

REDFIELDIID FISHES FROM THE
TRIASSIC-LIASSIC NEWARK SUPERGROUP
OF EASTERN NORTH AMERICA

BOBB SCHAEFFER AND NICHOLAS G. MC DONALD

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AMERICA

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CONTENTS

Abstract	133
Introduction	133
Acknowledgments	134
Abbreviations	134
Systematics	134
Order Redfieldiiformes Berg, 1940	134
Family Redfieldiidae Berg, 1940	134
Genus <i>Redfieldius</i> Hay, 1899	134
<i>Redfieldius gracilis</i> (J. H. Redfield, 1837)	134
Genus <i>Dictyopyge</i> Lyell, 1847	144
<i>Dictyopyge macrurus</i> (W. C. Redfield, 1841)	144
<i>Dictyopyge meekeri</i> , New Species	145
Redfieldiids Common to the Dockum, Chinle, and Newark Rocks	154
Geological Occurrence	155
Conclusions Regarding Geologic Occurrence	168
Literature Cited	169

ABSTRACT

Two genera of redfieldiid fishes, *Redfieldius* (Redfield) and *Dictyopyge* Lyell, are completely described and adequately diagnosed for the first time since their discovery more than a century ago. The number of *Redfieldius* species is reduced from seven to one—*R. gracilis*. Two species of *Dictyopyge* are recognized, *D. macrurus* (Redfield) and a new species, *D. meekeri*, on the basis of meristic characters. According to recent palynological and paleobotanical

evidence, the rocks of the Newark Supergroup containing *Redfieldius* are Liassic in age and those including *Dictyopyge* are Upper Triassic. The presence of other redfieldiids in the Newark Supergroup, first described from rocks of similar age in the western United States, is briefly mentioned. The geologic occurrence of fishes in the Newark Supergroup is discussed and a correlation chart for the major basins is included.

INTRODUCTION

In 1837 J. H. Redfield proposed the name *Catopterus gracilis* for certain fishes from the Liassic (until recently Upper Triassic) rocks of the Newark Supergroup (Van Houten, 1977; Olsen, MS) in the Connecticut Valley. Redfield distinguished this genus from other fishes found in the same strata by the extreme posterior position of the dorsal fin and by the relatively small, delicate fulcra on all the fins. Redfield believed that *Catopterus* should "be ranked between the genera *Semionotus* and *Pholidophorus*, being analogous to both in the structure of the tail, and in its serrated fins, and to the latter in the articulation of the rays."

In 1841 W. C. Redfield (father of J. H. Redfield) recognized a new species of *Catopterus*, *C. macrurus*, from the Newark Supergroup in Chesterfield County, Virginia, on the basis of "its broad and flowing fins" and particularly its extended anal fin. Four years later (1845) Sir Charles Lyell was given a specimen of *C. macrurus* during a visit to the Richmond (Virginia) basin, which he subsequently showed to Louis Agassiz and Sir Philip Egerton. All agreed that it was a "large-finned *Catopterus*" and Egerton suggested that it be called *Dictyopyge* because of the netlike appearance of the segmented anal fin rays. Although *Dictyopyge* is usually attributed to Egerton, 1847, it was first described in Lyell's 1847 paper on the James River Coal basin, with proper acknowledgment to Sir Philip. Lyell, rather than Egerton, is thus the official first describer.

Woodward (1890) included *Catopterus* and *Dictyopyge* in the family Catopteridae on the basis of various characters in common, including the remote dorsal fin and the prominent snout. He also recognized several species of *Dictyopyge* in the Australian Triassic. As the name *Catopterus*, J. H. Redfield, 1837, is preoccupied by *Catopterus* Agassiz, 1833, Hay (1902) changed the name to *Redfieldius* and the family name to Dictyopygidae. Berg (1940), in turn, preferred the name Redfieldiidae, which he assigned to his new Order Redfieldiiformes. Redfieldiid (or redfieldiiform) relationships have been considered by Stensiö (1921), Brough (1931, 1936), Schaeffer (1955, 1967) and, along with a revision of the South African and Australian genera, by Hutchinson (1973).

The purpose of this paper is to provide, for the first time, complete descriptions and adequate diagnoses of *Redfieldius* and *Dictyopyge* based, in part, on recently collected and prepared specimens, and to discuss the occurrence of all redfieldiid taxa in the Newark Supergroup. All previously designated types and figured specimens have also been examined, along with other specimens originally identified by the Redfields and by J. S. Newberry.

With the publication of this paper, all the positively identified redfieldiiforms have been described or redescribed within the last dozen years. In spite of the extensive early literature on American, South African, and Australian forms the information gained through modern

preparation and illustration techniques has made most of the older descriptions of little more than historical interest. On the basis of the newer data, Schaeffer plans a cladistic interpretation of redfieldiiform relationships with special regard to time-space distribution within Pangaea.

ACKNOWLEDGMENTS

The authors are indebted to Dr. Keith Thomson and Mr. Paul Olsen, Peabody Museum of Natural History, Yale University; Dr. Farish A. Jenkins, Jr. and Mr. Chuck Schaff, Museum of Comparative Zoology, Harvard College; Mr. Robert Purdy and Mr. Robert Weems, National Museum of Natural History, Smithsonian Institution; Dr. Gregory Horne, Wesleyan University; Dr. David D. Gillette, formerly with the Academy of Natural Sciences of Philadelphia; Dr. David C. Parris, New Jersey State Museum; Dr. Donald Baird, Princeton University Geological Museum; Dr. Donald Hoff, Pennsylvania Historical and Museum Commission for the loan of specimens used in this study. Dr. Colin Patterson, British Museum (Natural History), kindly supplied a peel of the *Dictyopyge* specimen described by Charles Lyell as well as information concerning its acquisition by that institution. Paul Olsen and Bruce Cornet have generously provided field data and other information for the section on geologic occurrence.

Most of the recently collected specimens of *Redfieldius* and *Dictyopyge* were prepared by Walter Sorensen, Bruce Cornet, and Paul Olsen. The drawings and many ray and scale counts were made by Lorraine Meeker. The photographs were taken by Chester Tarka. Annlinn Kruger assisted with the scale counts and the cataloguing. A majority of the specimens found by the junior author and Robert Demicco in Virginia and Connecticut have been deposited in the American Museum of Natural History and those obtained by Paul Olsen are in the Peabody Museum of Natural History.

ABBREVIATIONS

The following abbreviations are used for catalogued specimens:

AMNH, the American Museum of Natural History
ANSP, Academy of Natural Sciences of Philadelphia
BM(NH), British Museum (Natural History)
BSNS, Buffalo Society of Natural Sciences
MCZ, Museum of Comparative Zoology, Harvard University
NJSM, New Jersey State Museum
NMNH, National Museum of Natural History, Smithsonian Institution
PU, Princeton University
WU, Wesleyan University
YPM, Peabody Museum of Natural History, Yale University

SYSTEMATICS

ORDER REDFIELDIIFORMES BERG, 1940

FAMILY REDFIELDIIDAE BERG, 1940

GENUS *REDFIELDIUS* HAY, 1899

Catopterus J. H. Redfield, 1837, p. 39 (not *Catopterus* Agassiz, 1833, p. 3).

Redfieldius Hay, 1899, p. 789 (replacement name for *Catopterus*, which was used by Agassiz, 1833, for dipnoan genus *Dipterus* Sedgwick and Murchison, 1828).

Type Species. *Redfieldius gracilis* (J. H. Redfield).

Distribution. Lower Jurassic (upper part of

Newark Supergroup), Massachusetts (Hartford basin only), Connecticut, New Jersey, Virginia (Culpeper basin only).

Diagnosis. *Redfieldius* differs from other genera in the family Redfieldiidae in having a strongly tuberculated skull, three parietal bones in a transverse row, and two ovoid suborbital bones in series with the postorbital and dermohyal.

Redfieldius gracilis (J. H. Redfield, 1837)
Figures 1-7

Catopterus gracilis J. H. Redfield, 1837, p. 39.

Catopterus anguilliformis W. C. Redfield, 1841, p. 27.

Catopterus parvulus W. C. Redfield, 1841, p. 28.

Catopterus redfieldi Lyell, 1847, p. 278 (although this species is generally attributed to Egerton, 1847, p. 278, Lyell is the sole author of this paper).

Catopterus minor Newberry, 1888, p. 57.

Catopterus ornatus Newberry, 1888, p. 58.

Type. YPM 3206, nearly complete specimen, lacking only epicaudal lobe. Figured in J. H. Redfield, 1837, pl. 1; Eastman, 1911, pl. 9.

Distribution. Same as for genus. See also section on Geologic Occurrence.

Diagnosis. Same as for genus.

Referred Specimens. The specimens listed below include only the types and figured specimens of the synonymized species (see also discussion on pp. 142-143) plus the specimens especially prepared for this study. All the represented institutions have numerous additional specimens, mostly collected before the turn of the century and almost without exception badly preserved or poorly prepared.

From the Shuttle Meadow Formation, Durham Locality, near Durham, Connecticut, Hartford basin: AMNH 544, AMNH 558, 636, 639, AMNH 648, AMNH 650, AMNH 2431, WU 944. From the Shuttle Meadow Formation, Bluff Head Locality, near Durham, Connecticut, Hartford basin: AMNH 5824, 5825, AMNH 6702-6726, AMNH 6733, 6734, AMNH 6736-6750, AMNH 6758, 6759, AMNH 6761-6769. From the Bull Run Shale, Midland, Virginia, Culpeper basin: AMNH 4803, AMNH 4828, AMNH 4833, 4834, AMNH 4933, 4934, AMNH 5721, AMNH 6751, 6752, AMNH 6756, 6757, NMNH 215153, 215154, NMNH 21658. From the Bull Run Shale, Haymarket, Virginia, Culpeper basin: NMNH 18329. From the East Berlin Formation, Westfield, Connecticut, Hartford basin: YPM 7117, YPM 7204. From the Brunswick Formation, Boonton, New Jersey, Newark basin: AMNH 578, AMNH 592, AMNH 619, AMNH 655, AMNH 663, YPM 7046-7050, YPM 7052, YPM 7064, YPM 7068, 7069, YPM 7075, YPM 7572, NJSM 2962. From the Portland Formation, Middlefield Locality, Middlefield, Connecticut, Hartford basin: YPM 3206 (type).

Description. The complete specimens of *Redfieldius* range in size from about 30 mm. to 164 mm. measured from the tip of the snout to the posterior margin of the caudal body scales (figs. 1, 2). The skull (tip of snout to posterior border of subopercular) is somewhat less than one-quarter of this length. The dorsal fin is remote, with its origin in the posterior third of the body. The pelvic fin originates near the middle of the body and the anal fin a short distance in front of the dorsal (in terms of vertical or circumferential scale rows, the origin of the dorsal is about on the same row as the last rays of the anal). The number of vertical (circumferential) scale rows along the entire lateral line is 43 to 45.

The parasphenoid, dermal palatal elements, and the hyomandibular can be observed in several specimens, but particularly in AMNH 6732, a dissociated skull (fig. 3). The parasphenoid ends behind the robust ascending processes as in *Ischnolepis* (Hutchinson, 1973, fig. 4). This is a primitive osteichthyan character frequently correlated in the palaeonisciforms with the presence of the ventral otic fissure. There is, however, no evidence of the fissure in the redfieldiiforms, although the braincase is of the palaeonisciform type (Schaeffer, 1967, pl. 19). Endopterygoids with minute teeth on the medial surface resembling those of *Ischnolepis* are evident in several specimens. It has not been possible, however, to demonstrate the separation of the endo- and ectopterygoid by a contact between the dermopalatine and the dermometapterygoid as in *Ischnolepis* (Hutchinson, 1973, p. 246). The hyomandibular (fig. 3) has a weakly developed opercular process, which may have articulated with the anterodorsal portion of the opercular—in contrast with the condition in *Ischnolepis* and *Brookvalia* (Hutchinson, 1973, p. 326).

The dermal skull of *Redfieldius* (figs. 4-6) has been figured and briefly described by Brough (1931) and by Schaeffer (1967) on the basis of a single specimen. The following comments are based on 40 more or less complete skulls prepared by the air-abrasion method. The skull pattern is similar to that of *Cionichthys* (Schaeffer, 1967), *Helichthys* (Hutchinson, 1973), *Geitonichthys* (Hutchinson, 1973), and *Molydbichthys* (Hutchinson, 1973) in the rela-

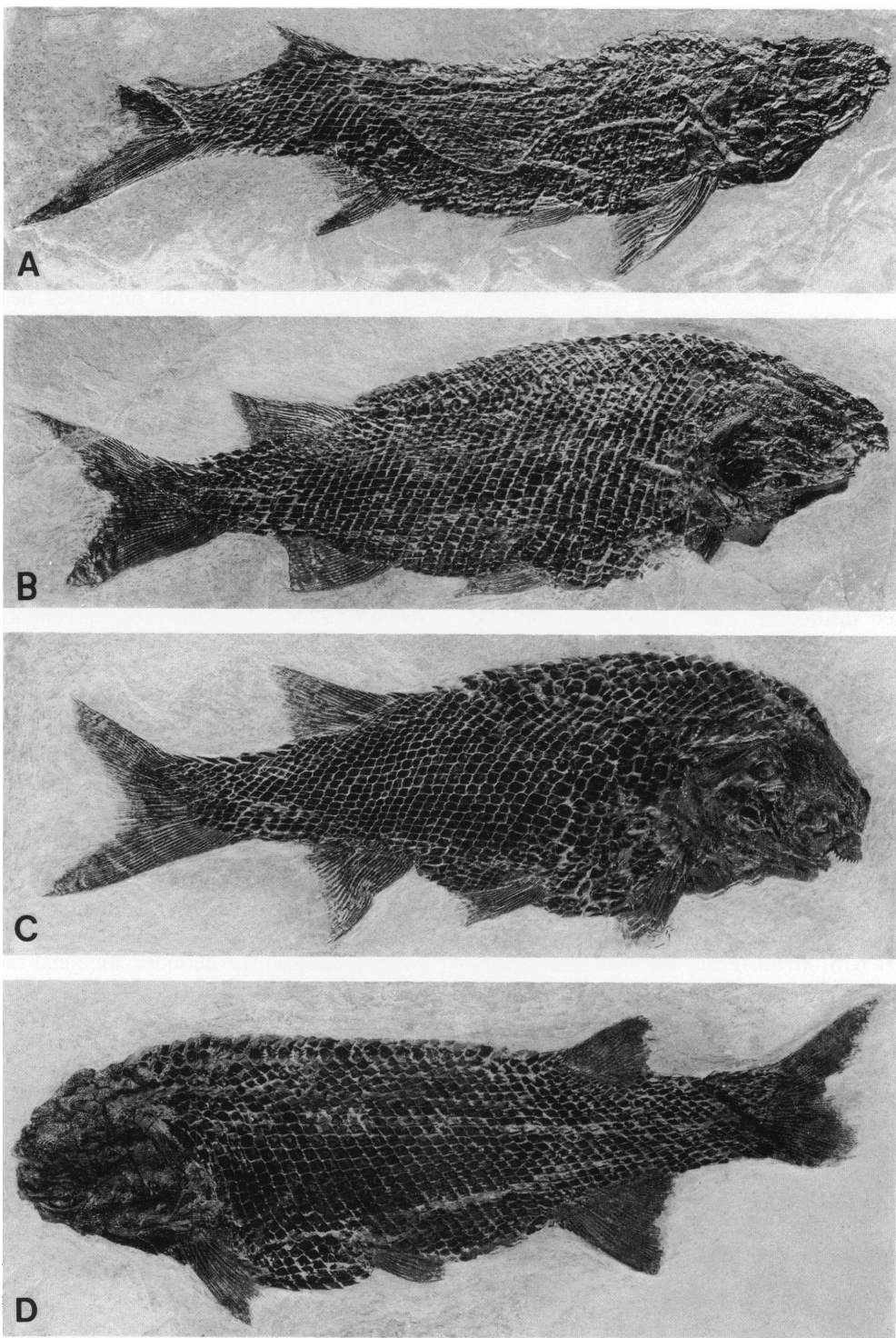


FIG. 1. *Redfieldius gracilis* (J. H. Redfield). A, YPM 3206, type, $\times .59$. B, AMNH 6701, $\times .68$. C, AMNH 6702, $\times .83$. D, AMNH 6717, $\times .68$.

