NOTES ON CERTAIN AMERICAN PALEOZOIC FISHES.

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ABSTRACT. Several new finds of American Paleozoic fish are described: *Thursius? clappi*, sp. nov., from the Devonian of Scaumenac Bay, Quebec; *Amblypterus stewarti*, sp. nov., from the Permian of Pennsylvania; and the following from the Permo-Carboniferous of Texas: *Orodus? corrugatus*, sp. nov.; *Brachyrhizodus wichitaensis*, gen. et sp. nov.; *Ctenacanthus amblyxiphias* Cope; "*Hybodus*" *copei* Hay; *Macrodontacanthus kingi* gen. et sp. nov.; "*Anodontacanthus americanus*" Hussakof; and an ossified Paleozoic shark vertebra.

DURING the past few years there have accumulated in the collections of the Museum of Comparative Zoölogy a number of interesting specimens of Paleozoic fish types which are described below. We are grateful to Dr. and Mrs. Henry S. Clapp for the Scaumenac Bay specimens noted below and to Dr. Paul R. Stewart for the privilege of describing the type of *Amblypterus stewarti*. We have profited by discussion of certain points in reference to the fossils described with Drs. A. B. Dawson, D. H. Dunkle, J. A. Moy-Thomas, E. C. Olson, C. M. Sternberg and T. S. Westoll.

THURSIUS? CLAPPI, sp. nov., a new Scaumenac Bay Crossopterygian.

(Plate 1, Figure 1).

Among a series of fish remains obtained by Dr. and Mrs. Henry S. Clapp of the University of New Hampshire from the well-known Upper Devonian fish-bearing deposits of Scaumenac Bay was the specimen described here (M.C.Z. No. 7196). It was obtained from the upper part of the exposures, zone 5 of Russell's nomenclature (Russell, 1939, p. 9). The matrix is a sandstone. The type of preservation is unfortunate; the organic remains are in the form of a black carbonaceous material which preserves little of structure or form and in general leaves but poor impressions on the sandstone matrix.

The fish is a small one, the total length as preserved being but 7.5 cm. In contrast to the flattening seen in specimens from the shales of this locality, the trunk has preserved its breadth to some degree, the exposed surface being gently convex dorsoventrally. Obviously the fish was fusiform, without the depth of body seen, for example, in such crossopterygians as *Holoptychius* and *Glyptolepis*; the greatest depth is contained in the length about seven times.

Much of the skull is present, but details are difficult to observe. Obviously the skull was moderately elongate. Beneath, along the broken margin of the slab, is a pair of large lateral gulars of characteristic crossopterygian type which appear to have extended nearly the full length of the jaw.

The squamation is difficult of determination because of the indistinct nature of the carbonaceous material, and nothing can be said of shape or ornamentation. The position of the lateral line is distinct along most of the trunk.

The slab containing the specimen was broken off along the ventral line of the trunk and hence, unfortunately, nothing is preserved of the paired fins. The median fins, on the contrary, are well preserved. Two dorsals are present. The second is broad based and highly developed, more after the fashion of *Tristichopterus* or *Dipterus* than the relatively narrow fin of typical crossopterygians. The first dorsal has a narrow base but is exceedingly elongate, more so than in any other crossopterygian with which we are familiar. The caudal fin is typically heterocercal, without any evidence of the trend toward diphycercy seen even in many Devonian Choanichthyes.

It is obvious from such conclusive data as, for example, the gulars, that we are dealing with a rhipidistian crossopterygian, but one apparently new to the Scaumenac fauna. Except for *Elpistostege*, with which comparison is impossible, only two crossopterygians have been described from this locality—*Eusthenopteron foordi* and *Glyptolepis quebecensis*. Our specimen can be assigned to neither. We have attempted to identify it with the latter, known chiefly from the type specimen (Whiteaves, 1888, 77-78, Pl. 5, Fig. 4). Certain of the differences seen may be due to imperfections in the material of the *Glyptolepis* specimen, as the appearance of the tail region and the seeming shortness of the first dorsal. But the second dorsal, for example, appears to be more posteriorly situated than in our specimen, and still more serious is the question of bodily proportions. The type of *G. quebecensis* is a deep-bodied fish, as is proper in members of the genus *Glyptolepis*; we have not seen the original specimen, but Curator C. M. Sternberg of the National Museum of Canada informs us that its proportions as figured appear to be natural, and not due to crushing. That

Whiteaves' species belongs to *Glyptolepis* is suggested by the fact that both Whiteaves and later writers have noted the presence in the Scaumenac beds of fragmentary remains of larger individuals with typical *Glyptolepis* characters.

