not strongly defined, although it represents a long period of non-deposition and a great time break. The Carboniferous limestones are sometimes brecciated and lithologically unlike those below. No traces of the Silurian and Devonian groups have been obtained.

The bed of shale (number 2 of the section) is very persistent along the six miles of outcrop examined. Fragmentary fish plates and scales occur in the lower portion, but they were not observed in the upper part nor in the superjacent limestones. The shale appears to include the closing deposit of the ichthyic fauna in this region.

The basal layer of limestone resting on number 2 is in many places almost entirely made up of casts of fossils that crumble into a red dust when the rock is broken. At a few localities they are better preserved, and 54 species in all were collected. Traces of fossils occur all the way through the 170 feet of impure limestone, but it is not until the upper portion of number 4 of the section is reached that well-preserved specimens occur. In number 4*c*, 57 species have been recognized, only 7 of which occur in number 3.

The character of the sediments from the basal sandstone to the uppermost layer of limestone beneath the Carboniferous breccia indicates that they were deposited in a bay or interior sea that was protected from the open ocean. After the epoch of the accumulation of the beach sands and

shales the water deepened, the ichthyic fauna disappeared, and the typical invertebrate fauna of the Trenton epoch of New York flourished and was imbedded in the calcareous sediments. The study thus far made of the upper portion of the Silurian (Ordovician) section and the Carboniferous strata has not shown the presence of Silurian or Devonian strata. If deposited in this region they were eroded away by the Carboniferous sea. The study of the breccias resting on the Carboniferous, or forming its upper portion, may possibly throw some light upon this interval. Mr. Stanton considers that the detailed sections give evidence of at least two, and perhaps three, periods of upheaval and erosion from the Silurian (Ordovician) to the Trias, inclusive.

The Invertebrate Fauna.

Harding Sandstone.—The invertebrate fauna of the sandstone series is molluscan with the exception of one species of crustacean. As would be expected in such a deposit, the acephalus mollusks number more than one-half of the species of the entire fauna. The largest number of specimens were collected in *b* and *d* of the section, figure 1. The fauna has been partially identified and will be more thoroughly studied when the collections now being made are available. The genera and species recognized are as follows:

BRACHIOPODA.

Lingula, like *L. attenuata*, Salter, and *L. belli*, Billings.

LAMELLIBRANCHIATA.

Modiolopsis, like *M. trentonensis.*
" 3 sp. undet.
Cypricardites, like *C. ventricosa*, Hall.
" like *C. rotundata*, Hall.
Cypricardites, 2 sp. undet.
Orthonota, sp. undet.
Tellinomya, 3 sp. undet.

GASTEROPODA.

Helicotoma, sp. undet.
Pleurotomaria, sp. undet.
Murchisonia, sp. undet.

CEPHALOPODA.

Orthoceras multicameratum, Hall.
Cytoceras, sp. undet.

CRUSTACEA.

Leperditia, type of *L. fabulites*, Conrad.

Summary.

	Genera.	*Species.*	*Species identified.*
Brachiopoda	1	1	1 (?)
Lamellibranchiata	4	12	3
Gasteropoda	3	3	0
Cephalopoda	2	2	1
Crustácea	1	1	1
Total	11	19	6
Recurrent above	9	1	1
Limited to	2	18	5

The presence of forms apparently identical with *Lingula attenuata*, *Modiolopsis trentonensis*, *Cypricardites ventricosa*, *C. rotundata*, *Orthoceras multicameratum*, and *Leperditia fabulites* leads to the conclusion that the Trenton fauna is represented, and (from the known range of those species in the New York section) that the fauna is lower Trenton or that of the Black River and Birdseye limestones. This is further sustained by the occurrence of the Trenton fauna higher up in the section.

Only one species (*Orthoceras multicameratum*) is known to range upward into the limestone, although it is probable that some of the species of lamellibranchs may be found to be identical in the two formations.

Fremont Limestone.—The fauna of the base of the limestone, number 3 of the section, extends through some earthy and semicrystalline layers ranging from 4 to 10 feet above the upper bed of sandstone. It is large and varied, and contains the following genera and species, as determined in the preliminary study of the fauna:

PROTOZOA.

Stromatopora, sp. undet.
Receptaculites, sp. undet.
Receptaculites oweni, Hall.

ACTINOZOA.

Streptelasma, sp. undet.
Zaphrentis, sp. undet.
* *Halysites catenulatus*, Linn.
Monticulipora, sp.?
Phyllopora, sp. undet.
* *Columnaria alveolata*, Goldfuss.
Favosites, sp. undet.
Heliolites, sp.?

ECHINOZOA.

Echinosphærites, n. sp.
Glyptocrinus, sp. undet.

BRACHIOPODA.

* *Strophomena alternata*, Conrad.
* *Streptorhynchus filitextum*, Hall.
Orthis tricenaria, Conrad.
" sp. undet.

BRACHIOPODA—Continued.