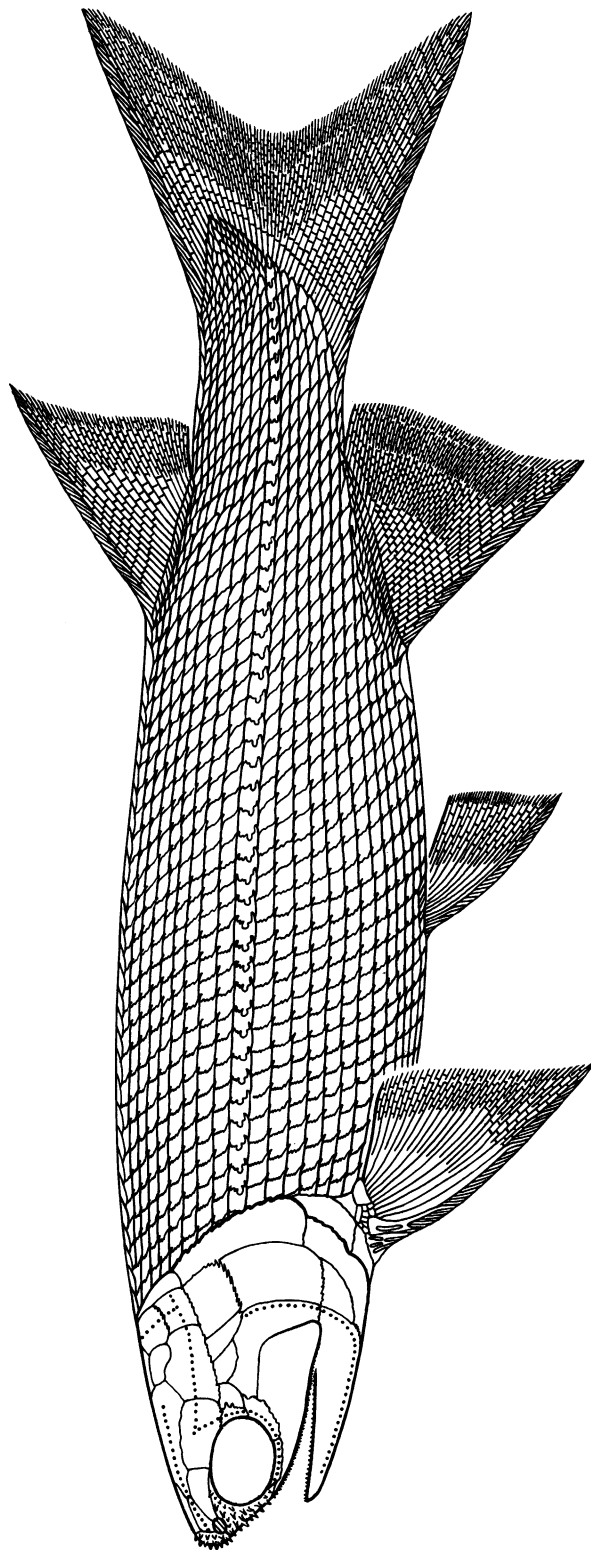


FIG. 2. *Redfieldius gracilis* (J. H. Redfield). Reconstruction.

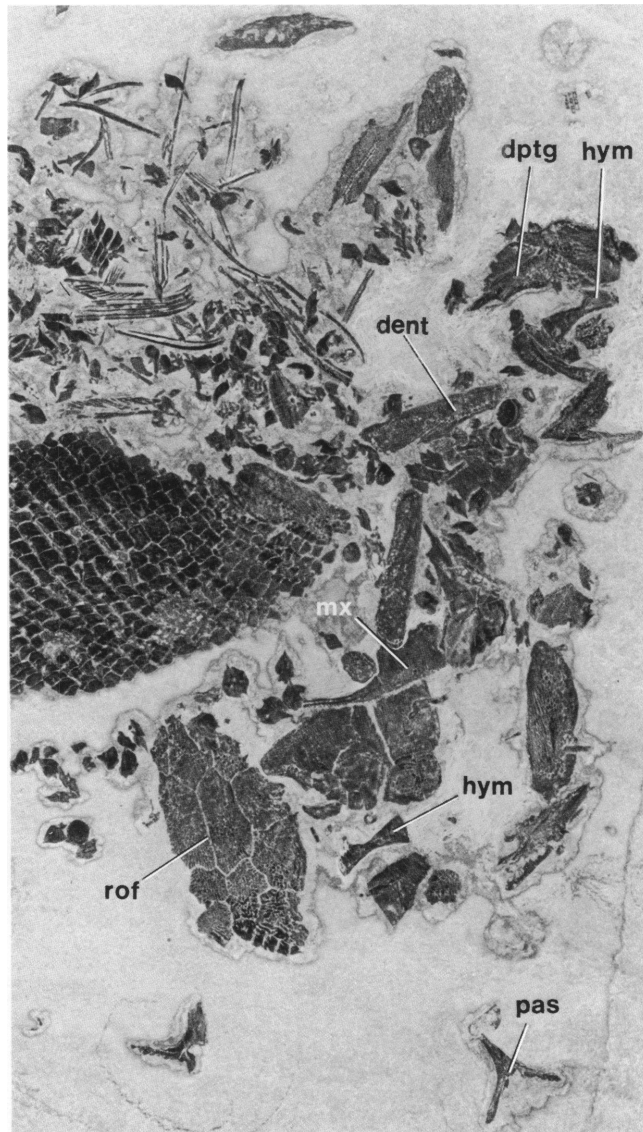


FIG. 3. *Redfieldius gracilis* (J. H. Redfield). AMNH 6732, dissociated skull, $\times 1.05$. Abbreviations: dent, dentary; dptg, dermal palate; hym, hyomandibular; mx, maxilla; pas, parasphenoid; rof, skull roof.

tive proportions and shape of the frontals, and in the separation of the nasals by the postrostral. However, it differs from all other redfieldiid genera in possessing three parietals in a transverse row. This character has been observed in all but one of the specimens (about

20) in which the parietal region is unequivocal. In one specimen (AMNH 6732) the parietals are apparently paired and are nearly equal in size. The left element has an anterior pointed projection that fits into a notch between the frontals, much as the anterior border of the

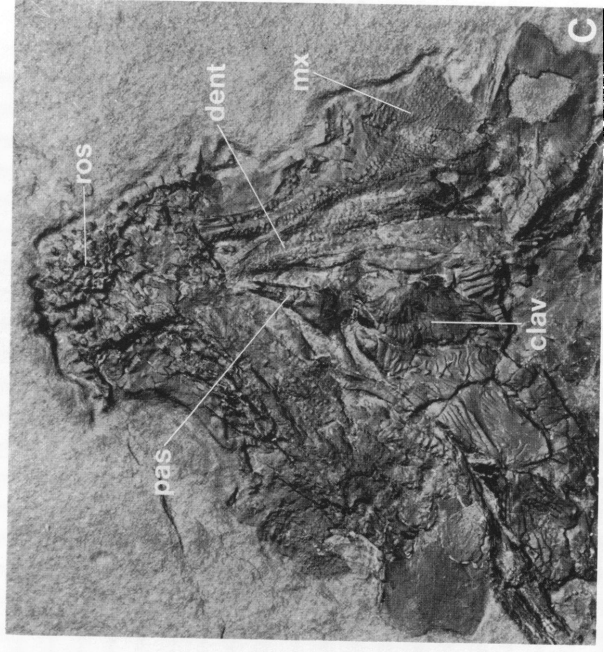
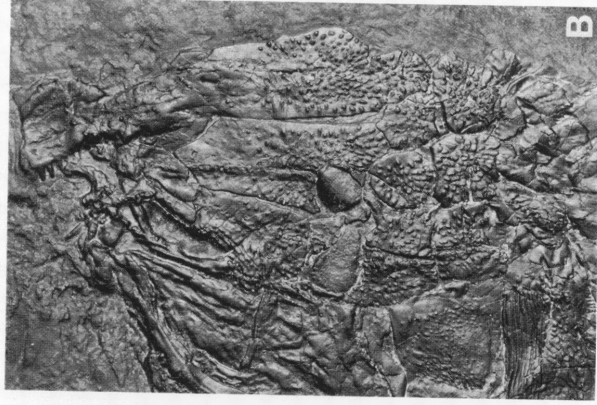
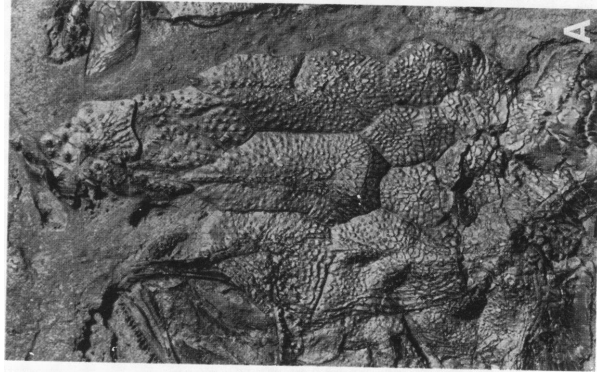


FIG. 4. *Redfieldius gracilis* (J. H. Redfield). A, AMNH 6733A, skull in ventral aspect, $\times 1.83$. Abbreviations: clav, clavicles; dent, dentary; ms, maxilla; pas, paraspine; ros, rostral.

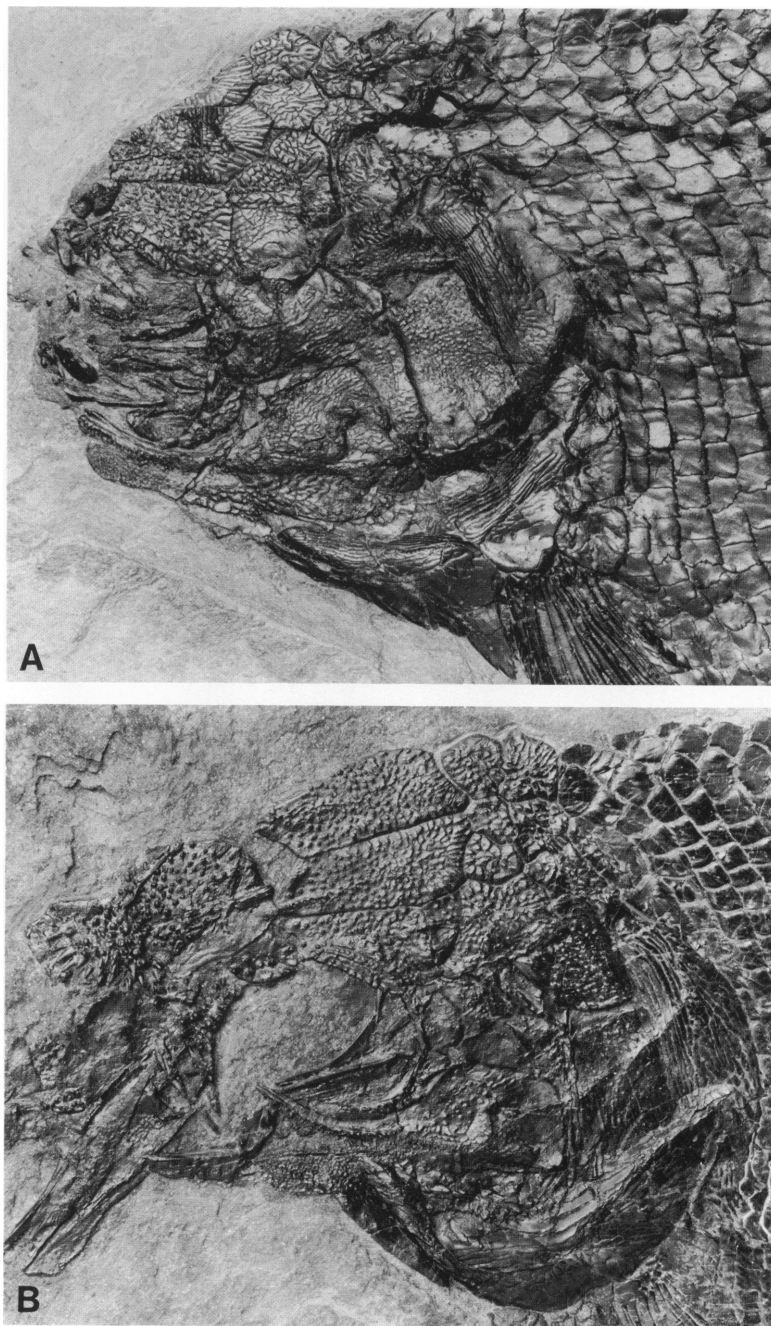


FIG. 5. *Redfieldius gracilis* (J. H. Redfield). A, AMNH 6717, cheek area and partial skull roof, $\times 1.9$. B, AMNH 6712, cheek area and skull roof, $\times 2.7$.

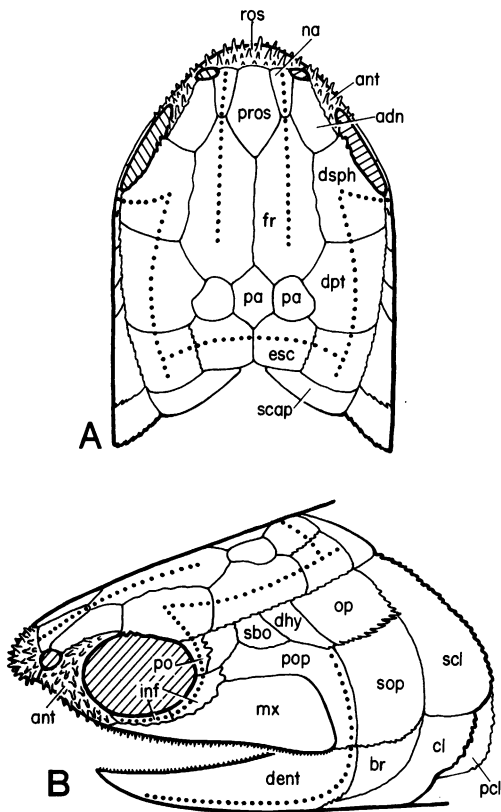


FIG. 6. *Redfieldius gracilis* (J. H. Redfield). Reconstruction of skull. A, dorsal aspect. B, lateral aspect. Abbreviations: adn, adnasal; ant, antorbital; br, branchiostegal; cl, cleithrum; dent, dentary; dhy, dermo-hyal; dpt, dermopterygoid; dsph, dermo-sphenoid; esc, extrascapular; fr, frontal; inf, infraorbital; mx, maxilla; na, nasal; op, opercular; pa, parietal; pcl, postcleithrum; po, postorbital; pop, preopercular; pros, postrostral; ros, rostral; sbo, suborbital; scap, suprascapular; scl, supracleithrum; sop, subopercular.

medial parietal does in the other specimens.¹

The rostral and the antorbitals are strongly tuberculated, with the bases of the tubercles

¹In a sample of 100 *Amia* skulls in the American Museum collection, one specimen has a single median parietal instead of the usual pair. This variation hardly invalidates the conclusion that *Amia* characteristically possesses two parietals. Likewise, *Redfieldius* typically has three of these elements.

fused to their respective bones. The tubercles are relatively larger, fewer in number, and apparently more separated than in *Dictyopyge*. The preopercular is gamma-shaped and is bordered above its anterior arm by two suborbitals and a dermo-hyal. The presence of two nearly ovoid suborbitals between the postorbital and the dermo-hyal is another unique *Redfieldius* character.

The well-ossified elements of the dermal shoulder girdle (figs. 2, 5, 6) include an elongated, ovoid supracleithrum and cleithrum ornamented with continuous parallel ridges anteriorly and interrupted, diverging ridges posteriorly. The clavicles (fig. 4C) with prominent transverse ridges overlap the cleithra and meet in the midline. A median gular can be made out in AMNH 6740, apparently covering most of the area between the clavicles and the mandibular symphysis. The absence of serially arranged branchiostegals, which is a redfieldiiform synapomorphy, may imply that the opercular opening was reduced (Schaeffer, 1967; Hutchinson, 1973), but it is possible that the opening was continued to the ventral side of the head between flaps of skin that covered much of the clavicles.

The pectoral fin (figs. 1, 2), which originates behind the ninth or tenth vertical scale row, consists of eight to 10 principal rays that are segmented and bifurcated distally. Three or four basal fulcra and more than 30 fringing fulcra border the first ray. The pelvic fin includes eight or nine principal rays, also bifurcated and segmented distally. The anterior principal ray supports about four basal fulcra and at least 20 fringing ones. The anterior border of the remote dorsal fin is behind the thirtieth vertical scale row. It is made up of 25 to 30 completely segmented and distally bifurcated rays with four basal fulcra and about 24 to 29 fringing fulcra (including the short anterior rays that terminate in fulcra) along the anterior border. The anal fin, which is about the same length as the dorsal, originates at the twenty-first or twenty-second (twenty-sixth according to Brough, 1931, p. 275) vertical scale row. It is composed of 26 to 30 completely segmented distally bifurcated rays with three or four basal and at least 30 fringing fulcra.