A combination of fusiform shape and a typical heterocercal tail is present among adequately known Devonian crossopterygians only in the *Osteolepis-Thursius* group, and our form seems rather more closely comparable with restorations of the latter genus than of the former. As Westoll notes (1937b, p. 28) *Thursius* is apparently a composite genus. Because of the imperfections of our specimen it is inadvisable to consider questions of generic separation; it is herewith described as *Thursius? clappi*, sp. nov., the specific name in recognition of its discoverers, and the development of the dorsal fins noted above, and the relative positions of the median fins serving as specific characters. Although members of the genera *Osteolepis* and *Thursius* are mainly Middle Devonian, remains are known from Baltic horizons approximately equivalent to that of Scaumenac Bay.

AMBLYPTERUS STEWARTI, sp. nov., from the Permian of Pennsylvania.

(Plate 1, Figure 2).

Although palaeoniscoid scales are abundant in American Pennsylvanian and early Permian rocks, skeletons of this group of fishes are far from common. Most of those known are normally-shaped fusiform palaeoniscoids, such as *Haplolepis* (*Eurylepis*) and *Pyritocephalus*, abundantly present in the famous Linton (Ohio) cannel (Cf. Westoll, 1938). Of deep-bodied palaeoniscoids, the specialized platysomids have been reported from several localities and horizons, but more "normal" deep-bodied forms, comparable to the familiar European *Amblypterus*, are almost unknown. In various localities are found large, smooth scales of appropriate shape (cf., for example, Price, 1927, Fig. 7), but these have always been found isolated.

The specimen here described is therefore of interest. It consists of the body, lacking the head, of a large palaeoniscoid fish, preserved on a slab of bituminous shale. It had been for many years in the collections of Washington and Jefferson College, at Washington, Pennsylvania, but had received no scientific attention until, in the course of a survey supported by the American Philosophical Society, it came under the observation of Dr. Paul R. Stewart, who transmitted it to the writer for study. No locality data was found with the specimen, but the circumstances surrounding the find have been investigated by Dr. P. R. Stewart and his associate in the survey, Dr. B. K. Stewart. The fish was found in the black shales immediately above the Upper Washington Limestone. It thus comes from beds transitional between the Washington and Greene Formations of the Dunkard Group, a horizon which is generally considered as close to the base of the Permian.[1]

The fish exhibits a nearly complete trunk and tail, seen from the right side. It is unfortunate that the head is missing, since recent work on palaeoniscoids has shown that a wide diversity of cranial structures may exist among fishes which appear very similar in trunk and tail. Part of the body and fins have retained the actual skeletal materials; in other regions the skeleton has weathered off, but has left good impressions of scales and fin rays. No internal elements are preserved, but a distinct longitudinal depression indicates the position of the vertebral column.

The portion of the fish preserved has a length of 37 cm.; if the head were of normal proportions the total length would have been about 42 cm. The body is moderately deep; as preserved, the depth is contained in the estimated total length only 3 1/3 times. Despite the depth there is, however, none of the tendency seen in the platysomids toward a rhombic body contour. The tail is typically heterocercal and appears to have been deeply cleft. The dorsal and anal fins are placed far posteriorly, the posterior end of the anal almost touching the base of the caudal and the center of the base of the dorsal being about opposite the front end of the anal. The dorsal is considerably expanded in both dimensions. An impression of the base of a pelvic is seen about midway between operculum and root of tail; the pectorals are missing. There is little evidence of enlarged fulcra in advance of either dorsal or caudal. The rays of the median fins are divided into a fringe distally. The scales are smooth, as in the European *Amblypterus* and in contrast with most palaeoniscoids. Dorsally and ventrally the scales are subquadrate; on the flanks they are somewhat elongate, the height of the exposed surface exceeding the width by about 1/3.