Streptorhynchus sulcatum, Verneuil.
" sp. undet.
Orthis biforata, Schlotheim.
" *flabellum*, Sv.?
* " *subquadrata*, Hall.
**Rhynchonella capax*, var. *increbescens*, Hall.
Rhynchonella dentata, Hall.
Camarella, sp. undet.

LAMELLIBRANCHIATA.

Ambonychia bellastriata, Hall.
" 2 sp. undet.
Modiolopsis plana, Hall.
Modiolopsis, 2 sp. undet.
Cypricardites, 2 sp. undet.
Tellinomya, sp. undet.

GASTEROPODA.

Metoptoma, sp. undet.
Helicotoma (casts of the interior).
Murchisonia tricarinata, Hall.
" 2 sp. undet.
Cyclonema bilex, Conrad.
" *percarinata*, Hall?
" sp. undet.
Bellerophon bilobatus, Sow.

CEPHALOPODA.

**Endoceras proteiforme*, Hall.
Ormoceras tenuifilum, Hall.
" *crebriseptum*, Hall?
Orthoceras vertebrale, Hall.
" *multicameratum*, Hall.
Gomphoceras powersi, James?
" sp. undet.
Cytoceras, 2 sp. undet.
Lituites, sp. undet.

TRILOBITA.

**Asaphus*, like *A. platycephalus* (fragment of pygidium).
Illænus crassicauda, Wahlen.
* " *milleri*, Billings.

Summary.

	Genera.	*Species.*	*Species identified.*
Protozoa	2	3	1
Actinozoa	8	8	2
Echinozoa	2	2	0
Brachiopoda	5	12	9
Lamellibranchiata	4	9	2
Gasteropoda	5	9	4
Cephalopoda	6	9	6
Trilobita	2	3	2
Total	34	55	26
Recurrent above	19	9	9
Confined to	15	46	17

Of this fauna *Halysites catenulatus*, *Columnaria alveolata*, *Strophomena alternata*, *Streptorhynchus filitextum*, *Orthis subquadrata*, *Rhynchonella capax* var. *increbescens*, *Endoceras proteiforme*, *Asaphus platycephalus* (?), and *Illænus milleri* extend up to the next strongly marked fossiliferous horizon, 215 feet above. Without exception, all these species have an extended vertical range in the Silurian (Ordovician) strata either in North America or Europe. The fact that 25 of the 27 identified species are identical with those of the Trenton fauna of Wisconsin and New York is sufficient to locate the horizon in the Ordovician fauna. *Halysites catenulatus* is not known from the Trenton zone elsewhere in America; but in Wales it ranges through the Bala and the subjacent Llandeilo. *Orthis flabellum* is also a Bala species. There is nothing among the unidentified species to indicate a higher horizon than the Trenton of the New York section.

Scattered and fragmentary fossils occur in the 225 feet of superjacent limestone; but it is in the beds 225 to 245 feet above the Harding sandstone that the fauna is best preserved. From this zone the following species have been collected:

ACTINOZOA.

Streptelasma corniculum, Hall.
" 2 n. sp.
Columnaria alveolata, Goldfuss.
Favosites gothlandicus, Lamark.
Pleurodictyum, n. sp.
Halysites catenulatus, Linn.
Monticulipora, 2 sp.?

ECHINOZOA.

Loose plates or segments of crinoidal columns.
Cyclocrinus, sp.?

BRACHIOPODA.

Leptæna sericea, Sowerby.
" sp. undet.
Strophomena alternata, Conrad.
" *alternata* var. *nasuta*, Conrad.
Strophomena deltoidea, Conrad.
Streptorhynchus filitextum, Hall.
" *nutans*, James.
Streptorhynchus planoconvexus, Hall.
" *planumbonus*, Hall.
" *subtentum*, Conrad (?).
Orthis subquadrata, Hall.
" *testudinaria*, Dalman (?).
Rhynchonella capax, Conrad.
" *capax* var. *increbescens*, Hall.

LAMELLIBRANCHIATA.

Pterinea, sp. undet.
Tellinomya dubia, Hall (?).
" *levata*, Hall (?).
" *nasuta*, Hall.
Tellinomya ventricosa, Hall.
Cypricardites, 3 sp. undet.
Modiolopsis faba, Conrad.
" sp.?

GASTEROPODA.

Metoptoma, sp. undet.
Helicotoma planulata, Salter.
" sp.?
Trochonema beachi, Whitfield (?).
Murchisonia milleri, Hall.
" *pagoda*, Salter.
Murchisonia, 3 sp. undet.
Subulites (?), sp. undet.
Bucania bidorsata, Hall.
" *buelli*, Whitfield.
Cyrtolites, sp. undet.

CEPHALOPODA.

Orthoceras annellum, Conrad.
" *junceum*, Hall.
Endoceras proteiforme, Hall.
Gomphoceras, sp.?

CRUSTACEA.

Leperditia, sp.?

TRILOBITA.

Ceraurus icarus, Billings.
" sp.?
Bathyurus (?), sp. undet.
Proetus (?), sp.?
Asaphus platycephalus, Stokes.
" *megistos*, Locke.
Illænus milleri, Billings.