The caudal fin, as in other redfieldiiforms, is equilobate, hemiheterocercal, and moderately cleft. It is composed of 36 to 40 principal rays, completely segmented and distally bifurcated. The dorsal lobe is bordered anteriorly by three basal and about 30 fringing fulcra and the ventral lobe by four basal and approximately 50 fringing fulcra.

The scales of *Redfieldius* (figs. 1, 2) are typically rhomboidal. They are largest on the anterior part of the body, decreasing in size posteriorly and ventrally. The free borders of the scales are finely denticulated, probably as far posteriorly as the origin of the caudal fin. In a number of specimens (e.g., AMNH 6701) the scales of the anterior eight or 10 rows are partly covered by oblique ridges that extend anterodorsally from the denticulated border. This character is variable, however; in individuals of about the same size the ridges may be weakly developed or absent (AMNH 6717). Also, in some (e.g., YPM 7052) the anterior scales along and near the dorsal line are moderately to weakly tuberculated. Although no conclusive correlation has been found between the degree of denticulation, ridge development, or tuberculation and the vertical or horizontal distribution of *R. gracilis*, specimens from the uppermost fossiliferous horizons in New Jersey and Connecticut (Boonton and Middlefield) seem to have a greater degree of scale ornamentation than specimens from older horizons (e.g., Durham, Bluff Head, Midland, etc.).

The details of scale structure are well demonstrated in thin sections of specimens from Connecticut (fig. 7). The upper surface is composed of enameloid laminae that successively interdigitate with the dentine lamellae as in, e.g., *Elonichthys* (Aldinger, 1937, fig. 2, pl. 4), *Acropholis* (Aldinger, 1937, fig. 8, pl. 13) and *Scanilepis* (Ørvig, 1957, fig. 1). The arborescences of dentine tubules are arranged in linear fashion and there is no indication of partial resorption or stacking of the dentine lamellae. Bone cell spaces are distributed throughout the basal bone, which exhibits the typical laminar structure. Canals for the collagenous "fibers of Sharpey" are also in evidence. Berg (1940, p. 404 and 1958, p. 129) stated, in error, that the dentine layer is absent

in *Redfieldius* and that the scales are lepisosteoid.

Discussion. The reduction in the number of *Redfieldius* species from seven to one is based on a general survey of dermal bone pattern, of dermal bone and scale ornamentation, and on meristic characters. At the level of discrimination permitted by this material, we have been able to recognize only one species. Although there is some variation in meristic characters, body measurements, and scale ornamentation, all of which are obviously influenced by the vicissitudes of preservation, there is no convincing evidence of character clustering that

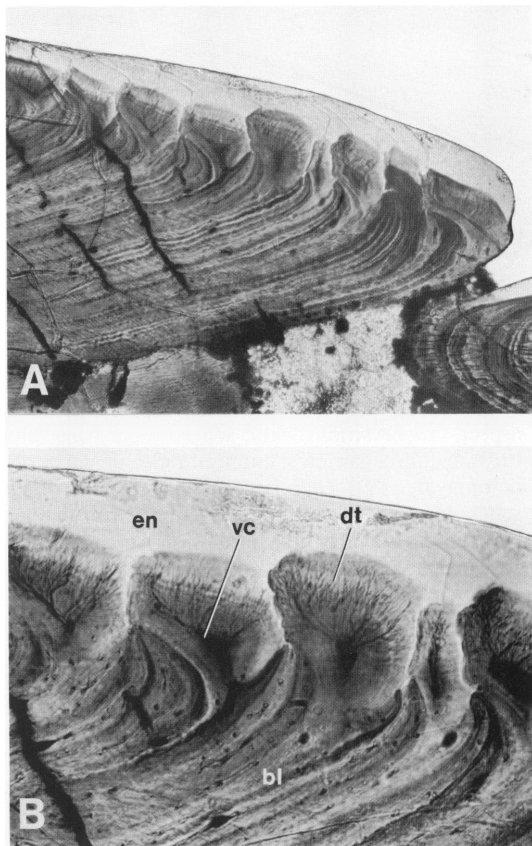


FIG. 7. *Redfieldius gracilis* (J. H. Redfield). Vertical section of flank scale. A, $\times 175$. B, $\times 371$. Abbreviations: bl, bone lamellae; en, enameloid; dt, dentine; vc, vascular canal.

might suggest the presence of more than one species.

As most of the *Redfieldius* species synonymized in this paper have been discussed in one context or another for many decades, it may be of interest to record brief comments on the types, figured specimens, and original diagnoses.

Catopterus gracilis J. H. Redfield, 1837 (p. 39, pl. 1): The type specimen of the type species (YPM 3206) has the following label—"taken from the southern locality in Middletown, [now Middlefield, Connecticut] one or two miles north of the stage house in Durham, July 21, 1836 by William C. Redfield, John H. Redfield, Dr. Richard Warner and presented to Yale Nat. Hist. Soc. 1836." The earliest illustration of *Catopterus* is the copper engraving of the *C. gracilis* holotype accompanying J. H. Redfield's 1837 paper (pl. 1). This is an accurate representation of the specimen prior to further exposure of the skull and fins by air-abrasion.

Catopterus anguilliformis W. C. Redfield, 1841: All the specimens identified by W. C. Redfield (1841) and Newberry (1888) as *C. anguilliformis* are poorly preserved and come from "Middletown (Westfield) Ct." The counterpart of the type specimen (YPM 7204; formerly YPM 7206) has been further exposed by air abrasion, and it is obvious that the body is much deeper than was supposed by either Redfield or Newberry. The specimen figured by Newberry (1888, pl. 8, fig. 5) is probably the counterpart of YPM 7117, which had apparently been desiccated prior to burial. It is therefore difficult to agree with Newberry (1888, p. 60) that *C. anguilliformis* is an eel-like fish with "great delicacy of organization" that may require "reference to a new genus."

Catopterus parvulus W. C. Redfield, 1841: The poorly preserved type specimen (YPM 7068) from Boonton, New Jersey, has an attached label that reads "matched specimen sent to Sir Philip Grey Egerton." W. C. Redfield regarded *Catopterus parvulus* as a separate species on the basis of small size, delicate body, and fewer "raylets" (fulcra), which are longer but of "more unequal length" than in the fins of other species (W. C. Redfield, 1841, p. 28).

Newberry (1888, p. 61) believed that the size and "delicacy" of the rays indicate immaturity and suggested that the specimens assigned to *C. parvulus* may be the young of *C. gracilis*. Eastman (1905, p. 96; 1911, p. 48) concurred in this opinion, but did not synonymize *C. parvulus* with *C. gracilis*. Newberry (1888, pl. 16, fig. 4) figured the type specimen for the first time, along with a referred specimen (AMNH 655; pl. 16, fig. 6), which was then in the collection at Columbia College.

Catopterus redfieldi Lyell, 1847: The whereabouts of the holotype, which was found at the Durham Locality in Connecticut and procured by Charles Lyell during his trip to the Hartford basin in 1842, is unknown. Much of Lyell's personal collection was dispersed after his death, and it may be assumed that this specimen was never presented to the British Museum. According to Lyell (1847, p. 278), *C. redfieldi* is "broader" than *C. gracilis* with scales that are shorter in proportion to their depth. Newberry (1888, p. 53) referred specimens from Durham, Connecticut, to *C. redfieldi*, which he regarded as "a large and broad species."

Catopterus minor Newberry, 1888: The identified cotypes (AMNH 639, AMNH 640, and 650), from the Durham Locality in Connecticut, are poorly preserved and were damaged during preparation. Newberry (1888, p. 58) suggested that these specimens might be the young of *C. redfieldi*, but then decided that *C. minor* is a valid species on the basis of "the pointed head, the rounded and vertically flattened body, the ornamented scales varying comparatively little in size, and the opposite position of the anal and dorsal fins."

Catopterus ornatus Newberry, 1888: The holotype (WU 944) and only specimen assigned to this species, from Durham, Connecticut, is preserved with the ventral squamation exposed. The ornamentation is typical of the antero-ventral scales in other specimens of *Redfieldius*.

Redfieldius obrai Bock, 1959: This species is based on a single poorly preserved specimen (ANSP 15649), from Gwynedd, Pennsylvania. As indicated by the remote dorsal fin and the supracleithral ornamentation it is a redfieldiid, but it is otherwise indeterminate.

GENUS *Dictyopyge* LYELL, 1847

Catopterus J. H. Redfield, 1837, p. 39 (in part).

Dictyopyge Lyell, 1847, p. 276. (Although this name is generally attributed to Egerton, 1847, the paper in which it first appears was written by Charles Lyell, 1847.)

Type Species. *Dictyopyge macrurus* (W. C. Redfield).

Distribution. Upper Triassic part of Newark Supergroup, in Richmond, Taylorsville, and Scottsburg basins, Virginia.

Diagnosis. *Dictyopyge* differs from *Redfieldius* and other genera in the family Redfieldiidae in having the snout region either weakly ossified or unossified but covered with minute, closely spaced, blunt, bony tubercles; frontals relatively large, length nearly twice greatest width; single ovoid suborbital; no dermohyal; dermal skull bones ornamented with flattened, somewhat imbricating tubercles or ridges; anal fin (when completely preserved) lobate rather than triangular, with broad, segmented fin rays.

Dictyopyge macrurus (W. C. Redfield, 1841)
Figures 8, 9, and 17

Catopterus macrurus W. C. Redfield, 1841, p. 27.

Dictyopyge macrurus: C. Lyell, 1847, p. 276.

Dictyopyge decipiens Brough, 1931, p. 275.

Lectotype. YPM 3207A. Specimen lacking caudal fin. Collected for (or by) W. C. Redfield prior to 1841 from unknown Richmond basin coal mine in Chesterfield Co., Virginia.

Transfer of type specimen status for *D. macrurus* from BM(NH) 11129 to YPM 3207A requires explanation. In W. C. Redfield's (1841, p. 27) original description of *Catopterus macrurus* he stated that a slab containing nearly 20 specimens was presented to the Lyceum of Natural History of New York (which later became the New York Academy of Science). The collections of the Lyceum, presumably including this slab, were destroyed by fire in 1866 (Fairchild, 1887). But according to the records of the Peabody Museum of Natural History, J. H. Redfield presented the Redfield collection of fossil fishes to Yale University on October 19, 1870. Included in this collection are three slabs

of micaceous siltstone containing specimens of *Dictyopyge macrurus* (YPM 2913, YPM 2924, YPM 3207) which are labeled "cotypes of *Catopterus macrurus* Redfield" and "Redfield collection." The two Redfields worked closely together in their paleoichthyological endeavors, and there is little reason to doubt that these specimens of *Catopterus macrurus* were available to W. C. Redfield when he prepared the original description of this species.

The specimen in the British Museum (Natural History), BM(NH) 11129, which has been regarded as the holotype of *Dictyopyge macrurus* (mentioned in Brough, 1931, p. 270, without catalogue number) was figured by Lyell (1847, pl. 8) in the same paper that includes the original description of *Dictyopyge*. This specimen was apparently in Charles Lyell's personal collection and was presented to the British Museum by his nephew, Sir Leonard Lyell, in 1913 (Colin Patterson, personal commun., 1976).

In view of this evidence, it appears that one of the Redfield syntypes must be designated as the lectotype of *D. macrurus*, to replace the specimen in the British Museum (Natural History) formerly designated as the holotype.

Distribution. Same as for genus. See also section on geologic occurrence.

Revised Diagnosis. Differs from *D. meekeri*, new species, in having 45 or 46 vertical scale rows along the lateral line; pelvic fin origin behind the eleventh vertical scale row; anal fin origin behind the twenty-second vertical scale row; dorsal fin origin behind the twenty-eighth vertical scale row. Sample size range from approximately 105 mm. to 125 mm.

Referred Specimens. From the Coal Measures, Watkins Landing, near Huguenot Springs, Virginia, Richmond basin: AMNH 4877. From the Coal Measures, Boscobel Quarry, south of Manakin, Virginia, Richmond basin: AMNH 1541, AMNH 4764, AMNH 4769, YPM 7919. From the Coal Measures, Sallee Pits, north of Midlothian, Virginia, Richmond basin: AMNH 654G. From an unknown locality, Chesterfield Co., Virginia, Richmond basin: YPM 3207A (lectotype). From unknown localities, Richmond basin: BM(NH) 11129, BSNS E2126, MCZ 13402, YPM 2924.

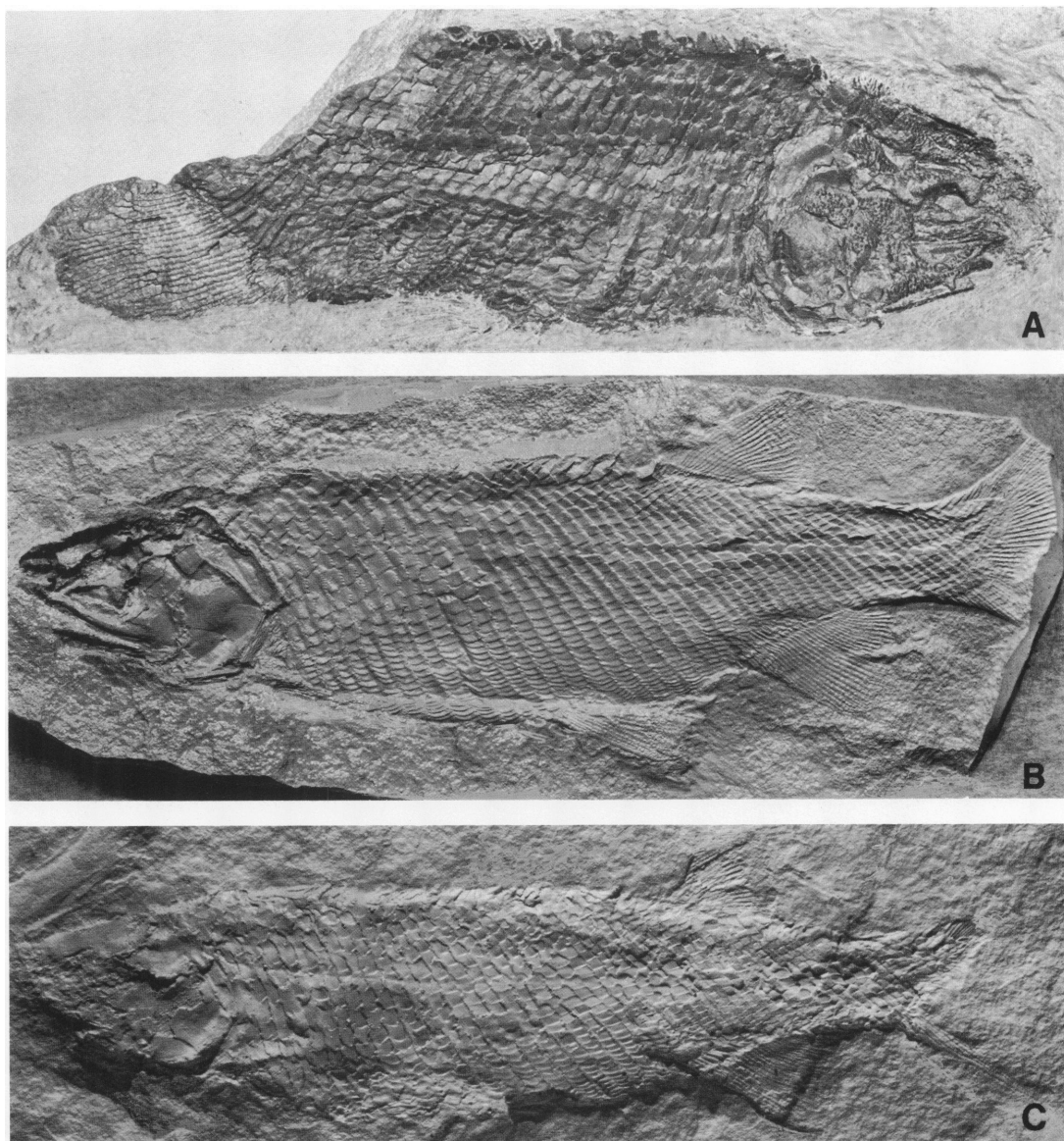


FIG. 8. *Dictyopyge macrurus* (W. C. Redfield). A, YPM 3207A, lectotype. $\times 1.36$. B, Smooth-on peel of MCZ 5068, $\times 1.14$. C, Silicone peel of BM(NH) 11129, $\times 1.05$.

***Dictyopyge meekeri*, new species**

Type. AMNH 4762. Impression of complete fish. Collected by Paul Olsen and N. G. McDonald in 1976 from the Coal Measures, Boscobel Quarry, south of Manakin, Virginia, Richmond basin.