[1] Doctor Stewart informs me that his survey has found *Callipteris* used as a Permian index fossil some 200 feet below this horizon.

In attempting to assign this fish to a systematic position, the absence of the skull is unfortunate, since cranial structure may vary widely among *Amblypterus*-like fishes (Westoll 1937a). In the lack of other evidence the specimen may be provisionally assigned to *Amblypterus*, as *A. stewarti*, sp. nov. Geographic and stratigraphic position suggest specific distinctness from the European forms generally included in *Amblypterus*. Formal specific diagnostic characters which separate it from the European species are found in (1) the somewhat greater depth of body (2) the extreme posterior position of the anal fin.

TEXAS PERMO-CARBONIFEROUS MARINE FISHES.

In the Texas redbeds the main interests of collectors have been centered on terrestrial forms, and the occasional marine horizons in the collecting areas have been in general avoided. Although vertebrates are rare in these horizons, specimens are occasionally present in clays which lie close to marine limestones and hence are probably salt-water deposits; further, forms presumably marine are sometimes found in other deposits which may be of estuarine nature. Except for "*Anodontacanthus*," the fishes mentioned in the remainder of this paper constitute the known marine faunal assemblage of the Texas deposits. As will be noted, they include members of the shark groups common in the Carboniferous. In this regard, as in the nature of the tetrapod assemblages, the Wichita and Clear Fork Groups of Texas show us not the initiation of a new Permian fauna, but a final stage in the life of the Carboniferous.

The localities from which the described specimens are derived may be noted here in ascending stratigraphic order.

1. Little Bitter Creek, Young County, Texas; Moran Formation, Wichita Group.
2. Cottonwood Creek (headwaters), Archer County; Moran Formation, Wichita Group.
3. Coleman Junction, Limestone near Throckmorton, Texas; Summit of Putnam Formation, Wichita Group.
4. Rattlesnake Canyon, Archer County; Admiral Formation (Upper part), Wichita Group.
5. Godwin Creek, Baylor County; Admiral Formation (Upper part), Wichita Group.
6. Former Woodrum Ranch, south of Dundee, Archer County; Admiral or Belle Plains Formation, Wichita Group.
7. Culbertson Pasture, east of Wichita Falls, Wichita County; ? Admiral or Belle Plains Formation, Wichita Group.

8. Daggett Creek, Baylor County; Belle Plains Formation, Wichita Group.
9. Little Wichita River below Fulda, Baylor County; Belle Plains Formation, Wichita Group.
10. Military Trail below Kemp Lake dam, Baylor County; Lueders Formation, Clear Fork Group.

ORODUS? CORRUGATUS, sp. nov.

(Plate 1, Figure 6).

This species is represented by two well-preserved teeth (M.C.Z. 7198) from Rattlesnake Canyon. They are of the flat-crowned type, with low and somewhat shouldered roots, seen in a large series of Paleozoic and Mesozoic chondrichthyan genera, such as *Orodus* and *Helodus*, to which have been referred teeth which may be variably hybodont, cochliodont or edestid. For the most part the two teeth are distinct, but the central third of the roots are fused, suggesting the initiation of cochliodont conditions. The wrinkled coronal surfaces suggest *Orodus*; however there is little indication of the longitudinal axis from which the striations radiate in typical members of that genus, and the crenulations are fine and uniform. We tentatively refer this specimen to *Orodus*, as *O. corrugatus*, sp. nov., characterized by the nature of the coronal markings.

BRACHYRHIZODUS WICHITAENSIS, gen. et sp. nov., an aberrant petalodont?

(Plate 1, Figures 7, 8).