Summary.

	Genera.	*Species.*	*Species identified.*
Actinozoa	6	9	4
Crinoidea	1	1	0
Brachiopoda	6	12	11
Lamellibranchiata	4	10	5
Gasteropoda	7	13	6
Cephalopoda	3	4	3
Crustacea	1	1	0
Trilobita	5	7	4
Totals	33	57	33

This fauna is distinctly of a Trenton facies, but as a whole it is upper Trenton or Lorraine rather than lower Trenton.

Recapitulation.—On assembling the faunas of the three fossiliferous zones, the distribution of genera and species is found to be as follows:

	Genera.	*Species.*	*Species identified.*
Harding Sandstone	11	19	6
Fremont Limestone (lower portion)	34	55	27
" " (upper portion)	33	57	33
	78	131	66
Recurrent	28	10	10
Total fauna	50	121	56

An analysis of the fauna will not be attempted at present, as the collections now being made will enlarge the data for comparisons, and the final study of the fauna will result in the identification of a greater number of species. I think sufficient data are given clearly to prove that the invertebrate fauna of the Harding sandstone corresponds to that of the lower Trenton of the New York section or the lower Bala of Wales. The fauna of the two limestones is to be compared to that of the middle and upper Trenton of America or the Bala of Europe. It is not to be expected that an absolute correlation can be made of all the genera and species common to the Colorado, Mississippi valley and New York sections. The vertical range of some genera and species will be found to vary, but as a whole the succession is the same in the several sections.

The discovery of so large and varied a fauna of Trenton facies is of great interest, irrespective of its bearing on the stratigraphic position of the ichthyic fauna. It clearly proves the continuation of the fauna of the Trenton sea from Wisconsin, Iowa and Missouri to the western side of the great interior sea.*

The range of *Halysites catenulatus* has hitherto been considered to be limited to the Niagara terrane of the American Silurian, and it has often been the sole means of identifying that horizon. With the extended range it is now known to have in the Ordovician fauna of Colorado we can speak less confidently of the stratigraphic horizon identified by its presence. In Wales and England it ranges from the Llandeilo through the Bala or Caradoc.

The Vertebrate Fauna.

General Character.—The evidence of the existence of vertebrates at this early epoch is limited to the plates and scales of ganoid fishes and what appears to be the ossified chordal sheath of a fish allied to the recent *Chimæra*. The latter correlation is based entirely upon the resemblance between the fossil form and the calcified chordal sheath of *Chimæra monstrosa*. This resemblance is too striking to be passed over, although there are certain differences that render it of less value in classification than at first appears. The *Holoptychius*-like scales and the *Asterolepis*-like plates are their own interpreters and prove their connection with the lower Devonian types with which they are compared. They are clearly the diminutive ancestral types of the great fishes that at a later date swarmed in the Devonian sea and left their remains in the classic "Old Red sandstone."

*Quite recently I received from Professor F. R. Carpenter *Maclurea logani* and *Endoceras annulatum* that were collected from a band of limestone beneath the Carboniferous of the Black Hills of South Dakota, thus establishing another outpost in the Trenton sea.

Mode of Occurrence.—The stratigraphic section shows the vertical range of the fish remains to be from about 20 feet above the base of the sandstone to its summit and one or two feet into the superjacent argillaceous shale; in all, 75 to 80 feet in the Harding quarry section. The horizontal distribution extends along some eight miles of outcrop west of Canyon City, and another locality was discovered 150 miles to the northwestward, by Mr. George H. Eldridge, on Cement peak, southeast of Crested butte, Gunnison county, Colorado. This locality is now under investigation.

In the Harding sandstone the fish remains are most abundant in a reddish, sandy shale that occurs in irregular bands at several horizons. They are also scattered irregularly through the more massive beds. This is the case with the chordal sheaths more than with the plates and scales. The latter usually occur in great numbers with only a few traces of the former, while in the massive sandstone the plates and scales are infrequent and the sheaths more or less abundant. The invasion of the sand in large quantity appears to have overwhelmed the *Chimæra*-like fish and acephalous mollusks, while the armor-plated fishes, gasteropods and cephalopods, escaped to subsequently perish and have their remains rolled about by the currents spreading the thinner and finer sandy layers. The acephalous mollusks and the sheaths occur in the latter, but less frequently. In the upper bed of coarse sandstone numerous plates and fragments of plates occur, but all are more or less injured by the trituration of the sand as they were rolled along with it. The same is true of the greater portion of the fish remains in all the shaly bands. As yet no bed has been discovered where the conditions were favorable to the preservation of the united plates or scales forming the armor of the fish.* The chordal sheaths show less evidence of abrasion, but no other portions of the same fish have been found with them.