Distribution. Same as for genus. See also section on Geologic Occurrence.

Diagnosis. Differs from *D. macrurus* in having 39-40 vertical scale rows along the lateral line; pelvic fin origin behind the eighth or ninth vertical scale row; anal fin origin behind the fifteenth to sixteenth vertical scale row; dor-



FIG. 9. *Dictyopyge macrurus* (W. C. Redfield). YPM 3207, slab from the Redfield collection with numerous specimens, including lectotype (YPM 3207A), $\times .55$.

sal fin origin behind the twenty-fifth vertical scale row.

Referred Specimens. From the Coal Measures, Watkins Landing, near Huguenot Springs, Virginia, Richmond basin: AMNH 4876, AMNH 4884, AMNH 4922, AMNH 4927. From the Coal Measures, Boscobel Quarry, south of Manakin, Virginia, Richmond basin: AMNH 4733, AMNH 4735, AMNH 4737, AMNH 4738, AMNH 4740, AMNH 4741, AMNH 4743, AMNH 4756, AMNH 4760, AMNH 4762 (type), AMNH 5244, YPM 7936. From the Coal Measures, Dover Mines, Manakin, Virginia, Richmond basin: NMNH 3586. From the middle unit, basal portion, south bank

of South Anna River, south of Taylorsville, Virginia, Taylorsville basin: NMNH 243984–243992.

Description. The more complete specimens of *D. macrurus* and *D. meekeri* show no significant changes in body proportions within their respective size ranges. The head (tip of snout to posterior border of subopercular) averages about 28 percent of the total body length (fig. 11). The maximum body depth is about equal to the head length. The triangular dorsal fin originates well behind the middle of the body and anterior to that of the lobate anal. The pelvic fin arises at the middle of the body although its origin is much closer to the origin of the anal

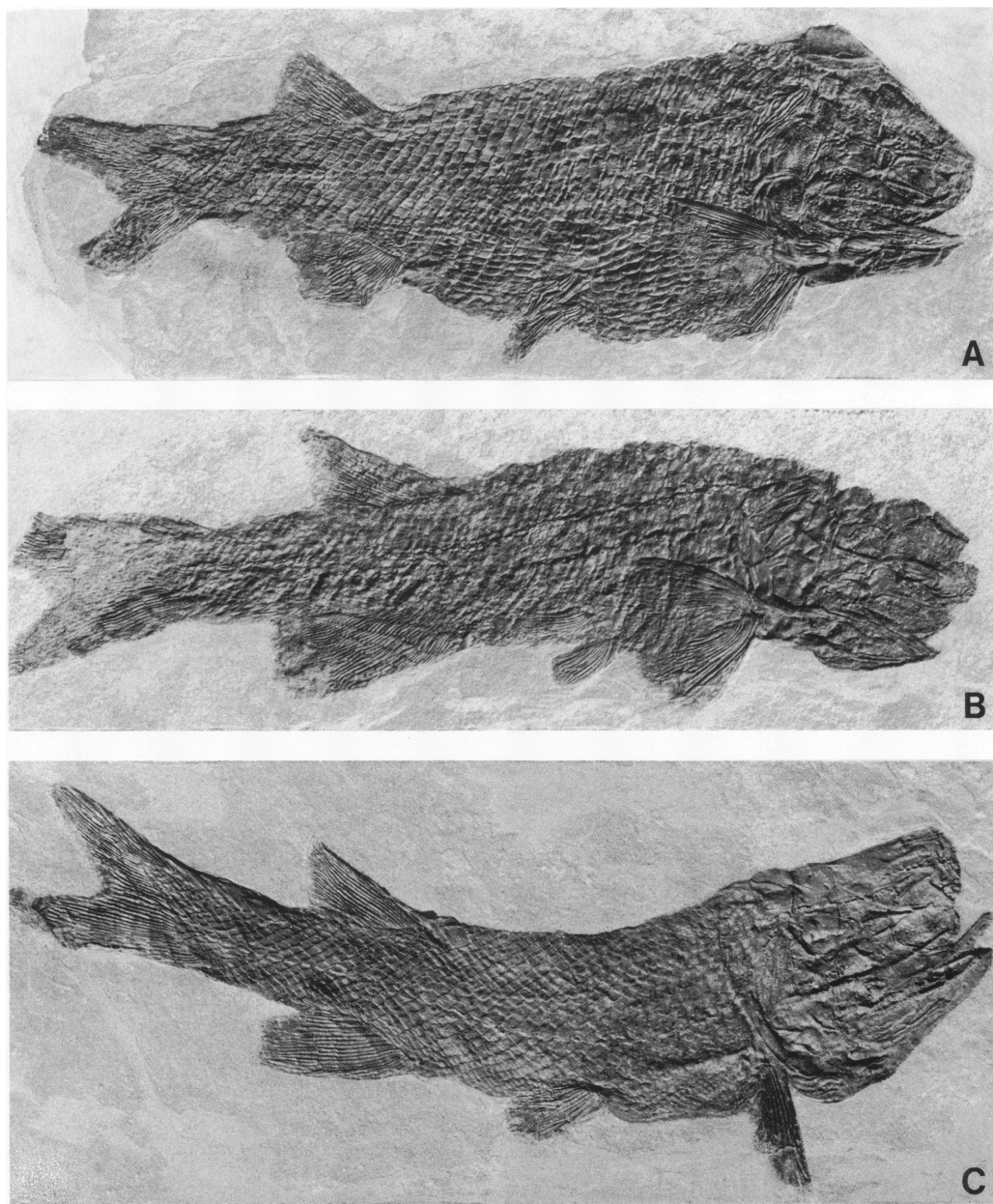


FIG. 10. *Dictyopyge meekeri*, new species. A, AMNH 4762, type, $\times 2.02$. B, YPM 7936, $\times 3.05$. C, AMNH 4756A, $\times 3.15$.

than to the origin of the pectoral. The hemiheterocercal caudal fin is equilobate and moderately cleft.

The dermal skull pattern (figs. 12-15), which has remained elusive until now, has been worked out mostly from smooth-on peels pre-

pared from carefully cleaned impressions. The elongate, ovoid suprascapulars do not meet in the midline. There are four somewhat rectangular extrascapulars as in *Cionichthys* and *Redfieldius*. In YPM 3207A the median pair of extra-scapulars is replaced by a single element. One pair of small, nearly rectangular parietals has been noted in all specimens where this area is reasonably well preserved. The exceptionally wide frontals are about four times the length of the parietals and considered together are about as wide as long. Their anterior border is nearly straight and somewhat beveled. Posteriorly, the frontals become narrowed to equal the width of the parietals.

As in other redfieldiids, the dermosphenotic and dermopterotic are subequal in size. The median border of the latter swings inward rather sharply to meet the lateral border of the parietals.

The snout area of *Dictyopyge* is always covered with a disorganized mass of tiny, blunt tubercles of uniform width that resemble rice grains. In life they covered the area occupied by the adnasals, postrostral, rostral, and antorbitals in other redfieldiids. Even in specimens of *Dictyopyge* that retain some aspect of the third dimension, the tuberculated snout region remains disorganized and enigmatic (e.g., YPM 3207). Either ossification in this area was very thin or absent entirely except for the tubercles.

The mouth is characteristically subterminal, the orbit typically far forward and about one-third the total skull length. The suspensorium, as in most other redfieldiids, is nearly vertical. The posterior and ventral border of the orbit is formed by a postorbital and three infraorbitals. In the best-preserved cheek areas (AMNH 4765, 4766, 4768 and 6770) the preopercular is represented as a gamma-shaped bone with the two arms joined at an angle of less than 90 degrees. There is a single suborbital element but no certain indication of a dermohyal. The shape of the maxilla, with its high, narrow postorbital expansion, is unique among the redfieldiids. The dentary is shaped as in related taxa, although it may appear narrower anteriorly because of the preservation angle. The marginal teeth of the maxilla and dentary are

very small, uniform and acuminate. Somewhat more robust teeth are present on the coronoid and on the dermal palate (AMNH 4927).

The opercular is almost rectangular and is less than half the size of the subopercular. The single branchiostegal is roughly triangular and is typically situated behind the angular. The throat area is difficult to interpret. There is probably a median gular extending to the mandibular symphysis behind which are paired lateral gulars that articulate with the single branchiostegals of each side.

The elaborate ornamentation of the dermal skull is particularly well shown in AMNH 4765 (fig. 14A). It consists of flattened elevations, either tubercles or short ridges that occasionally anastomose. The elevations vary in size and shape and in some areas are slightly imbricated. Although many of the redfieldiids have strongly ornamented skulls (*Cionichthys*, Schaeffer, 1967, seems to be an exception), the form of the ornamentation in *Dictyopyge* coupled with the oddly tuberculated snout give the skull a distinctive appearance.

The supracleithrum, cleithrum, and clavicle are strongly ridged. In ventral aspect the shoulder girdle is like that of *Redfieldius*. A well-ornamented median gular is also present in front of the clavicles. The pectoral fin is bordered by about 50 fringing fulcra and is composed of 10 or 11 principal rays, which are segmented in their distal half. The pelvic fin has one basal, at least 35 fringing fulcra, and 10 to 11 segmented and distally bifurcated rays.

The triangular dorsal fin (fig. 11) is made up of about 17 completely segmented, distally bifurcated rays and is bordered by three basal and more than 40 fringing fulcra. The anal fin has about the same basal length as the dorsal, but in most specimens the broad rays are spread to give a characteristic lobate outline. The rays number about 23, are completely segmented, and only bifurcate near their free ends. The anterior ray supports two or three basals and at least 45 fringing fulcra.

The moderately forked caudal fin (figs. 11, 16), which cannot be readily separated into dorsal and ventral lobes, has five basal and 55 fringing fulcra bordering both the dorsal and



FIG. 11. *Dictyopyge macrurus* (W. C. Redfield). Reconstruction.

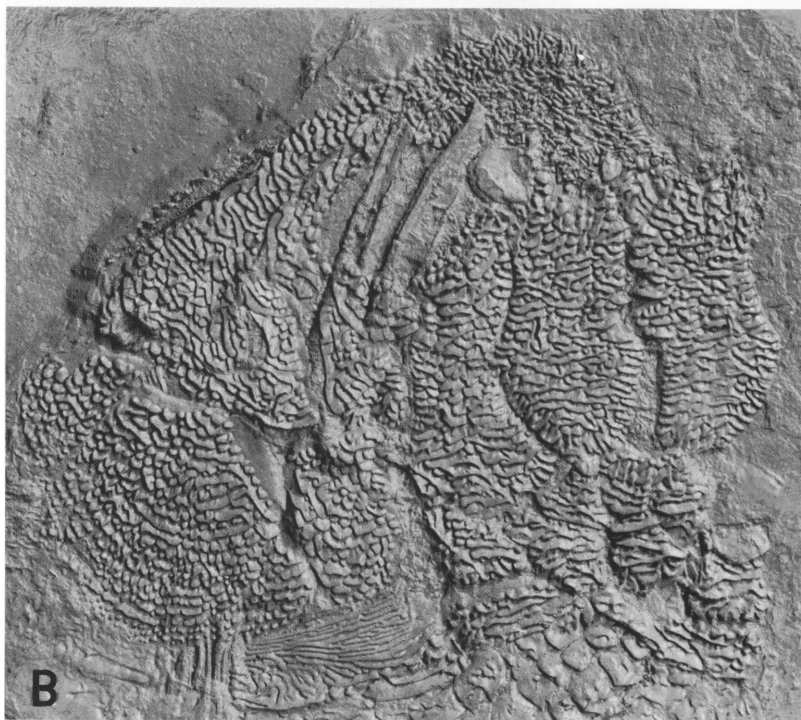
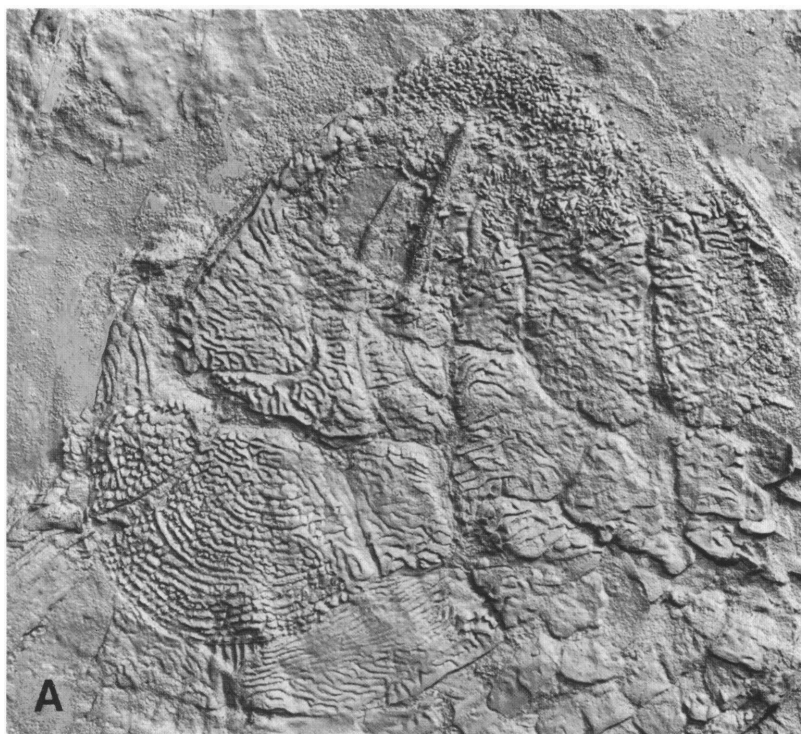


FIG. 12. *Dictyopyge* cf. *macrurus* (W. C. Redfield). Smooth-on peels of cheek area and skull roof. A, AMNH 6770, $\times 2.35$. B, AMNH 4768, $\times 2.85$.

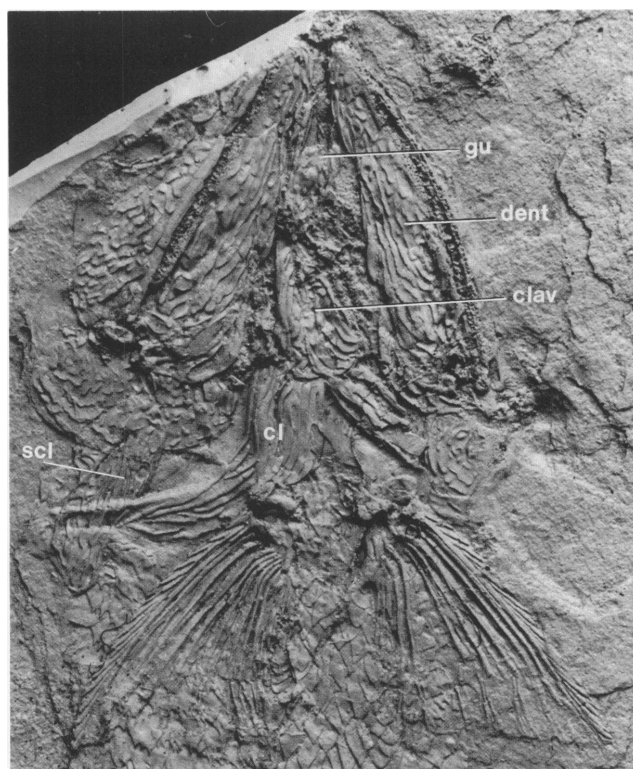


FIG. 13. *Dictyopyge* cf. *meekeri*, new species. Smooth-on peel of AMNH 4746, skull in ventral aspect, $\times 4.2$. Abbreviations: cl, cleithrum; clav, clavicle; dent, dentary; gu, possible gular; scl, supracleithrum.

ventral lobes. There are 38 to 40 principal rays. About seven enlarged ridge scales are situated between the dorsal fin and the origin of the dorsal lobe of the caudal. The rhomboidal scales diminish in size both posteriorly and ventrally. On the anterior half of the body the scales are strongly denticulated but on the posterior portion the free scale margins appear to be smooth. The belly scales between the pectoral and anal fins are about half the width of the flank scales and have a single deep notch. The histology of the scales (fig. 17) is similar to that of *Redfieldius*.

Discussion. *Dictyopyge* has several derived characters that distinguish it from other redfieldiid genera. One is the apparent absence of adnasals, antorbitals, nasals, rostral, and postrostral, although these elements may be lightly ossified and obscured by the abundant blunt

rostral tubercles. In any case, this condition clearly differs from the snout ossification and ornamentation of the other American, South African, and Australian genera. In these genera, the rostral bones are distinct and well ossified regardless of their ornamentation. A second autapomorphy in *Dictyopyge* is the relative size and shape of the anal fin, together with the scalelike aspect of the anal fin ray segments. A third is the lateral expansion of the frontal bones, which makes them relatively larger than in the other genera.