The tooth here described (M.C.Z. No. 7197) was found in an apparently marine layer at Godwin Creek. The upper surface is gently convex in both longitudinal and transverse planes and would appear to have been essentially smooth in life, the scratches visible being probably post-mortem in nature. The two longer margins are essentially parallel to each other; one end of the plate has a V-shape which is apparently natural; the other end is broken but nearly complete.

The crown has a depth of 3 mm.; below is a short root portion, likewise 3mm. in depth. This is quite distinct in coloration, as preserved. Along the concave margin crown and root are separated by a distinct but shallow groove, but on the opposite margin the edge of the crown passes smoothly down to the root. The most distinctive feature of the tooth is the fact that the root is divided into five portions by well-incised transverse grooves.

The specimen obviously formed part of a battery of pavement teeth of some sort. An obvious comparison can be made immediately with *Myliobatis* both as regards the general shape of the plate and the subdivisions of the root. However, it is impossible that this relatively recent type can be related to a Permo-Carboniferous form. The subdivided roots suggest, among Paleozoic forms, assignment to the Petalodontidae. Here a difficulty arises not only from the brevity of the root (cf. *Polyrhizodus*) but from the fact that in the present case the root lies directly beneath the crown, without the marked "shoulder" found in characteristic members of that family. Provisionally, however, this tooth may be placed here, as *Brachyrhizodus wichitaensis,* with the brevity of the root and its polyrhizodont condition as characteristic features.

CTENACANTHUS AMBLYXIPHIAS COPE.

(Plate 1, Figure 3).

Spines of the *Ctenacanthus* type are common in Carboniferous deposits; their presence in the Texas redbeds is of interest as an upward extension of their stratigraphic range. One such Texas specimen was described by Cope (1891, p. 449, Pl. 28, Fig. 3) as *C. amblyxiphias,* and Hussakof (1911, p. 161, Pl. 30, Figs. 6, 6a) described a second. In neither case was the locality or horizon given and data appears to be lacking on these specimens (AM 7283, 7282). A third fragmentary spine (AM 7263) is from the "Military Trail." The Harvard collections contain a number of *Ctenacanthus* spines or fragments of them, one of which is figured here. Most of them (M.C.Z., Nos. 7199-8002) are from Little Bitter Creek (locality 1); another is from locality 5. In default of any worthwhile diagnostic characters we refer this material to Cope's species.

"HYBODUS" COPEI, HAY.

Cope in 1891 (p. 448, Pl. 28, Fig. 2) described, as *Hybodus regularis,* a large and nearly complete spine of hybodont type from a Texas locality which he regarded as Triassic in age. No further attention has been paid to this specimen by later workers except that Hay, noting that the specific name was preoccupied, renamed the specimen *Hybodus copei* (1899, pp. 783-784).

Investigation conclusively indicates that this specimen is actually from the Permian, not the Triassic. The American Museum records state that it came from the neighborhood of Seymour, Texas, and was collected by Jacob Boll in 1880. It cannot be Triassic because (1) there are no Triassic beds within 100 miles or so of Seymour; (2) the specimen is embedded in a limestone matrix, and no limestone strata are recorded in the Texas Trias; (3) Boll never worked in the Triassic regions of the state (cf. Geiser, 1937, map, p. 30, etc.) and (4) the fossiliferous Triassic beds of Texas were not discovered until years after Boll's death. On the other hand, Boll worked in the Permian of the Seymour region in 1880 (and in fact died while there); appropriate marine limestones (including the Leuders limestones, locality 10) are present near Seymour; and *Hybodus*-like spines prove to be widespread in the redbeds from the Seymour district eastward.

Hussakof (1911, p. 157, Pl. 30, Figs. 5, 5a) noted the presence in the American Museum collections of fragments of a spine of hybodont type. This was collected at the "Military Trail" (locality 10), north of Seymour and is thus at approximately the same horizon as that at which the *H. copei* type may have been obtained. In the Harvard collections are other portions of hybodont spines from localities 1, 5 and 9; the distribution thus ranges from the Moran Formation upward to the Leuders. The fragments are closely comparable in the type of ridges present, general section and nature of the rows of alternating denticles along the margin to the type of *H. copei* and to the typical Mesozoic spines customarily assigned to *Hybodus*. It is, of course, improbable that these spines belong to that Mesozoic genus. Lacking, however, any associated material of the dentitian or other skeletal parts, accurate generic assignment of the species is impossible. *Wodnika*, for example, is a Permian genus bearing spines of hybodont type, while *Sphenacanthus* and *Acondylacanthus* are terms assigned to Carboniferous spines of this sort.