The invertebrate fauna associated with the fish remains is largely molluscan and of sand-loving types. The exceptions to this are found in the shaly beds where the rolled fragments of gasteropods and cephalopods indicate transportation from a more congenial habitat. The numerous specimens of *Lingula* and of lamellibranch shells and the vast number of annelid borings in some portions of the sandstones indicate the conditions of the deposition of the massive layers, while the shaly bands denote the period of minimum deposition and maximum accumulation of the fragmentary fish remains and the rolled fragments of invertebrates.

Position in the geologic Series.—This has already been determined by the study of the invertebrate fauna. The fish remains occur at the horizon of the lower Trenton in America, or the relatively similar horizon, the lower Bala of Wales.

* A single specimen of *Astraspis desiderata* has been found since this paragraph was written (p. 167).

Notes on the ichthyic Remains.—Fishes have been found in the Ludlow rocks of the Silurian of England and in the Bloomfield sandstone of Pennsylvania in America, a horizon of the upper portion of the Onondaga salt group. Professor E. W. Claypole has also described certain minute spines which he considered might belong to an elasmobranch fish that he found in the Clinton terrane.* The evidence, however, is not conclusive, as they may belong to some crustacean.

It is to be noted that the middle Silurian forms thus far found belong to the two families Pteraspididæ and Cephalaspididæ, and that no representative of the great placoderms of the Devonian has been found in the true Silurian. In strong contrast to this the ichthyic fauna of the Harding sandstone appears to contain a characteristic representative of the Placodermata and Crossopterygea of the Devonian, and what appears to be a type of the Chimæroidæ. Serious objection will undoubtedly be made to the classification, as it is based entirely upon the characters of the dermal plates and scales. These, however, are so pronounced that the classification is tentatively adopted. The vertical range of the ichthyic fauna is extended downward from the middle (Upper) Silurian to the base of the Lower Silurian (Ordovician), and the conclusion is reached that the differentiation of vertebrates and invertebrates must have begun in Cambrian time.

Pending the investigation of the beds containing the fish remains and the collection of more material, it is not desirable to illustrate the invertebrate fauna or to do more than outline the characters of the fragmentary fish remains. For convenience of reference to the latter, names are applied to three of the most marked forms and illustrations are given of typical fragments of these forms. The classification is tentative.

Since some doubt was expressed, during the discussion, as to the true zoologic character of the dermal plates, microscopic sections were made of the tuberculated *Asterolepis*-like forms. These showed microscopic characters much like those found in the Devonian *Asterolepis*, and Dr. Otto Jaekel kindly offered to make a few sketches and write a brief note upon them.†

Descriptions of the ichthyic Fauna.

CHIMÆROIDEA.

DICTYORHABDUS PRISCUS, N. GEN., N. SP.

This genus and species is based on a calcified chordal sheath that has some of the structural characters of the chordal sheath of *Chimæra mon-*

* Quart. Jour. Geol. Soc. London, vol. 41, 1885, p. 48.

† This note is appended as a part of Dr. Jaekel's discussion (pp. 168–170).

strosa, except that it is open below and gives rise on the sides to what appears to have been the support of the ribs. Further description will be given in a final paper.

The principal material upon which the genus and species are founded is illustrated on plate 3. Figure 1 is a side view of a portion of a rather large sheath. It shows the close transverse rings and the projecting lateral rib sockets or supports. Figure 2 is a view from above of a portion of the sheath shown in figure 1 to display the form and arrangement of the lateral rib sockets or supports. Figure 3 is an enlargement of the surface of a chordal sheath to show the characteristic network formed by the crossing of the two series of elevated, raised, curved striæ. It is considered that these represent the fibres of the sheath, while the vertical rings shown in figures 1 and 5 are the calcified rings. The fusion of the rings and the oblique fibers give rise to the continuous calcified sheath, as in *Chimæra monstrosa*. Figure 4*a* is a transverse outline of the chordal sheath to show that is was not closed on the ventral surface, and figure 4*b* is a transverse outline cutting across the lateral extensions or rib supports. Figure 5 represents a portion of a small chordal sheath, showing its flexible nature and indicating that the larger fish must have attained considerable size.

GANOIDEA.

Sub-order Placodermata.

Family Asterolepididæ (?).

ASTRASPIS DESIDERATA, N. SP.

This type is represented by fragments of plates allied to those of *Asterolepis ornatus* of the Devonian.

The material upon which the species is founded is illustrated on plates 3 and 4. On plate 1 figure 6 shows the inner surface of a plate with a portion broken away so as to exhibit the base and transverse sections of the tubercles of the outer surface, and figure 7 represents the interior surface of a plate for comparison with figure 6. Figure 8 represents a fragment of a supposed ventral plate of the body, figure 9 a plate referred to the cephalic region, and figure 10 a small elevated tuberculated plate. Figure 11 shows the supposed inner surface of a plate similar to that represented in figure 10, and figure 12 the inner surface of a plate similar to that seen in figure 11. Figure 13 is a transverse section of a narrow, elongate plate, showing a cellular structure and the projecting tubercles. The latter expand at the summit into a round knob, the upper surface of which is cut by radiating striæ, so as to give it a star-like *Astræ*-form

appearance. This is more clearly shown in figure 14, which is a side view of the knob-like *Astræ*-form tubercle of the outer surface when unabraded. On plate 4 figure 1 represents a dermal plate with two raised tubercles and numerous small *Astræ*-form tubercles, and figure 2 is the outer surface of a supposed lateral plate. Figures 3 and 4, plate 4, represent the outer surfaces of partially abraded plates.*

SUB-ORDER CROSSOPTERYGEA.