The relationships of *Dictyopyge* within the Redfieldiidae are not immediately evident, and further consideration of this matter must await a review of the entire family.

The single specimen of *Dictyopyge* (AMNH 654) described as a new species, *D. decipiens*, by Brough (1931, p. 275) is here synonymized

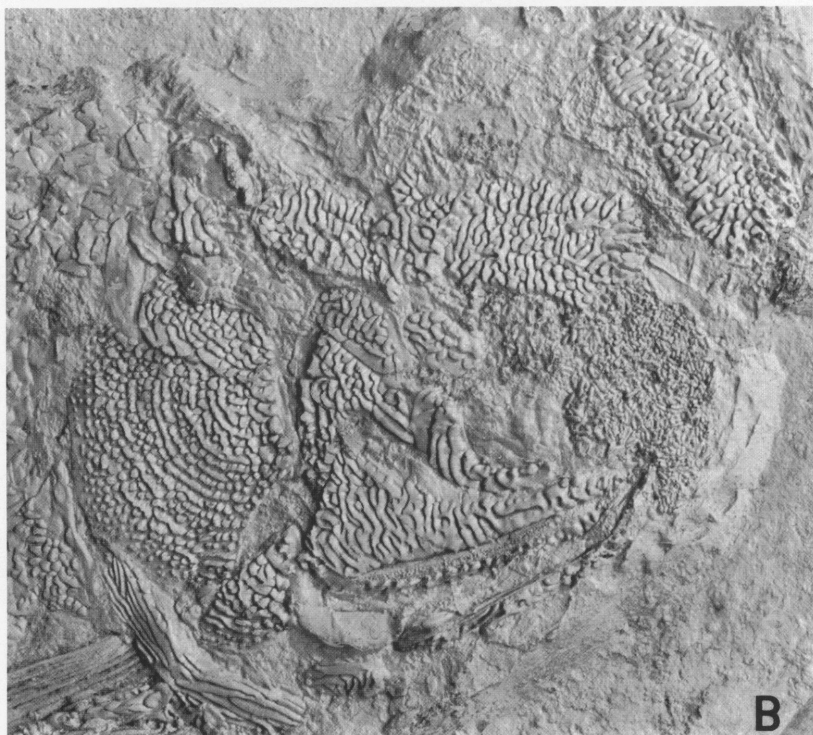


FIG. 14. *Dictyopyge* cf. *macrurus* (W. C. Redfield). Smooth-on peels of lateral aspect of skull and shoulder girdle. A, AMNH 4765, $\times 1.63$. B, AMNH 4766, $\times 2.55$.

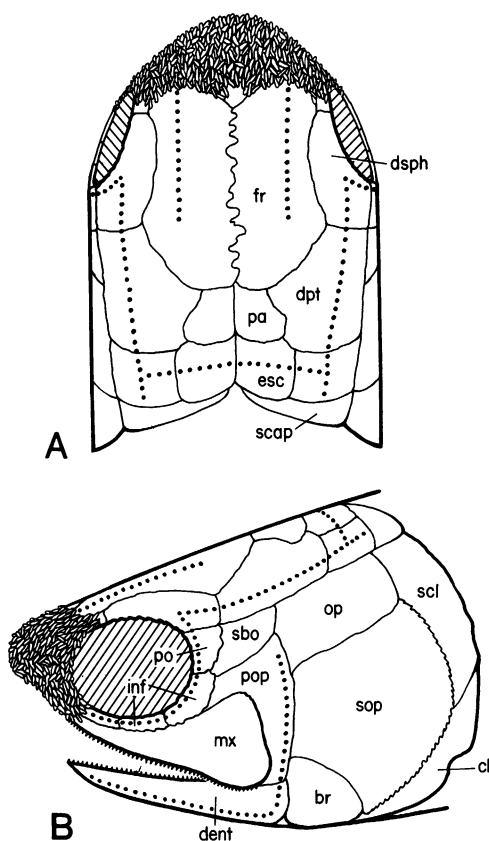


FIG. 15. *Dictyopyge* cf. *macrurus*. Reconstruction of skull. A, Dorsal aspect. B, Lateral aspect. Abbreviations: adn, adnasal; ant, antorbital; br, branchiostegal; cl, cleithrum; dent, dentary; dhy, dermohyal; dpt, demopterygoid; dsph, dermosphenoid; esc, extrascapular; fr, frontal; inf, infraorbital; mx, maxilla; na, nasal; op, opercular; pa, parietal; pcl, postcleithrum; po, postorbital; pop, preopercular; sbo, suborbital; scap, suprascapular; scl, supracleithrum; sop, subopercular.

with *D. macrurus*. Although this specimen suffered damage after it was studied by Brough, it is possible to reject most of the unique derived characters noted by him. The presumed greater body depth in the vicinity of the anal fin seems to be a compression phenomenon. The relative positions of the dorsal and anal fins are the same as in *D. macrurus*. The origins of these fins are separated by six vertical scale rows in

each. Also the number of fin rays in the anal and caudal fins agrees with the ray counts for *D. macrurus*.

The two species of *Dictyopyge* recognized in this paper are based on the total number of vertical scale rows, and on differences in pelvic, dorsal and anal fin position as expressed by the number of vertical scale rows separating the origins of these fins. In all the specimens used for the scale counts the squamation is complete, which means that no additional scale rows were added with increase in size. In addition to the differences in scale count and in position, the two species may also be separable in terms of maximum size. However, the latter is a more tenuous distinction in view of the available sample.

After the genus *Dictyopyge* was established in Lyell's paper of 1847, various European and Australian forms, some of which had previously been assigned to other genera, were referred to *Dictyopyge*, as follows:

1. *D. socialis* Strüver, 1864 for *Semionotus socialis* Berger, 1843, from the Upper Keuper, Coburg, Germany.
2. *D. catoptera* Traquair, 1877 for *Paleoniscus catoptera* Egerton, 1858, from the Keuper, Tyrone, Ireland.
3. *D. superstes* von Zittel, 1887 for *Paleoniscus superstes* Egerton, 1858, from the Upper Keuper, Warwickshire, England.
4. *D. rhenana* Deeke, 1889. From Bunter Sandstone, Degerfelden, near Basel, Switzerland.
5. *D. symmetrica* Woodward, 1890. From Narrabeen Shales, Scythian or Anisian, Gosford, N. S. W., Australia.
6. *D. illustrans* Woodward, 1890. From Narrabeen Shales, Scythian or Anisian, Gosford, N. S. W., Australia.
7. *D. robusta* Woodward, 1890. From Narrabeen Shales, Scythian or Anisian, Gosford, N. S. W., Australia.
8. *D. (?) draperi* Woodward, 1893. From Stormberg Beds, Rouxville, Orange Free State, Union of South Africa.

Brough (1931, p. 271) noted more than 40 years ago that the Old World forms assigned to *Dictyopyge* should be removed from that genus

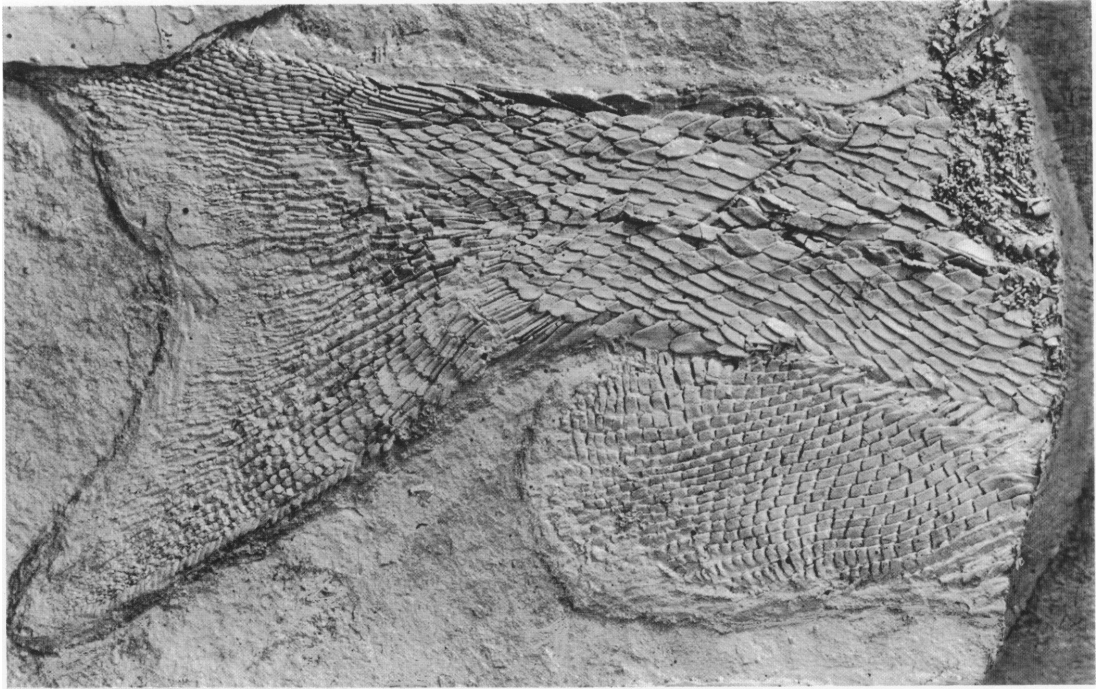


FIG. 16. *Dictyopyge* cf. *macrurus*. Smooth-on peel of AMNH 5241, details of anal and caudal fins, $\times 3.08$.

for lack of unequivocal diagnostic evidence. To our knowledge this has never been formally accomplished, and Lehman (1966, p. 112) has included, by implication, these eight taxa in his summary of the distribution of the genus. Examination of the original figures of the European forms indicates that they cannot be referred to *Dictyopyge*, and that most of the specimens may be indeterminate. In regard to the Australian forms assigned by Woodward (1890) to *Dictyopyge*, Wade (1940, p. 208) and Hutchinson (1973, p. 291) agreed that they are redfieldiiforms, possibly belonging to the Brookvaliidae (Hutchinson, 1973). *D. (?) draperi* (Woodward, 1893) has a somewhat con-

fused history (see Brough, 1931, p. 247). The specimen on which the generic identification is based (Woodward, 1893, pl. 17, fig. 1) is too poorly preserved (or prepared) to demonstrate redfieldiiform affinity.

In summary, *Dictyopyge*, with two species, is a distinctive redfieldiid that is presently known only from the Richmond, Taylorsville, and Scottsburg basins in Virginia. Recently collected specimens of *Dictyopyge* (YPM 8066-8074), from near Wolf Trap, Virginia, in the Scottsburg basin (approximately 1 mile north-east of Route 716 along Southern Railroad cut), have not been identified to species.

REDFIELDIIDS COMMON TO THE DOCKUM, CHINLE, AND NEWARK ROCKS

Several genera first described from the Chinle and Dockum formations of the western United States (Schaeffer, 1967) have been dis-

covered in the Newark Supergroup. *Synorichthys* Schaeffer occurs in the Lockatong Formation (Schaeffer and Mangus, 1970) at North

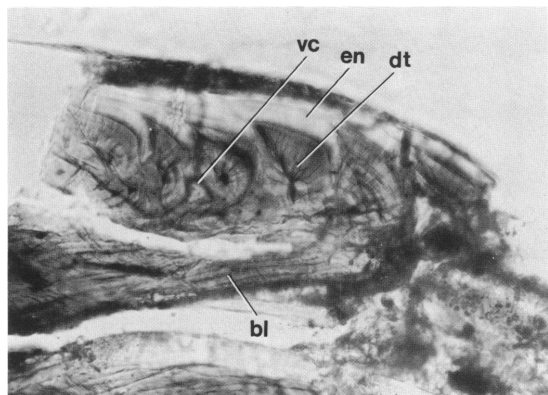


FIG. 17. *Dictyopyge macrurus* (W. C. Redfield). Vertical section of incomplete flank scale, $\times 172$. Abbreviations: bl, bone lamellae; en, enameloid; dt, dentine; vc, vascular canal.

Bergen, New Jersey (AMNH 3983, 3984, 5300) and at Princeton (PU 21854) and possibly at several localities in the Deep River and Dan River basins in North Carolina. *Synorichthys* differs from its sister taxon *Lasalichthys* Schaeffer mainly in the dermal bone pattern of the snout, which is not completely preserved in any of the New Jersey specimens. However, the anterior borders of the frontals indicate the condition in *Synorichthys*. *Rushlandia gilli* Bock, 1959 (ANSP 15661, 15662 and uncatalogued fragments) is an indeterminate redfieldiid closely resembling *Synorichthys*.

Specimens that are referred to the genus *Cionichthys* Schaeffer (YPM 792) have been found at the Boscobel Quarry locality in the Richmond basin by Paul Olsen (personal com-

mun.). This genus has the typical subequal dermopterotic and dermosphenotic of the redfieldiids, but has retained the primitive palaeonisciform paired rectangular parietals and supraorbital canals that extend through the frontals for about two-thirds of their length.

Perhaps the most unexpected discovery in the older collections of Newark fishes is a fragmentary specimen (AMNH 1427) from the Richmond basin (fig. 18B) with an attached note in Newberry's handwriting: "Anal? Fin of new species of *Catopterus*? Fin rays and dorsal scales highly ornamented." The incomplete fin is an anal with rather broad, completely segmented fin rays ornamented with very delicate ridges and grooves that parallel the long axis of the rays. This ornamentation is known to occur only in *Tanaocrossus* Schaeffer, 1967, among the Newark-Chinle-Dockum fishes. It was originally described from a single specimen (AMNH 5700, fig. 18A) collected in the upper part of the Chinle Formation, Dolores River Canyon, Colorado. The Virginia specimen can be referred to this genus with some confidence, pending the discovery of more complete individuals.

Tanaocrossus has numerous branchiostegals (unlike the redfieldiids), a triangular preopercular resembling that of *Perleidus* (Lehman, 1952), an opercular that is larger than the subopercular, a hemiheterocercal caudal fin, a deep fusiform body, a dorsal fin that extends nearly the entire length of the back, and a relatively short anal. The relationships of this actinopterygian remain unknown.

GEOLOGICAL OCCURRENCE

Rocks of the Newark Supergroup (Van Houten, 1977; Olsen, 1977) of eastern North America are contained in a nearly linear series of separated, elongated, partially fault-bounded basins, extending from the northern border of South Carolina to eastern Nova Scotia (fig. 19). Newark deposits are also thought to underlie large portions of the coastal plain and continental shelf from Florida to Newfoundland (Marine and Siple, 1974; Jansa and Wade, 1975; Bal-

lard and Uchupi, 1975). The basins are aligned in a north-south or northeast-southwest direction, generally parallel to the Appalachian fold belt; they are usually underlain by structurally complex Precambrian and Paleozoic igneous and metamorphic rocks. In most of the Newark basins the rocks dip gently to the northwest, but in the Hartford, Deerfield, and Deep River areas, dips are southeastward and eastward. Apparently the formation of the Newark basins