AN OSSIFIED PALEOZOIC SHARK VERTEBRA.

(Plate 1, Figures 9-12).

The object described here (M.C.Z. No. 8008) was found in a horizon, apparently marine, close to a fossiliferous limestone on the east side of Godwin Creek, (locality 5), near, but not definitely associated with fragments of "*Hybodus*" spines. It was obviously a vertebral centrum and was at first thought to pertain to the amphibian *Cricotus*, which it superficially resembles. Further study, however, showed that it could not be assigned to that form nor, indeed, to any known type of amphibian or reptile; it is obviously of piscine nature.

Among Paleozoic fishes, vertebral centra are rare. They are known in rhipidistian crossopterygians in the form of crescents quite different in shape (and in internal structure) from the present specimen. As far as we are aware, centra are unknown in other Paleozoic bony fish groups; neural and haemal arches are present, but the centra remained unossified and are not preserved.

On the other hand centra, while rare, have been reported in certain Paleozoic sharks, such as *Chondrenchelys* and *Eucentrurus* (Moy-Thomas, 1935, 1937). The present specimen agrees well with typical shark centra in all its superficial aspects. Its diameter is approximately 22 mm., its length 14 mm. The lateral surfaces are somewhat ridged longitudinally, but lack the deep excavations found between the calcified ridges in many living shark genera. The presumed dorsal margin (as may be seen in the section) carries paired grooves bordered by lateral ridges, presumably marking the area of

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Fig. 1. *Thursius? clappi*, holotype, × 4/5.

Fig. 2. *Amblypterus stewarti*, holotype, × 1/5.

Fig. 3. *Ctenacanthus amblyxiphias*, M.C.Z., 7199, × ½.

Fig. 4. *Pleuracanthus* spine (Walker Museum) from the Clear Fork beds of Gray's Creek, Texas, × ½.

Fig. 5. A pleuracanth spine of the so-called "*Anodontacanthus*" type from the Wichita beds of Little Bitter Creek, Texas. M.C.Z. 8013.

Fig. 6. *Orodus? corrugatus*, holotype, teeth, crown view.

Figs. 7, 8. *Brachyrhizodus wichitaensis*, holotype tooth, crown and root views.

Fig. 9. The shark vertebra described in the text, in end view.