Family Holoptychididæ.

ERIPTYCHIUS AMERICANUS, N. SP.

This species is based entirely upon the separated scales. It is not improbable that several species are represented in the material, the better preserved portion of which is illustrated in plate 4, figures 5 to 11. Figures 5 and 6 are broad scales, each showing the bearing surface or facet of the next anterior scale and the ornamented exterior surface. The latter has numerous elevated longitudinal lines upon it. Figure 7 is a fragment of a scale with irregular stellate surface ornamentation, and figure 8 another fragment of a scale of the same type. Figure 9 is a phase of surface ornamentation somewhat like that of figure 8, and figure 10 is an intermediate phase of ornamentation between that of figure 7 and those of figures 5 and 6. Figure 11 represents the interior of a narrow scale that shows the poriferous inner surface and, where broken away, the base of the elevated longitudinal lines of the outer surface.

Plate 5 illustrates the microscopic structure of the remains of both the species discriminated.

*During the fall of 1891, a portion of the head carapace of *Astraspis desiderata* was found in a very fine grained calcareous sandstone. It measures 73mm in length by 50mm in width at the posterior margin and 40mm toward the front. It is formed by the union of a great number of small plates, such as are illustrated on plate 3, figures 10–14. A median ridge formed of elevated, tuberculated plates extends from the posterior margin 43mm toward the front, very much as in the head shield of *Thyestes verrucosus*, Eichwald, from the Silurian rocks of the island of Oesel, Russia A similar ridge occurs on each side that extends forward 28mm from the posterior margin; they are 13mm from the median ridge at the base and 9mm from it at their anterior termination. A marginal ridge occurs on each side of the specimen that is continuous with the margin so far as the latter is preserved. Directly in front of the median ridge a group of 12 plates having elevated centers are clustered around a central plate that rises at the center above the others. On each side of this cluster of plates a larger plate (4 x 6mm) occurs that has six elevated tuberculated points on it. Anterior to this there is a plate with two points and another with three. Over other portions of the carapace the plates have usually only a single elevation near the center. The small *Astræ*-form tubercles occur on all the plates. The form of the portion of the carapace preserved and its appearance suggests the cephalaspian fishes of the Silurian of Russia, while the separate plates and *Astræ*-form tubercles foreshadow the Asterolepidæ of the lower Devonian.—*March, 1892.*

DISCUSSION.

Professor Dr. ZITTEL: I consider the fossils exhibited by Mr. Walcott to be dermal plates and scales of fishes. They differ considerably from everything hitherto known from Silurian strata, and show a decided resemblance to *Asterolepis* and *Holoptychius* of the Devonian rocks. Microscopic slides are needed to show with certainty the osteoblasts and the peculiar structure of the dermal ossifications of fishes.

Dr. FREDERICK SCHMIDT: I agree with Professor Zittel that the fossils are undoubtedly fish remains.

Professor E. W. CLAYPOLE: Before we can admit the existence of fishes during so early a period as the earlier Silurian, it will be necessary to use every means to prove the ichthyic character of the remains, especially the study of microscopic sections.

Professor E. D. COPE: It is very doubtful whether the remains of crossoptergyian fishes occur at so low a horizon. I consider it essential that the skeleton should be found before deciding that fishes were present, as the dermal covering of the lower vertebrate is not a reliable character in classification.

Mr. WALCOTT: Microscopic sections are being made and will be fully described in a final paper. Moreover, Mr. S. Ward Loper is collecting material in Colorado at the present time that may add materially to our knowledge of the fauna.

Dr. OTTO JAEKEL: The remains in their exterior characters do not recall the fish remains known from the Upper Silurian, but rather those of the Old Red sandstone. The resemblance to the latter becomes still more striking for the reason that the two appear in the same kind of rock and in like condition of preservation; but on closer comparison of the two it appears that the agreement is by no means so great as would seem at first sight. The forms resembling each other cannot be identified, and the fauna here spoken of exhibits types of microscopic structure that are as foreign to the Devonian as to the upper Silurian. Still, this much seems certain: that the pteraspidæ and acanthodians, dominating in the uppermost Silurian, are absent from this fauna; whereas, on the other hand, they ally themselves with the Devonian remains of Crossopterygea and placoderms and of true ganoids. Not a single fragment shows any resemblance with the placoid parts of the elasmobranchii.