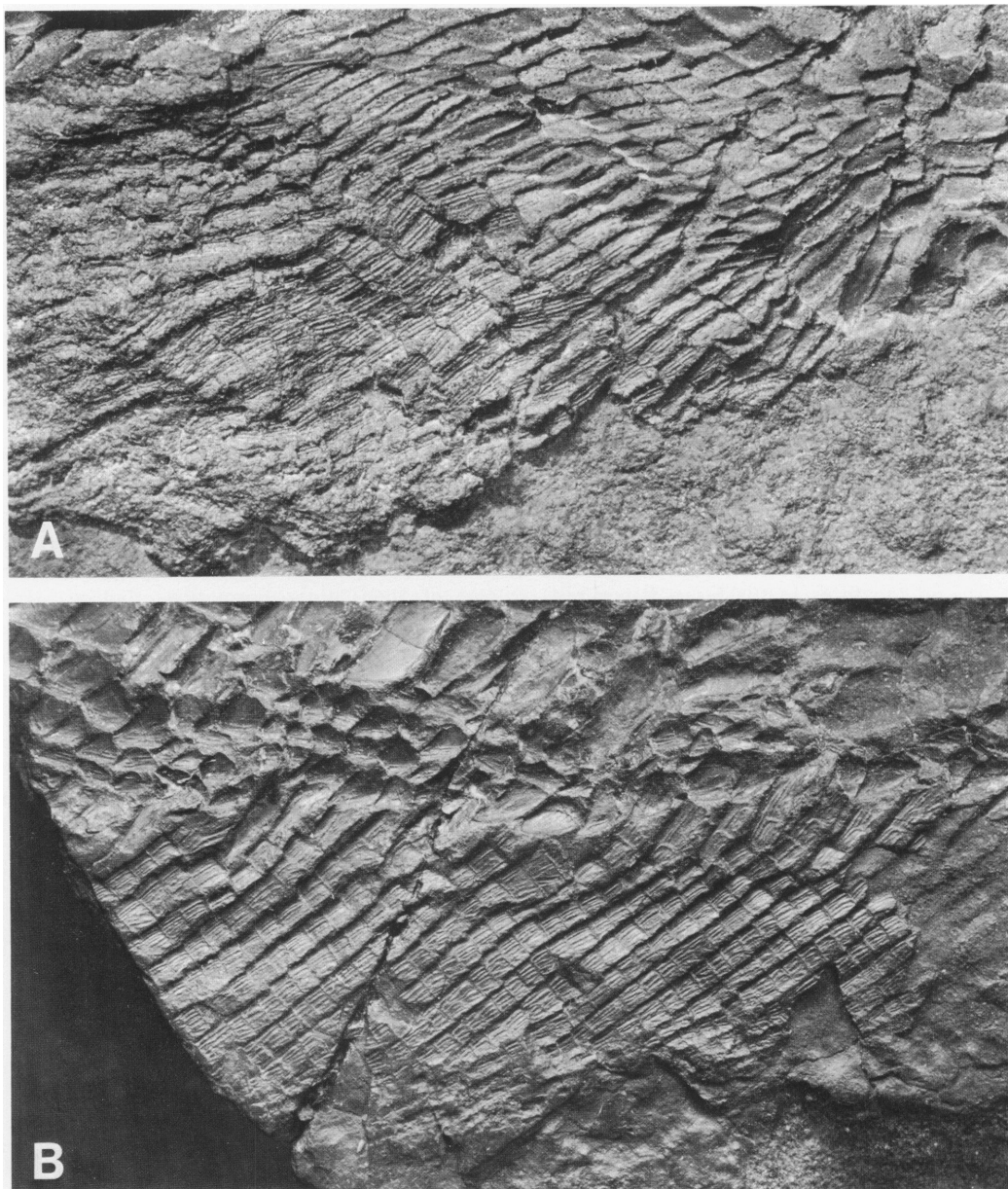


FIG. 18. *Tanaocrossus kalliokoski* Schaeffer. A, AMNH 5700, anal fin of type specimen from Chinle Formation, $\times 4.55$. B, AMNH 1427, anal fin of referred specimen from Richmond basin, $\times 4.55$.

was a response to the spasmodic breakup of Pangaea and the opening of the North Atlantic in the early Mesozoic (Dietz and Holden, 1970; Van Houten, 1977).

Most of the Newark basins contain rocks of nearly identical character. In many of the basins, the stratigraphic sequence consists of a coarse basal facies, largely conglomerate and

arkose, followed by finer-grained red to black clastic units (sandstone, slate, or argillite), and an upper facies largely composed of red shale and sandstone. Near the edges of most basins fanglomerates are common; coal seams are found in the larger southern basins. Diabase intrusives occur throughout most of the basins, basaltic lava flows are found in the more northerly basins. Newark lithologies generally reflect alluvial fan, paludal, fluvial, and lacustrine depositional environments (Hubert, Reed and Car-

ey, 1976, p. 1201), but as Byrnes and Horne (1974) and Schaeffer, Dunkle and McDonald (1975) have suggested, perhaps some environments were transitional or even shallow water marine.

The rocks of the Newark Supergroup have generally been correlated with those of the European Keuper, and have usually been assigned Carnian, Norian and Rhaetian ages (McKee et al., 1959). However, recent paleobotanical and palynological studies by Cornet, Traverse and

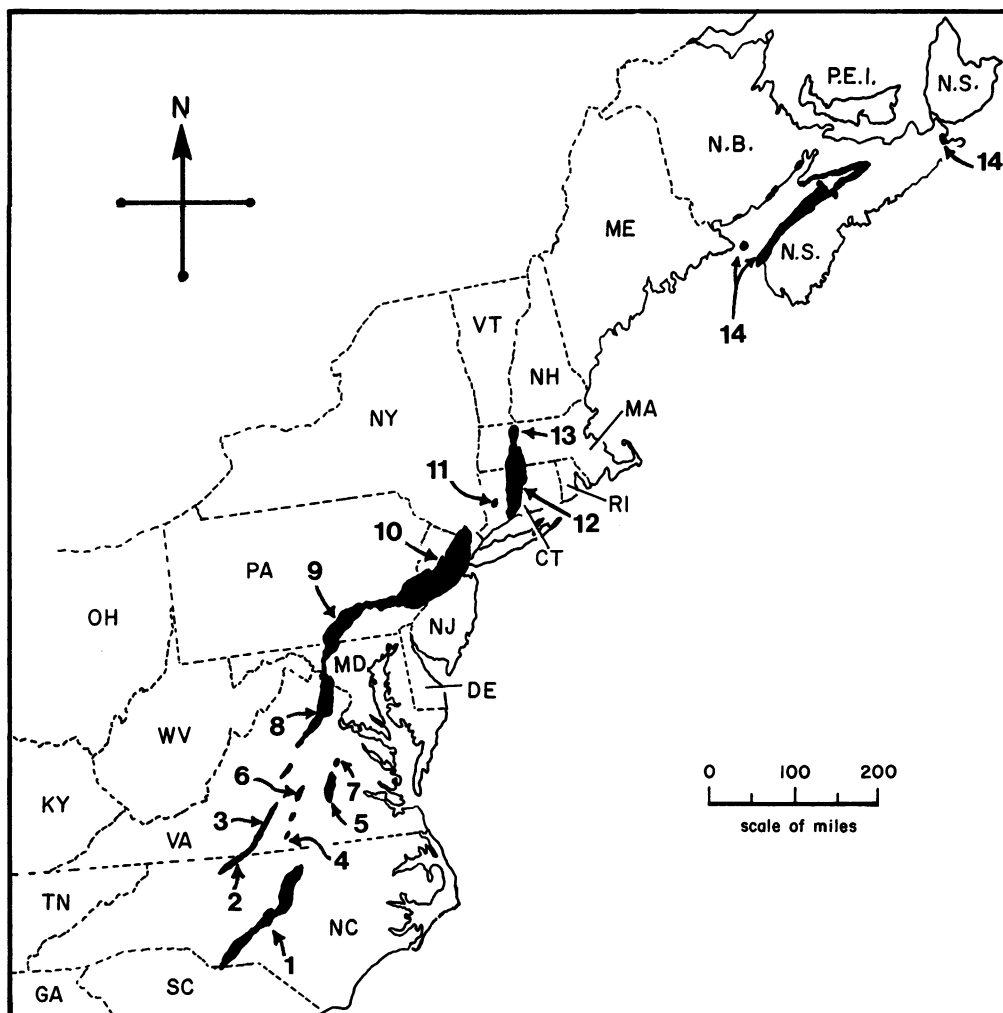


FIG. 19. Newark Supergroup basins. 1, Deep River basin; 2, Dan River basin; 3, Danville basin; 4, Scottsburg basin; 5, Richmond basin; 6, Farmville basin; 7, Taylorsville basin; 8, Culpeper basin; 9, Gettysburg basin; 10, Newark basin; 11, Pomperaug basin; 12, Hartford basin; 13, Deerfield basin; 14, Acadian basins.

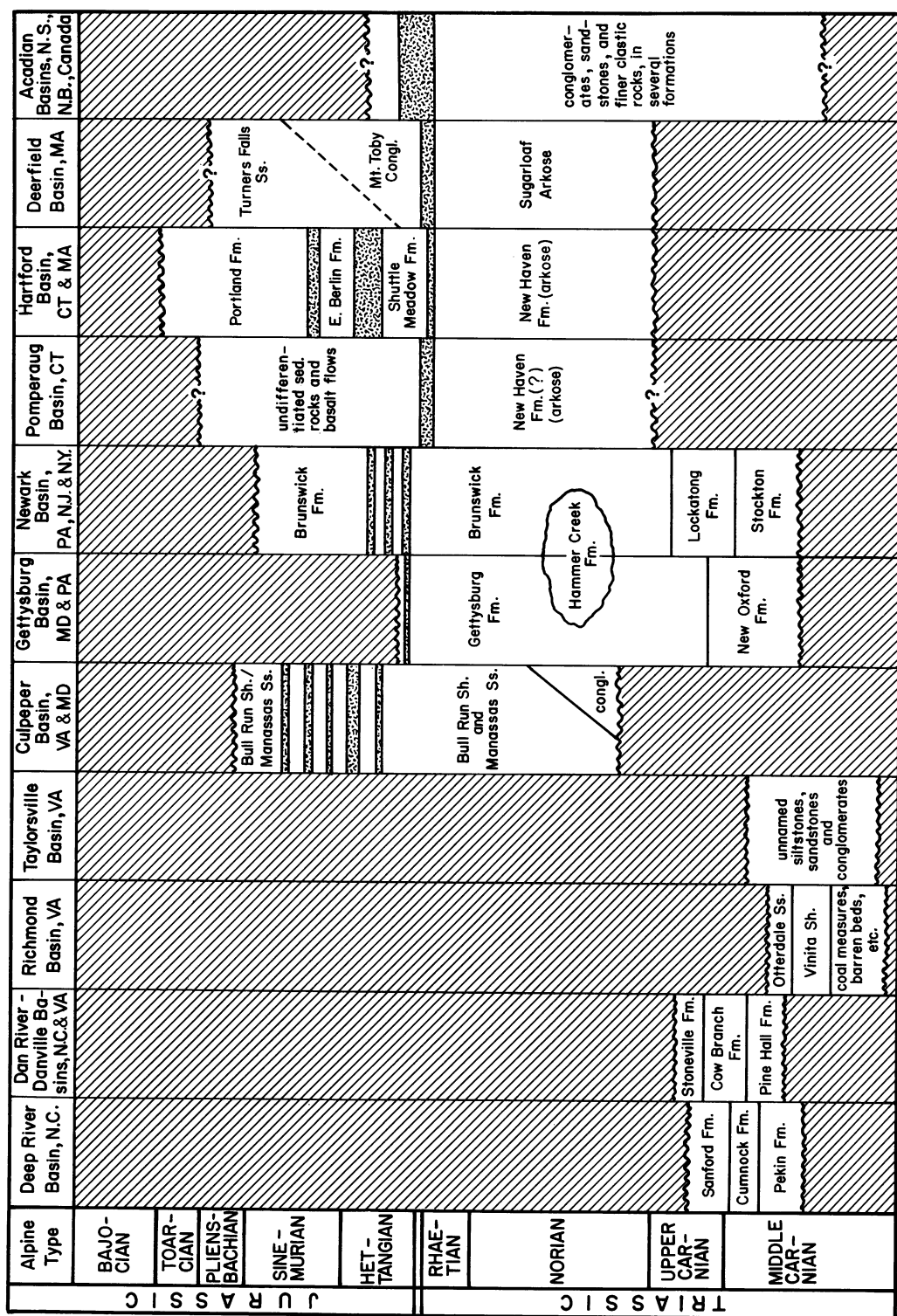


FIG. 20. Correlation chart of the major Newark Supergroup basins. Thicknesses are not to scale. Intrusive rocks omitted. Correlations are generalized, and are based in part on palynological and paleobotanical data provided by B. Cornet (personal commun., 1977) and vertebrate data supplied by P. Olsen (personal commun., 1977).

McDonald (1973) and Cornet and Traverse (1975) have indicated that considerable portions of the Newark sequence are Lower Jurassic in age (fig. 20).

The generally accepted stratigraphy for each of the Newark areas is outlined in the chart on page 158. The following section is devoted to a brief description and discussion of the generalized stratigraphy and fossil fish occurrences in the various basins.

Deep River Basin

The Deep River basin of central North Carolina is the largest of the southern Newark basins. It has been divided by some authors into three smaller basins (from north to south): Durham, Sanford, and Wadesboro basins, but the whole area is commonly called the Deep River basin (Stuckey, 1965). In the south-central portion of the basin, in the area known as the Deep River Coal Field (Sanford basin), the rocks have been divided into three formations by Campbell and Kimball (1923) and Reinemund (1955): (1) the Pekin formation, consisting largely of red and gray conglomerate, fanglomerate, coarse sandstone, red-and-brown siltstone and claystone; (2) the Cumnock Formation, composed of gray siltstone, fine-grained sandstone, light gray to black, calcareous, carbonaceous shale, and two thin units of coal; and (3) the Sanford Formation, consisting of a varied assortment of red or brown fine to coarse clastic rocks. North and south of the Deep River Coal Field, the rocks have not been mapped in detail, but there are units resembling the Pekin and Sanford formations. The Cumnock Formation is generally absent outside the Coal Field. The Pekin, Cumnock, and Sanford formations should be regarded as sedimentary facies rather than time-stratigraphic units.

With one or two notable exceptions, fossil fish remains in the Deep River basin are confined to the dark gray and black shales of the Cumnock Formation. Reinemund (1955, p. 53) has concluded that the Cumnock was deposited in a reducing environment in swamps and lakes on a poorly drained basin floor. On the other hand, the predominantly red lithologies of the Pekin and Sanford formations reflect oxidizing

environments, the sediments probably accumulating on well-drained alluvial piedmont slopes.

The Cumnock Formation has limited natural exposures throughout much of the Deep River Coal Field and most of the existing records of Cumnock fishes (see Emmons, 1856, p. 321; 1857, p. 42; 1858, p. 77; 1860, fig. 167) describe fragmentary specimens from old and presently inaccessible coal shafts and associated excavations. Many of Emmons's specimens presumably¹ came from the well-known Cumnock (Egypt) mine, just north of the town of Cumnock, or from the Carolina (Farmville) mine, 1½ miles east of Cumnock. Few recent writers have mentioned fossil fishes from this area, and none has provided information on specific fossil localities. Reinemund (1955, p. 50) has noted that many black shale beds in the Cumnock contain fragmentary fish remains. Analysis of Reinemund's drill core records (pp. 127-156) has established the presence of at least 15 fish-bearing horizons, broadly distributed through the middle and lower parts of the formation. The fossiliferous shale is typically dark gray to black, noncalcareous and fissile, and is in units of variable thickness up to 20 feet.

In recent years, fossil fishes have been collected from three localities in the Cumnock Formation by P. E. Olsen and N. G. McDonald. At the dump of the Carolina coal mine, scattered remains occur in blocks of massive, coaly, ferruginous, black silty shale, sometimes called "blackband." Reinemund (1955, p. 52) reported that the blackband commonly occurs near the coal seams in the lower part of the Formation. On the east bank of the Deep River, at the site of the Carbonton hydroelectric dam, fragmentary fish remains were found in a bed of massive, medium gray, hard and brittle shaly siltstone which was baked by a nearby diabase dike. The fishes are confined to a foot-thick zone near the top of the unit. Fish scales were also obtained from the Gulf coal seam in stream gullies near the village of Gulf, in beds of fissile, light gray to black carbonaceous

¹Unfortunately, the present whereabouts of Emmons's collection of fossil fishes is unknown; Stuckey (1965) has stated that many of Emmons's fossils were lost or damaged in the Civil War.

shale. The Gulf coal seam occurs near the base of the Cumnock Formation. The fossil fishes from these localities are usually dissociated and incomplete. Dermal bones and pectoral fin fragments from the Carolina mine can be assigned to *Cionichthys*; similar bones and fin elements from the Carbonton dam locality are tentatively assigned to *Synorichthys* sp. Coelacanth scales from the Gulf coal seam are assigned to *Diplurus* (see Schaeffer, 1954, pp. 4-5). The fishes are commonly associated with abundant remains of the branchiopod *Cyzicus* (= *Estheria*) *ovata* (Lea), ostracods, reptile bones and teeth, coprolites, and macerated plant fragments.

Outside of the Cumnock Formation, only a single occurrence of fossil fishes is known (Olsen, personal commun., 1976). The locality is in the lower Pekin Formation, exposed in a roadcut east of Pekin, Montgomery County. Isolated redfieldiid bones and reptile remains occur in friable, reddish brown to white coarse arkose. On the basis of shape and ornamentation, certain bones have been referred to *Synorichthys* sp.

Dan River-Danville Basins

The stratigraphy of the contiguous Dan River and Danville basins in North Carolina and Virginia has been outlined by Thayer (1970) and by Meyertons (1963). Thayer has divided the stratigraphic sequence of the Dan River area into three units: (1) the Pine Hall Formation, largely gray to red sandstone, siltstone and conglomerate; (2) the Cow Branch Formation, composed essentially of gray to black shale and argillite with minor red-brown mudstone and sandstone and a thin unit of coal; and (3) the Stoneville Formation, consisting of red to gray conglomerate, sandstone, and mudstone. The three formations are lithologic facies that interfinger throughout much of the basin and are not distinct time-stratigraphic units (Thayer, 1970, p. 9). Thayer has not recognized Meyerton's (1963) stratigraphic terminology for the Danville area; presumably Thayer's nomenclature is applicable in this region as well as in the Dan River basin.