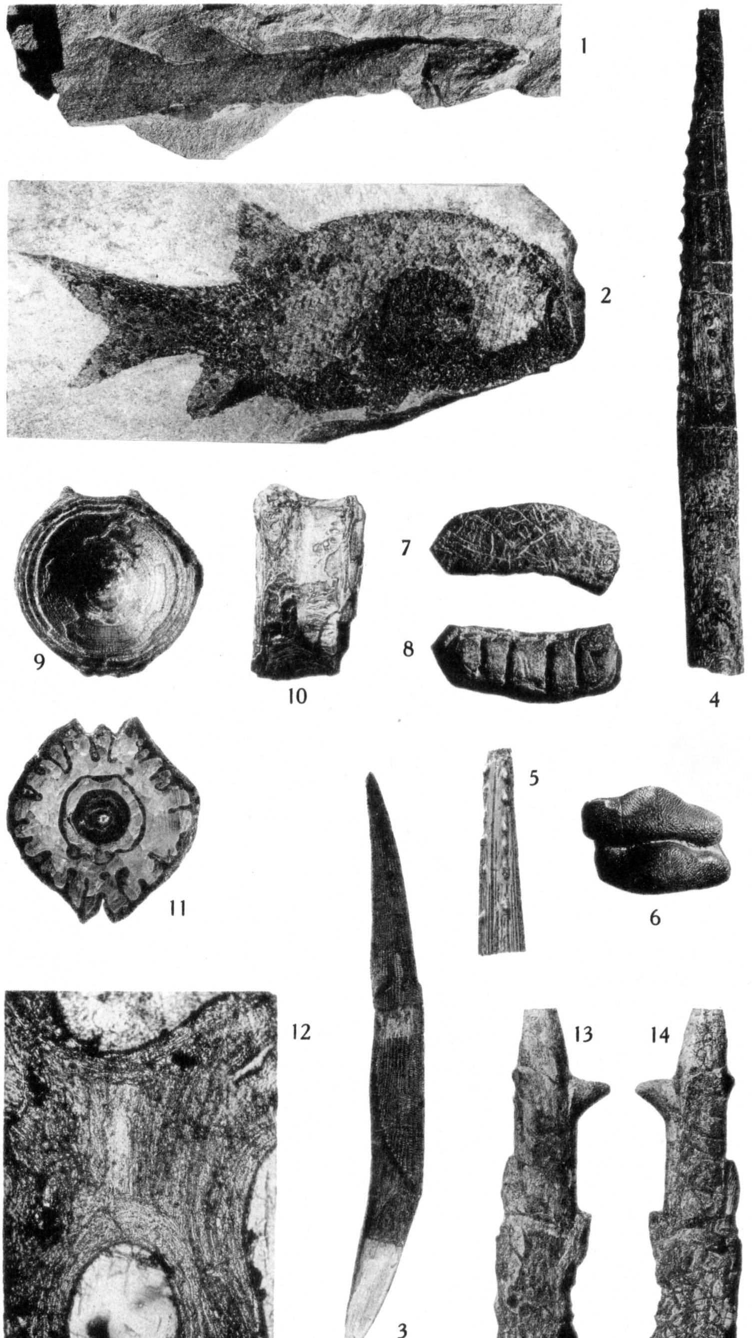
Fig. 10. Side view of the same.

Fig. 11. Transverse section of the same.

Fig. 12. Photomicrograph (× 200, approx.) of a portion of this section. Visible is the lamellar bonelike material, parts of two Haversian canals, and cell spaces which, however, are irregular rather than stellate in outline.

Figs. 13, 14. *Macrodontacanthus kingi*, holotype, × ½. On portions of the surface the ornament of parallel lines is visible. Near the distal end may be seen a pair of large lateral denticulations; a pair lower down is broken and displaced. The side of the spine shown in Fig. 14 is longitudinally grooved, but the amorphous material filling the groove has been left in place.

All figures not otherwise specified are natural size.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attachment of the neural arch; a single groove with adjacent ridges appears to mark ventrally the attachment of the haemal arch.

The section is of interest. Much of the area is filled with crystalline material which has replaced cartilage. A harder skeletal substance is, however, prominent. A thick ring of this material surrounds the cavity of the notochord, and a second ring is present external to this. To this extent the structure is tectospondylous. More externally radiating ridges of hard material form a pattern of asterospondylous type; it will be noted, however, that these ridges are not formed, as in a majority of sharks, in centrifugal fashion, but centripetally (rather as in *Raja*), growing inward from a continuous external layer presumably in the general position of the elastica externa. A continuous outer skeletal sheath is rare in modern forms, but is obviously an ancient type, since it was present in *Chondrenchelys*.

The most interesting feature of the section is, however, revealed under the higher powers of the microscope. It was assumed that, as in modern sharks, the preserved skeletal material consisted of calcified cartilage. This, however, is not the case. The material is unmistakably bone. Its structure is well laminated; various areas of resorption and secondary deposition can be made out; and there are many characteristic Haversian canals. Further, there are numerous cell lacunae of irregular shape, contrasting with the cell arrangement found in cartilage and agreeing perfectly with that seen in bone.[2]

We thus have here one of the oldest known specimens of shark vertebrae and find that we are dealing with an osseous rather than a cartilaginous structure. This is in entire agreement with modern beliefs in the degenerate nature of the skeleton in typical sharks.