*In response to an invitation from Mr. Walcott to discuss briefly the micro-structure of the fish remains, I may observe, as regards the histo-

*Note communicated after examining the slides made from the fossils.

logic state of preservation of the remains, it unfortunately leaves much to be desired. In a general way, the fossils show merely the coarser histologic structure, while the finer details are for the most part invisible. The material is in this respect somewhat in the same condition as the Devonian fish remains from the Old Red sandstone of Scotland, in which likewise the finer histologic details are usually not present, while in the remains from the Russian Devonian they are finely preserved. The state of preservation depends on the retention of the fine dentine and primitive tubules; and this again depends on their being filled with air or with a dark infiltrate. At times it is seen that in one part of the slides the fine canals are completely preserved, while in the other parts of the same preparation either (*a*) only single parts of the tubules are preserved or (*b*) the tubules are altogether invisible. In such case the outlines of the tubules are sometimes seen in oblique illumination. This is the case with our fish remains. The fine details are mostly invisible, but are preserved in some parts and may then be easily recognized with an oblique converging light. Add to this that all hard parts are more or less worn and probably changed in various ways by acids. This being premised, the micro-structure exhibits the following conditions:

Figure 1 of plate 5 shows a vertical section through a scale or a carapace fragment. In the upper part of the preparation there are seen tubercles of dentine (*D*), containing a pulp from which numerous dentine tubules run out. These are especially well preserved in part in the middle dentine tubercle, while the outlines of the pulp appear greatly corroded. These conditions are seen more distinctly in figure 2, in which two dentine tubercles lying side by side are enlarged about 70 diameters. Here not only are the dentine tubules seen well preserved, but the outline of the pulp, too, is unchanged. It is furthermore important to note in them the concentric lamination, which appears in primary connection with the dentine tubules. The concentric lamellæ do not run in uniform curves, but arch independently between the dentine tubules, the curvature being directly inward. Toward the outside the lamellæ run more uniformly parallel to the surface. This concentric building up out of lamellæ appears with like distinctness in the dentine tubercle represented in figure 3, which in its outer form reminds one of a tooth. It also greatly recalls the teeth which are described by Rohon from the blue clay of St. Petersburg. There can hardly be any doubt that this concentric structure of the hard parts represents a low stage of development. At any rate, I believe that the most essential difference between the calcified hard parts of the lower animals and those of the vertebrates consists in this: that in the former growth took place only by apposition, and that

they show merely a stratification of lamellæ lying one above the other, while in vertebrates growth takes place from within by special cells, odontoblasts or osteoblasts. The fossil proofs for the former are the dentine tubules; for the later, the outlines surrounding the osteoblasts. The former we saw in the dentine tubercles, figures 1–3; the latter are distinctly recognized in figure 4, which is enlarged to about 350 diameters. It plainly shows small, irregularly bounded hollow spaces with ramifying and anastomosing shoots. These I can only regard as true osteoblasts, peculiar to the hard dermal parts of the ganoids, inclusive of placoderms. Their existence might at once be conjectured from the outer appearance of the remains. Of course only detailed investigation can show whether they exist in all the remains here described. In the cross-section shown in figure 1 they appear to be preserved in the lower parts, yet their state of preservation there is far less perfect, so that their existence can merely be designated as probable. Briefly speaking, the observations show the following facts:

1. The existence of undoubted dentine tubules proves beyond doubt that the remains, so far as they have been microscopically investigated, belong to vertebrates.

2. The occurrence of true osteoblasts distinguishes these hard parts beyond doubt from those of the elasmobranchii and relegates them to the division of the ganoids. Enamel could not be found in the specimens studied. On account of this and by the strikingly distinct concentric lamination in the dentine tubercles, the hard parts investigated indicate a low stage of development.

Professor JAMES HALL:* In reference to the invertebrate fossils shown me as coming in above the beds containing fish remains, I need only say that they have a general Lower Silurian facies and represent in their genera and species the fauna of the Trenton period, including Birdseye, Black river, and Trenton limestones. Some of them which were pointed out as coming from the higher beds as exposed in the section seem to me to be representatives of the Hudson River horizon; for example, *Orthis (Plasæomys) subquadrata*. The abundance and large size of the specimens of *Rhynchonella increbescens* or *R. capax* seem scarcely compatible with the strict limitation of the Trenton horizon. Comparing the lists of the species which have been made, I can have no hesitation in coinciding with the determinations, thus leaving no doubt whatever of the nature and age of the deposits.

*A note communicated to the author.

With regard to the fish remains I hesitate to express any opinion beyond this, that they have a remarkable similarity to Devonian forms. The nature and mode of aggregation of the material in which they are imbedded has a most decided Devonian aspect, and had they been presented to me without other evidence, I should not have hesitated in expressing my opinion as to their Devonian age.

Description of Plates.

Plate 3.

Figures 1–5.—Various views of the supposed chordal sheath referred to *Dictyorhabdus priscus*, n. gen., n. sp.

Figures 6–14.—Dermal plates of *Astraspis desiderata*, n. sp.

Plate 4.

Figures 1–4.—Outer surface of partially abraded plates referred to *Astraspis desiderata*, n. sp.

Figures 5–11.—Various views of dermal scales referred to *Eriptychius americanus*, n. sp. It may be that several species are represented.