Fossil fishes in the Dan River and Danville areas have been found only in the lacustrine

and paludal dark shales of the Cow Branch Formation. In the extreme northern part of the Dan River Basin, near the town of Eden, the fossiliferous lower portion of the Cow Branch Formation has been exposed in a number of quarries, stream cuts, and road cuts. Fishes occur sparingly in the Cow Branch; they are mostly confined to thin units of fissile to flaggy, rhythmically bedded, calcareous, carbonaceous, medium to dark gray silty shale. In the southern part of the basin, near the town of Walnut Cove, Stokes County, part of the lower Cow Branch is exposed in cuts of the Norfolk and Western Railway and the Southern Railway. Both cuts reveal a series of thin, fissile to massive, dark gray to black, rhythmically bedded, fossiliferous silty shales, that alternate with thicker beds of yellowish and greenish sandstone and shale. Well-preserved specimens of *Turseodus*, *Diplurus newarki*, *Semionotus*, and *Synorichthys* have been collected from the Eden localities (Olsen, personal commun., 1976). *Cionichthys* has been tentatively identified from Walnut Cove, based largely on isolated skull bones and pectoral fin fragments. Schaeffer (1952, p. 55) has described a single specimen of *Diplurus newarki* from the Chatham, Virginia, area; presently this is the only known fossil fish locality in the Danville basin. The fossil fishes in the Dan River basin are usually found in association with the branchiopod *Cyzicus*, reptile remains, insects, coprolites, and fragmentary plant debris.

Richmond, Farmville, Scottsburg, and Taylorsville Basins

Shaler and Woodworth (1899) have divided the Newark of the Richmond basin into the following sequence: (1) the basal "Boscabel [*sic*] Boulder Beds," a local coarse conglomeratic unit; (2) the "Barren Beds,"¹ consisting of red, white, and gray arkose, sandstone, and shale; (3) the "Coal Measures," composed of interstratified beds of coal, black shale and feldspathic and micaceous sandstone; (4) the "Vinita Beds," which are largely fissile black shale and interbedded gray sandstone

¹Called "Barren Beds" because they lacked coal deposits.

units; and (5) the "Otterdale Sandstones," primarily made up of coarse, often feldspathic sandstone. Essentially the same stratigraphic sequence is recognized by Goodwin (1970, p. 13) in his description of the Hylas and Midlothian Quadrangles, although he does not retain Shaler and Woodworth's terminology or propose any new formational names.

Remains of fishes in the Richmond basin occur principally in the gray to black lacustrine and paludal shales and sandstones of the Coal Measures and Vinita Beds. The occurrence of fishes in the basin was noted by Grammer as early as 1818, and by many later nineteenth-century authors. Almost without exception, the early reports describe specimens from pits and shafts in the Coal Measures on the eastern and western margins of the basin. Shaler and Woodworth (1899, p. 433) reported the presence of fish-bearing beds in all the coal mine workings along the eastern border, and also in the wastes near the old mines in the western part of the field. In his 1500 foot section of the strata exposed in the shaft of the Old Midlothian mine, near Midlothian, Chesterfield County, Heinrich (1878, p. 256-260, pl. 6, fig. 1) has described at least 14 distinct, widely separated fish horizons, the lowest occurring 227 feet above the underlying granite, the highest some 1111 feet above the granite. Lyell (1847, p. 263) also observed that fossiliferous beds from 400 to 500 feet thick occur near the base of the Richmond basin section. It is evident from these and other early reports that fossil fishes occur throughout much of the stratigraphic sequence in the basin. Unfortunately, all the old coal workings in the basin are inaccessible and collecting must be confined to the old dump piles and scanty surficial exposures.

In the eighteenth and nineteenth centuries, coal mining was mostly centered in the Manakin and Gayton districts north of the James River, and also in the Midlothian, Huguenot Springs and Winterpock districts south of the James River.¹ Scrap dumps in the Midlothian area still offer excellent collecting possibilities. The Blackheath pits, situated 1¼ miles north-

east of the town of Midlothian were probably the most famous of the Richmond basin coal mines. They were operated intermittently from about 1788 to 1855. Charles Lyell visited the mines in 1845 and obtained the specimen of *Dictyopyge macrurus* (BMNH 11129) referred to previously. It was figured by him in 1847 (pl. 8), by Emmons (1856, pl. 9, fig. 1) and by Newberry (1888, pl. 18, fig. 1). Newberry incorrectly listed the locality as "Clover Hill" (Winterpock). A label accompanying the type of *Dictyopyge decipiens* Brough, 1931 (AMNH 654) noted that the specimen was "taken from a coal pit in Chesterfield County, Virginia, on the south side of the James River—about 1 mile from the River, 30 feet from the surface." Probably the coal pit referred to was one of the Sallee pits, or perhaps Major Clarke's pits, both of which were situated along the eastern edge of the basin, about 3 miles north of Midlothian (see Eavenson, 1942, pl. 5).

In recent years, a number of new fossil fish localities have been discovered in the Coal Measures and Vinita Beds in the central and western portions of the Richmond basin near the villages of Vinita and Manakin. The most important of these is the Boscobel Quarry locality, 1 mile southwest of Manakin, which produced a large number of well-preserved specimens of *Dictyopyge* and a few specimens referred to *Cionichthys*. At the Boscobel locality, the basal shales and sandstones of the presumed Coal Measures are exposed at the eastern edge of the quarry, unconformably overlying the Paleozoic Petersburg granite. The primary fossiliferous beds, which occur some 80 feet above the granite, are approximately 10 feet thick, and are typically composed of fissile, dark gray to tan shale with interbeds of shaly siltstone and fine-grained micaceous sandstone. When weathered the shales assume a mottled tan-pink color and can be parted into paper-thin sheets. Other localities in this district have similar lithologies, although specimens from the old coal mines on the eastern border occur in a variety of lithologies from fissile, black, calcareous, bituminous, or pyritic shale to massive, coarse, gray carbonaceous or micaceous sandstone.

Dictyopyge is by far the most abundant form in the Richmond basin, occurring in large num-

¹An excellent map describing the history and distribution of the Richmond basin coal mines has been provided by Eavenson (1942, pl. 5).

bers throughout much of the stratigraphic sequence. Generally, the specimens are found as carbonaceous films or impressions; preservation ranges from fair to excellent, specimens occurring in finer-grained lithologies usually being better preserved. Most specimens are whole or only partly dissociated. In the absence of any definitive material the Richmond basin "*Tetragonolepis*" (see Lyell, 1847, p. 277) must be regarded as taxonomically indeterminate. *Cionichthys* occurs in limited numbers and has been found only at the Boscobel Quarry site; the recognition of *Tanaocrossus* is based on a single specimen (AMNH 1427) in the original Newberry Collection, from an unknown Richmond basin locality. The Richmond basin fishes are commonly associated with fragmentary plants, *Cyzicus*, ostracods, and occasional molluscs, coprolites, and reptilian remains.

The Farmville basin lies 30 miles west of the Richmond basin, and as Brown et al. (1952, p. 39) recorded, the stratigraphy and structure of the two basins is essentially the same. The occurrence of fossil fishes in this basin has been noted by Rogers (1839, pp. 326-327), Woodworth (1900, p. 43) and Applegate (1957, p. 1749), but no specimens have been found by us in the basin or in museum collections.

The Scottsburg basin of east-central Halifax County is one of the smallest of the Virginia Newark areas. The rocks of this basin have never been formally described, partly because outcrops are exceedingly rare and partly due to the basin's small size. Preliminary investigations in the region by Olsen (personal commun., 1977) suggest that the stratigraphic sequence closely resembles that of the Richmond basin, consisting largely of red, yellow, and black shale, siltstone, sandstone and conglomerate. Olsen has further noted the occurrence of fossil fishes in the Scottsburg basin; they are found in a badly weathered bed of soft, fissile, tan-pink, shaly siltstone exposed along the cut of the Southern Railway near the village of Wolf Trap. The specimens are generally fragmentary and are preserved as impressions. The presence of numerous well-preserved skull elements (operculae, maxillae, cleithra) leaves no doubt that the fishes belong to *Dictyopyge*. One specimen (YPM 8070)

shows the lobate anal fin characteristic of *Dictyopyge*. Exceptionally large estheriids (up to 1.5 cm. in length) occur in great numbers in the fish beds.

The Taylorsville basin in northeastern Virginia lies some 17 miles north of the Richmond basin in Hanover and Caroline counties; its areal extent is approximately 50 square miles. A much larger portion of the basin is thought to underlie parts of the coastal plain. The geology of the basin has been described in a preliminary report by Weems (1972; personal commun., 1976). He has mapped three distinct, presently unnamed lithologic units: (1) a basal unit consisting largely of massive, cross-bedded, gray-tan sandstone and conglomerate and occasional lenses of siltstone; (2) a middle unit of flaggy, tan sandstone, green, gray, and black siltstone and shale, and local coals; and (3) an upper unit composed of massive, frequently cross-bedded maroon sandstone, siltstone, and conglomerate. The upper and lower units represent alluvial fan, floodplain, and fluvial environments, whereas the middle unit reflects dominant lacustrine or perhaps paludal conditions.

Fossil fishes in the Taylorsville basin are largely restricted to the black shales and siltstones of the middle unit. A small collection recently made by Weems is the first record of fishes from this area. They occur in a partly weathered fissile to flaggy, dark gray-brown, micaceous, carbonaceous shaly siltstone about 5 feet thick, which is interbedded with layers of massive to well laminated gray-tan siltstone and sandstone. The section is exposed in the basal portion of the middle unit on the south bank of the South Anna River, south of the town of Taylorsville (Weems, personal commun., 1976). The fishes from this basin are similar to those obtained from the Boscobel Quarry in the Richmond basin; all can be assigned to *Dictyopyge*. They occur with abundant branchiopods, clams, plant fragments, and occasional reptile remains.

Culpeper Basin

The Culpeper basin of north-central Virginia and Maryland extends nearly 130 miles from Barboursville, Virginia, on the south to near

Frederick, Maryland, on the north. The rocks in this basin have been subdivided by Roberts (1928) into three general lithologic formations: (1) the "Border Conglomerates," found primarily along the western border and consisting of several distinct types of coarse conglomerate reflecting differing source lithologies; (2) the "Manassas Sandstone," composed generally of red, yellow and gray, fine- to coarse-grained, micaceous quartzose or arkosic sandstone; and (3) the "Bull Run Shale," made up of a varied assortment of red, gray and black, micaceous quartzose or arkosic argillaceous to sandy shale and siltstone. Because of the close field relations of the Manassas Sandstone and the Bull Run Shale, the two formations were mapped together by Roberts (1928) and are considered to be mostly contemporaneous facies. Diabase intrusives are found throughout a large portion of the Culpeper basin, and recently, McCollum (1971) has identified five mappable basalt flows that extend for considerable distances in the western part of the basin.

In contrast to the widespread occurrence of fossil fishes in the Richmond region, fishes have been found at only a few localities in the Culpeper basin. The majority of these are in the west-central portion of the basin, near the towns of Midland, Fauquier County, and Haymarket, Prince William County. At Midland, the fossiliferous beds are exposed in the shallow channel of Licking Run, approximately 1.3 miles north of the town. The beds are composed of fissile to flaggy, microlaminated, gray-black shale, siltstone and shaly limestone; the primary fossiliferous unit is on the order of 2 feet thick. *Redfieldius* is the most common form at Midland; *Semionotus*, *Ptycholepis marshi*, and *Diplurus longicaudatus* occur in lesser numbers. Estheriids, coprolites, and plant remains are frequently associated with the fishes. The Midland fishes are typically whole and are well preserved.

North and west of the town of Haymarket, a number of fossil localities occur in stream beds, road cuts, and quarry exposures. Many of these sites were described by Baer and Martin (1949). *Redfieldius* is present at two localities in the Haymarket region. Several specimens were obtained by Parrott and Dunkle (1948) from a road cut along state Rt. 55, 3.6 miles

west of Haymarket, and a number of excellent specimens of *Redfieldius gracilis* were collected by N. G. McDonald and Paul Olsen 0.4 mile north of Rt. 55 in the bed of Catletts Branch, a small brook that drains into Broad Run. The beds along Rt. 55 are not presently exposed, but their lithology (as revealed by specimens in the National Museum of Natural History) consists of a weathered, soft, finely laminated, buff-pink silty shale, and siltstone. At Catletts Branch, the fishes are contained in a fissile, finely microlaminated, medium gray to black calcareous silty shale with interbeds of light gray siltstone. *Ptycholepis marshi* and *Semionotus* occur along with redfieldiids in the beds at the Rt. 55 locality; abundant specimens of *Semionotus*, estheriids, and coprolites were also obtained at Catletts Branch. The fish beds at Midland and Haymarket presumably can be included in the Bull Run Shale. Olsen (personal commun., 1977) has concluded that the Midland beds lie between the lowest and second lava flows, and the Haymarket fossiliferous units occur above the highest lava flow in the Culpeper basin.

Gettysburg and Newark Basins

The largest of the Newark Supergroup basins extends for 250 miles from northern Maryland through southeastern Pennsylvania and central New Jersey to southeastern New York. It has been arbitrarily divided by several authors into the Gettysburg and Newark basins near the narrowest portion of the belt a few miles west of the Schuylkill River in northeast Lancaster County, Pennsylvania.

The stratigraphic sequence in the Gettysburg basin has been defined by Stose and Bascom (1929) and recently modified by Glaeser (1963). It consists of: (1) the basal New Oxford Formation, composed largely of arkose, conglomerate, red sandstone, siltstone, and shale and thin units of gray-black sandstone and shale; (2) the Gettysburg Formation, consisting of conglomerate, red, gray and white, fine- to medium-grained sandstone, red, green and gray shale, and argillite; and (3) the Hammer Creek Formation (Glaeser, 1963), a local unit of conglomerate and quartz sandstone, exposed generally between the Schuylkill and Susquehanna

rivers in Pennsylvania. Fishes are known from only two localities in the Gettysburg basin; both sites are in the New Oxford Formation and are exposed along Little Conewago Creek in northeastern York County, Pennsylvania. Fragmentary bones and scales of *Turseodus* occur in the bed of a small tributary of Little Conewago Creek near the town of York Haven (see Wanner, 1921, p. 29; Cornet, 1977, p. 170). Isolated redfieldiid bones and scales (probably referable to *Synorichthys*) were collected in 1970-1971 by Donald Hoff (pers. commun., 1976) from the middle of the New Oxford Formation on the southeast bank of Little Conewago Creek near the village of Zions View. The fishes are contained in massive to hackly, red shaly siltstone, and are associated with *Cyzicus* and reptile remains.

The stratigraphic terminology for the Newark basin (*sensu stricto*) is based on the work of Kümmel (1897, 1898), and Glaeser (1963). The sequence in much of this basin includes: (1) the Stockton Formation, composed largely of light-colored arkosic sandstone and conglomerate with interbedded units of red sandstone, siltstone, and shale; (2) the Lockatong Formation, a large, lacustrine lens primarily made up of cyclic alternations of massive, dark gray or reddish brown argillite and lesser amounts of fissile, gray-black mudstone and black shale; and (3) the Brunswick Formation, essentially composed of reddish brown siltstone, mudstone and shale, with lesser amounts of conglomerate, coarse to fine sandstone, gray-black shale and limestone. Interbedded with the sedimentary rocks of the Brunswick Formation are three basaltic lava flow units called (from oldest to youngest) the First, Second, and Third Watchung basalts. In the extreme southwestern portion of the Newark basin, the Brunswick Formation interfingers with the Hammer Creek Formation (Glaeser, 1963). As Kümmel (1898, p. 41) and later authors have noted, the Stockton, Lockatong, and Brunswick formations are not entirely time-stratigraphic units; in certain areas they are better regarded as interfingering lithofacies.

The remains of fossil fishes are extremely rare in the predominantly coarse clastic rocks of the Stockton Formation, but numerous fossil

localities occur in both the Lockatong and Brunswick. The most prolific Lockatong localities are near Gwynedd (North Wales) and Phoenixville, Pennsylvania, and Princeton, North Bergen, Weehawken, and Edgewater, New Jersey. Fishes are most abundant in the lower portion of the formation, occurring almost exclusively in the finely laminated, calcareous, gray-black shale and argillite which comprise the basal units of detrital and chemical Lockatong cycles (see Van Houten, 1962, pp. 568-569; 1964, p. 513).