It is unfortunate that this vertebra cannot be assigned to a specific type. As noted, it was found close to hybodont spine material; but vertebral centra have not been described in this group, and appear to have been purely cartilaginous in characteristic Mesozoic hybodonts.

[2] In *Chondrenchelys*, Moy-Thomas (1935) noted the fibrous (and hence presumably laminated) nature of the skeleton of the centra, but did not observe the cells.

MACRODONTACANTHUS KINGI, gen. et sp. nov., a new type of fish spine.

(Plate 1, Figures 13, 14).

Among materials from the Culbertson locality (No. 7) in the Texas redbeds, donated by Mr. R. H. King of Wichita Falls was a large, incomplete fish spine (M.C.Z. No. 8009) which we have been unable to identify with any type of ichthyodorulite in the available literature. The portion figured measures 9.3 cm. in length. Distally the tip is missing. The proximal end (not figured) is preserved, to a length of 4.5 cm.; with allowance for the missing segment, the complete spine may have measured 20 cm. or so in length.

The spine is in the main a tapering, cylindrical structure. On one surface, however, a longitudinal groove is present over the whole length. Distally the groove is narrow but deeply incised. More proximally the groove broadens to a rounded trough, so that the spine becomes essentially crescentic in section. The proximal, inserted end is shaped like the butt end of a penpoint. When the specimen was prepared, the groove was found to be filled by an irregular mass of material which differed markedly from the matrix covering the remainder of the spine. This material has been left in place; although peels from this material show no organic structure under the microscope, it may well represent a cast of some type of hard connective tissue which in life bound the grooved surface of the spine to the adjacent tissues of the fish.

The spine bears on either margin large, tooth-like, lateral projections. Near the apex a pair of these processes is in position (although one element is broken at the tip). Remains of a second pair are found more proximally; these processes, however, appear to have been broken before burial. Covering most of the areas of the spine and its denticulations in which the surface is well preserved is an ornamentation of fine parallel striations; certain portions of this can be seen in the illustrations.

As was said, we have found nothing in the literature which can be at all closely compared with the present specimen. We therefore designate it as *Macrodontacanthus kingi*, gen. et sp. nov., with the paired denticulations, the ornamentation and the longitudinal groove yielding combined generic and specific characters.

Obviously from its symmetry, the structure was a medial element. The laterally spreading denticulations make it probable that it was not a fin spine. We suggest that it may have lain flat in the upper surface of the head as a rostrally-directed element somewhat comparable to that seen in some early chimaeroids, *Squaloraja*, *Myriacanthus*. This suggests, in turn, that the spine may have pertained to some member of the Bradyodonti.

"ANODONTACANTHUS AMERICANUS"

(Plate 1, Figure 5).

Although apparently fresh water rather than marine, the shark spine given this name by Hussakof (1911, p. 162) may be discussed here. The genus *Anodontacanthus* was founded by Davis (1881, p. 427) for non-denticulate spines otherwise similar to those of pleuracanths. Part of this material was, however, later shown to belong to *Pleuracanthus* (in a broad use of that term) and probably all of it does. This is certainly true of Hussakof's species. The Harvard collections from Texas contain numerous fragments of spines comparable to his type. Some lack denticles, but others (as the specimen figured) bear near the tip (absent in Hussakof's specimen) two parallel rows of denticles in typical pleuracanth fashion. Such spines have been found at localities 1, 2, 6, 8 and 9. All are localities at which pleuracanth teeth or skulls are present, and in several instances the spines were apparently associated with *Pleuracanthus* material. Here, as in the case of European specimens of "*Anodontacanthus*" we are dealing with incomplete or worn pleuracanth spines.

Relatively small spines of the "*Anodontacanthus*" type, with marked striations and small teeth restricted to the terminal portion, have been found by us in Texas only in the Wichita group; on the other hand, large pleuracanth spines (as in Figure 4) with little striation and with a greater degree of denticulation, are apparently found in the overlying Clear Fork Beds, and in them alone. Data is not, however, available at the moment for determining the taxonomic status of the Texas pleuracanth species.

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