Plate 5.

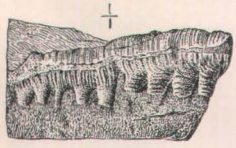
(*Greatly enlarged drawings to illustrate Dr. Otto Jaekel's remarks on the microscopic characters of the fossils.*)

Figure 1.—Cross-section through a plate with haversian canals (*V*), osteoblasts (*O*), and dentine tubercles (*D*).

Figure 2.—Two dentine tubercles enlarged to 70 diameters.

Figure 3.—Oblique section of dentine tubercle.

Figure 4.—Enlargement to 350 diameters to show osteoblasts (*O*). The margin is shown at *a*, *a*, and the rock at *R*, *R*.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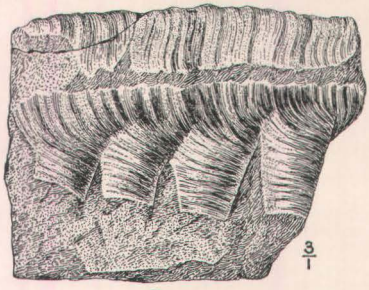
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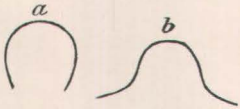
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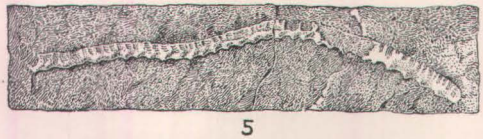
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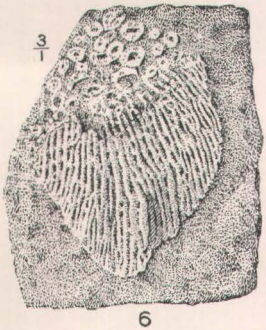
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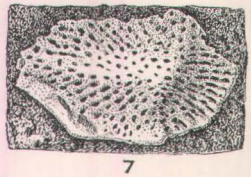
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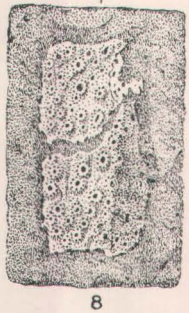
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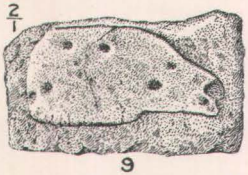
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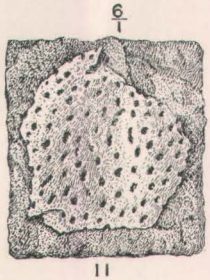
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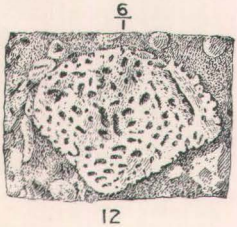
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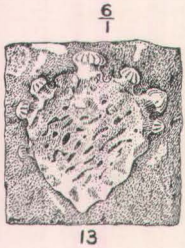
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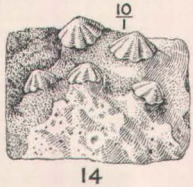
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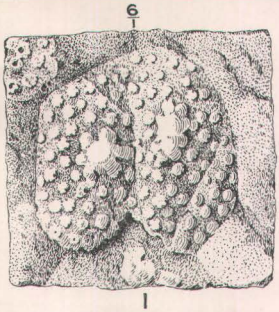
SILURIAN (ORDOVICIAN) FISH REMAINS FROM COLORADO.



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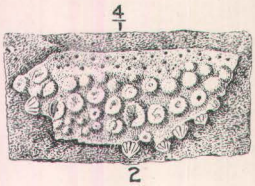

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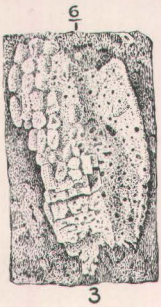

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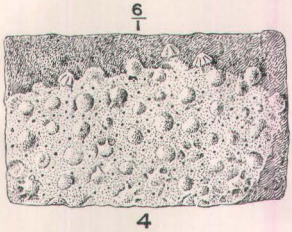

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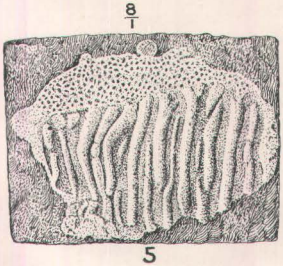

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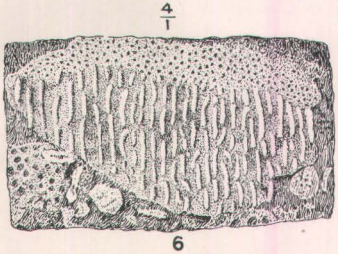

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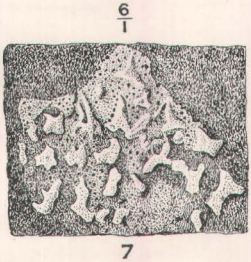

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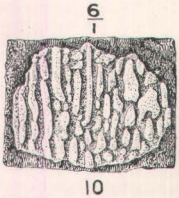

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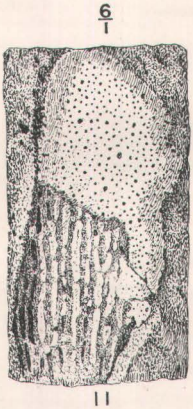

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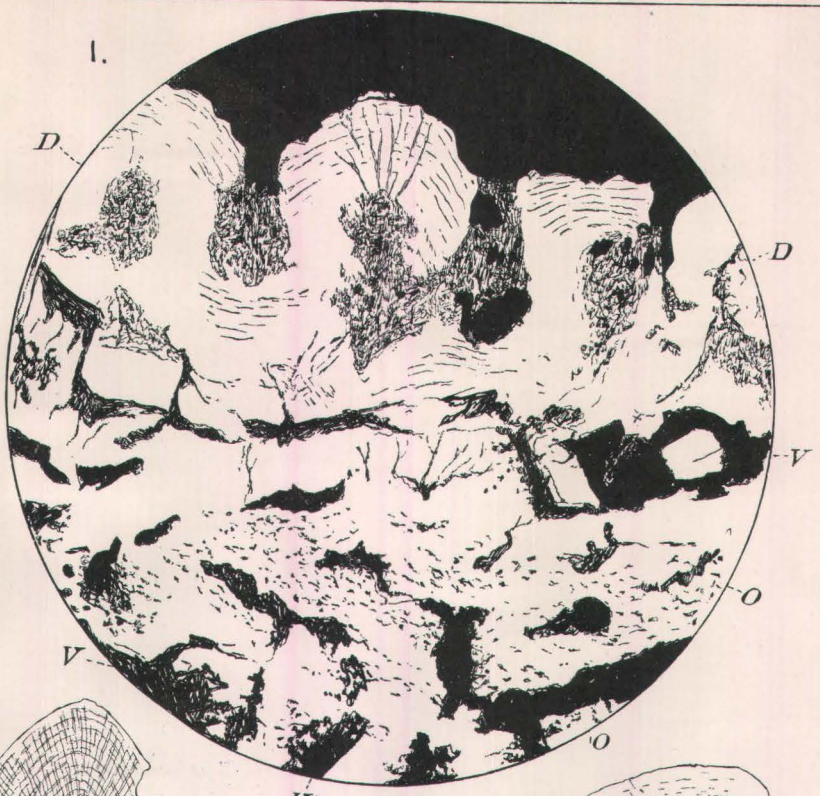
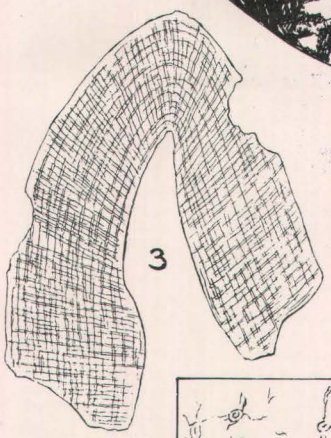
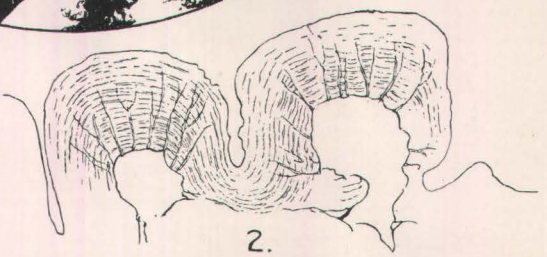
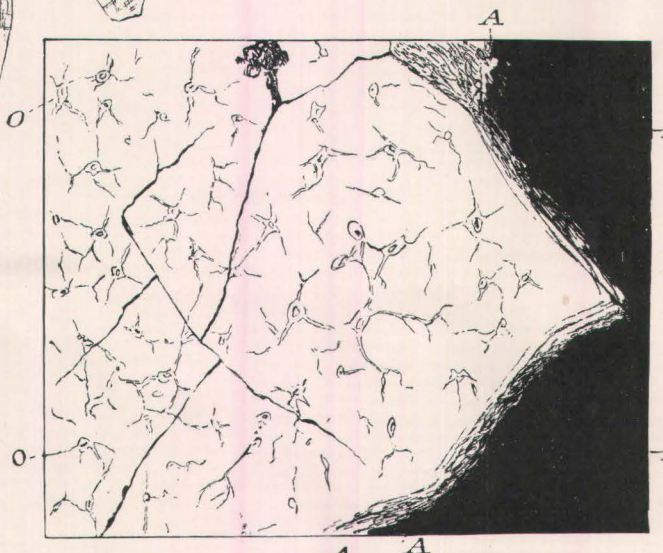
SILURIAN (ORDIVICIAN) FISH REMAINS FROM COLORADO.









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MICROSCOPIC SECTIONS OF SILURIAN (ORDIVICIAN) FISH REMAINS FROM COLORADO.