At Gwynedd, an extensive section of the Lockatong is exposed along a deep cut of the former Reading Railroad, roughly midway between the towns of North Wales and Gwynedd Valley. The lithologic sequence at this locality includes thick units of massive gray and brown argillite with several thin interbeds of fossiliferous, thinly bedded, faintly microlaminated, gray-black calcareous shale. The shaly beds have yielded specimens of *Turseodus*, *Synorichthys*, *Semionotus*, reptiles, plants, and estheriids as well as the type specimens of *Diplurus newarki* (Bryant) and *Carinacanthus jepseni* Bryant.

At Phoenixville, a thick sequence of the lower and middle Lockatong is exposed in and around the tunnel of the former Reading Railroad, which cuts through a narrow meander of the Schuylkill River, north of Phoenixville. The rocks here are predominantly massive, red-green argillites and thin, bituminous black shales. During the widening of the tunnel in 1857, numerous fossils were obtained from the black shale beds, including the type specimen of *Turseodus acutus* Leidy, *Diplurus*, redfieldiids, reptile remains, plants, and estheriids (see Wheatley, 1861).

In 1946, during excavations for the foundation of the Firestone Library at Princeton University, a remarkably productive fish horizon in the basal portion of the Lockatong Formation was uncovered. Schaeffer (1952, p. 58) noted that the fossiliferous beds at Princeton lie less than 200 feet above the underlying Stockton Formation. The fishes are contained in a 6-inch layer of hard, platy, black calcareous silty shale, which is frequently weathered to a soft, tan-yellow limonitic clay. They include *Di-*

plurus, *Turseodus*, *Semionotus*, reptile remains, plants, and estheriids. A recent examination of the collection from the Firestone Library at Princeton also produced specimens of *Synorichthys*.

Shainin (1943, p. 273), Schaeffer (1952, p. 58), and Colbert (1965, p. 5) have noted the occurrence of estherians, reptiles and fishes at the former Granton Quarry, North Bergen, New Jersey. The exposures there, which are now largely covered, include about 60 feet of cyclic, interbedded black and gray argillite, white, green and tan sandstone, and platy, fossiliferous, dark gray to black calcareous shale, capped by a diabase sill. Although originally included in the Stockton Formation, Johnson and McLaughlin (1957, p. 19), Colbert (1965, p. 5) and others, including the present authors, have placed this sequence in the lower portion of the Lockatong. Fishes from this locality include: *Diplurus*, *Synorichthys* (see Schaeffer and Mangus, 1970), and *Turseodus*, along with plants and reptile remains.

Fossiliferous, cyclic, platy black shales, and massive red and gray argillites are exposed below the Palisades sill at a number of localities along the western shore of the Hudson River. On the basis of lithology and stratigraphic position, these beds can also be placed in the basal portion of the Lockatong Formation. The fossiliferous units are best exposed in the vicinity of Weehawken and Edgewater, New Jersey. Generally, they are from 1 to 2 feet in thickness and occur at varying distances below the Palisades diabase. They are normally composed of a hard and brittle, fissile to massive, partly microlaminated, dark gray calcareous shale that is frequently thermally metamorphosed to hornfels by the overlying igneous rock. Fossils from these localities include small specimens of *Semionotus*, *Synorichthys*, *Diplurus*, *Turseodus*, reptile, plant, and estherian remains (Olsen, personal commun., 1976).

Fishes are known from a number of localities in the Brunswick Formation. *Semionotus* is abundant in the thin black shale and limestone units between the First and Second Watchung basalts and also in the dark shale beds between the Second and Third Watchung

flows; other forms, however, seem to be largely restricted to a single horizon at Boonton, New Jersey. The Boonton beds are about 1200 feet above the Third Watchung Basalt (Olsen, personal commun., 1977). Boonton is the most famous of the New Jersey fossil localities. The Redfields, J. S. Newberry, I. C. Russell, Kümmel, and others made extensive collections there. Unfortunately, the fish horizon was buried during construction of the dam for the Jersey City Reservoir. However, the fish are known to occur in a 3-foot-thick bed of flaggy to fissile, light gray, microlaminated, calcareous shale, with thin interbeds of dark to medium gray siltstone (Smith, 1900). The gray fossiliferous unit is contained within a thicker sequence of red-gray shale, sandstone, and coarse conglomerate. Specimens collected from this locality include many *Redfieldius* and *Semionotus*, occasional examples of *Diplurus longicaudatus* Newberry (including the type), and a single specimen of *Ptycholepis*. Plant remains and coprolites are also present.

Hartford, Deerfield, and Pomperaug Basins

In the Hartford basin of central Connecticut and south-central Massachusetts, the accepted Newark Supergroup nomenclature is largely derived from the works of Krynine (1950) and Lehmann (1959). Lehmann divided the strata into the following stratigraphic units: (1) the basal New Haven Formation, dominated by red and gray arkose and conglomerate, with subordinate units of red siltstone and shale; (2) the Talcott Formation, composed of usually one but locally up to four separate and distinct basalt sheets with thin, interbedded, largely arkosic sedimentary members (Sanders, 1970); (3) the Shuttle Meadow Formation, consisting largely of red-brown arkosic siltstone and shale with minor beds of black calcareous shale, yellow-gray sandstone, arkose, and conglomerate; (4) the Holyoke Formation, with at least two flows of blue-gray, dense basalt; (5) the East Berlin Formation, lithologically similar to the Shuttle Meadow Formation; (6) the Hampden Formation, with one or locally two distinct basalt sheets; and (7) the Portland Formation, composed mostly of coarse red arkose,

sandstone, and conglomerate with varying amounts of red and gray siltstone, mudstone and shale.

Fishes in the Hartford basin are almost entirely confined to the dark gray to black shales and limestones present in the Shuttle Meadow and East Berlin Formations and to a lesser extent in the Portland Formation. Some of the exposures of fossiliferous strata in the Hartford Basin probably represent parts of one or two widespread dark shale layers repeated by faulting (see Davis and Loper, 1891, p. 424; Hubert, Reed and Carey, 1976, p. 1196). Other units are apparently local and cannot be traced laterally. The most noteworthy fish localities include the Durham and Bluff Head sites in the Shuttle Meadow Formation, the East Haven, Stevens, and Westfield localities in the East Berlin Formation, and the Middlefield locality in the Portland Formation.

The Durham and Bluff Head localities are exposed in shallow stream beds on the northwestern and northeastern flanks of Totoket Mountain, 4 miles south-southwest of Durham, Connecticut. They have been recently described by Schaeffer, Dunkle and McDonald (1975, pp. 227-228). The fish horizons at these localities are presumably equivalent, occurring about 200 feet above the uppermost lava flow of the Talcott Formation. At Durham, the fossiliferous, microlaminated, calcareous black shale sequence is approximately 2 feet thick, and outcrops along with layers of thin unfossiliferous limestone and micaceous gray shale. Well-preserved specimens of *Redfieldius gracilis* and *Semionotus* are extremely common in the Durham beds; specimens of *Ptycholepis marshi*, *Diplurus longicaudatus*, coprolites, and plant remains have also been found. The beds at Durham are now largely covered or have been excavated, but productive heaps of black shale are present in the immediate area. At the Bluff Head locality, less than a mile northeast of the Durham site, the fossiliferous beds are 3 feet thick. The upper part of this unit is composed of a fissile, carbonaceous, micaceous, silty black shale with minor clay lenses, the lower part consists of slabby, dark gray to black, microlaminated, calcareous shale and shaly limestone. The unit is overlain by a thick bed

of buff-brown quartz sandstone, and underlain by a light brown to white clay bed. The fishes at the Bluff Head site are extremely abundant and well preserved; in the last six years, well over 1000 specimens of *Redfieldius* have been collected, along with numerous specimens of *Semionotus*, occasional specimens of *Ptycholepis marshi* and a single specimen of *Diplurus longicaudatus*. Coprolites, plant remains, and a tooth of a coelurosaur have also been obtained from these beds.

Near East Haven, Connecticut, fossiliferous black shales are exposed in a stream bed which drains from the east into Lake Saltonstall, near its southern end. The fossil-bearing beds are part of a poorly exposed sequence of red and gray siltstones and shales; they are about 5 feet thick and occur roughly 100 feet below the base of the overlying Hampden basalt. The fish beds are composed of a fissile to slabby, light to medium gray, micaceous, microlaminated silty shale, and siltstone. Fishes from this locality include *Semionotus*, *Redfieldius*, and at least one specimen of *Diplurus*. They are usually articulated, but the preservation does not equal that at Durham or Bluff Head.

The Stevens locality, exposed in the bed and the banks of Parmalee Brook, approximately 1 mile north of the northern tip of Totoket Mountain in the Durham [Conn.] Quadrangle, was named and briefly described by Davis and Loper (1891, p. 427). At this site, a 2 to 3 foot bed of fissile to flaggy, dark gray, microlaminated, calcareous silty shale is exposed along with thicker beds of gray and red shale, siltstone, and sandstone. Numerous specimens of *Redfieldius*, *Semionotus*, coprolites, and plant fossils have been obtained from this site over the years; in 1976 a fragmentary specimen of *Diplurus* was found there. The fish remains from this locality are usually coated with a bluish white mineral residue, and stand out distinctly in contrast to the dark-colored shale. Of all localities in the East Berlin Formation, the fishes from this site are the best preserved. An excellent specimen of *Redfieldius* from Stevens has been figured by Eastman (1911, p. 10).

The Westfield locality is one of the oldest fossil fish sites in the Hartford basin. It was described by Silliman in 1821. The locality is

contained in the East Berlin Formation, in the northern half of the Middletown [Conn.] Quadrangle and is exposed in a shallow stream bed north of the village of Westfield. Dark shales are uncovered for a considerable distance in the stream bed, but fishes are confined to a 2-foot-thick unit of flaggy, hard and brittle, dark gray to black, microlaminated calcareous silty shale with interbeds of massive, light gray, calcareous siltstone. This unit is contained within a thicker sequence of red and gray shale, siltstone and sandstone. Davis and Loper (1891, p. 427) noted that the fish bed occurs approximately 100 feet below the base of the Hampden basalt. Fossils from this site include *Redfieldius* and *Semionotus* in about equal numbers, several fragmentary specimens of *Diplurus longicaudatus*, coprolites, and plant debris. The fishes are usually poorly preserved, occurring as highly compressed organic smears.

The Middlefield locality is the most important of the Portland Formation fossil fish localities. It is situated in the extreme south-central portion of the Middletown [Conn.] Quadrangle, in the bed of a shallow, north-flowing stream that drains into Laurel Brook Reservoir. The fossiliferous beds at Middlefield are about 3 feet thick; they are contained in the lower portion of the Portland Formation. They consist of fissile to flaggy, dark gray, part-microlaminated calcareous silty shale with interbeds of massive, light gray, calcareous siltstone. The fossiliferous shales and siltstones are included in a thicker sequence of flaggy, gray-buff sandstone, red and gray siltstone and shale and coarse, red-brown conglomerate. The fish assemblage from Middlefield includes only *Semionotus* and *Redfieldius*, with the former outnumbering the latter by about 2:1. The overall preservation varies markedly; some examples are hardly more than organic smears, others are well preserved and finely detailed. One of the best-preserved fishes from this site is the type of *Redfieldius gracilis* (YPM 3206).

The Newark sequence in the Deerfield basin in west-central Massachusetts has been described by Emerson (1917) and Willard (1951, 1952). Four formations are recognized: (1) the basal Sugarloaf Arkose, lithologically similar to the New Haven Formation of the Hartford

basin; the Deerfield Basalt, typically black, fine-grained, massive and dense; (3) the Turners Falls Sandstone, composed largely of reddish brown sandstone, red siltstone, and red to black shale; and (4) the Mount Toby Conglomerate, consisting of a red-brown to gray-brown conglomerate with local interbeds of sandstone and siltstone. The Turners Falls Sandstone and Mount Toby Conglomerate are largely contemporaneous facies; they interfinger throughout a large portion of the basin.

Fishes have been found at a few localities in the Deerfield basin. The most productive are in the black shales exposed on the eastern bank of the Connecticut River north of the town of Sunderland, Massachusetts, and on the northern side of the Connecticut River near Turners Falls, Massachusetts. Both of these localities are well known for abundant and well-preserved specimens of *Semionotus*. Several authors, notably Packard (1871, p. 1), Newberry (1888, p. 58), and Dunkle (1940, p. 9) have reported *Redfieldius* from these localities, but no specimens have been found in existing collections.

The Pomperaug basin of western Connecticut is an outlier of Newark sedimentary rocks and basalts situated 13 miles west of the Hartford basin. The stratigraphic sequence in the basin has not been completely worked out, but it generally consists of thin red shale, sandstone and conglomerate units, local black shale and limestone beds, and at least three separate basalt flows. Scott (1974, p. 34) has concluded that the basal units in the southern portion of the Pomperaug basin are westward extensions of the New Haven and Talcott formations. Hobbs (1901, pp. 55-56) has described two of the old fish localities in the basin and has figured specimens of *Semionotus* and *Redfieldius*. Recent collecting in the southern portion of the basin has revealed the presence of *Semionotus* in a unit of blocky, medium gray, partly microlaminated silty limestone exposed in a stream bed 0.2 mile east of South Britain. *Redfieldiid* remains were also obtained from a bed of massive, gray-white limestone exposed on the banks of the same stream 0.3 mile northeast of Rattlesnake Hill. The latter is the "Red Spring" locality mentioned by Hobbs (1901, p. 56).

Scott's (1974, p. 1) map indicates that these localities occur in the uppermost sedimentary unit of the Talcott Formation.

Acadian Basins

The stratigraphy of the Newark in Nova Scotia and New Brunswick has been discussed by Klein (1962). In general, the rocks represent an intertonguing complex of continental red beds and tholeiitic basalts. Conglomerate and coarse red clastic rocks largely make up much of the Lepreau, Quaco, Echo Cove, and Chedabucto formations; red claystone, sandstone, and conglomerate comprise the Wolfville Formation; red claystone, siltstone, and sandstone occur in the Blomidon Formation; and interbedded brown, purple, and green claystone,

white limestone and brown and gray sandstone compose the Scotts Bay Formation. The lava flows of the McKay Head basalt locally overlie the Wolfville Formation, the North Mountain Basalt overlies the Blomidon Formation and parts of the Wolfville Formation.

Fishes have been reported from a few localities in the Acadian Newark. *Semionotus* occurs in the upper part of the Scots Bay Formation at Five Islands Park, Colchester County, N. S. and Broad Cove, Kings County (Olsen, personal, commun., 1976), in the Blomidon Formation at Lower Blomidon and Del Haven, Kings County, N.S. Carroll et al. (1972, p. 27) have reported the discovery of redfieldiid remains in the Blomidon Formation at Lyons Cove, Kings County.

CONCLUSIONS REGARDING GEOLOGIC OCCURRENCE

The four Newark redfieldiid genera have a geographically restricted and stratigraphically limited distribution in the strata of the various Newark basins. *Dictyopyge* is confined to the rocks of the Richmond, Taylorsville, and Scottsburg basins in Virginia; *Cionichthys* has been found only in the Deep River, Dan River, and Richmond areas. *Synorichthys* is known from the strata of the Deep River and Dan River basins in North Carolina, and also from the Lockatong and New Oxford formations of the Newark and Gettysburg basins in New Jersey and Pennsylvania. *Redfieldius* is apparently restricted to the uppermost beds in the Culpeper and Newark basins, and also occurs in the rocks of the Hartford and Pomperaug basins in Connecticut and Massachusetts.

In an attempt to understand this distributional pattern, two explanations come to mind: (1) that the fishes were restricted at the time of their preservation to certain basins because of topographical, geographical, and/or paleoecological factors; or (2) that the distribution is related to the restriction of the various taxa to different time intervals in the history of the Newark basins. Both of these suggestions may

have some credibility, for certainly *Dictyopyge* shows a very narrow geographic and stratigraphic distribution in the Newark. On the other hand, *Redfieldius* and *Synorichthys* have a very broad geographic distribution. The typical Newark fish bed lithology is a fissile to flaggy, gray to black, microlaminated, pyritic, carbonaceous or calcareous shale, siltstone or argillite; presumably this lithology indicates perennial reducing lacustrine or paludal environments, with anaerobic bottom waters rich in H_2S (see Hubert, Reed and Carey, 1976, pp. 1193-1205, for a discussion of perennial lacustrine depositional environments). In light of recent studies by Cornet, Traverse and McDonald (1973), Cornet and Traverse (1975), Cornet (1977), and Olsen (personal, commun., 1976) the second explanation seems to be the most tenable. Cornet and Traverse (1975, p. 26) have observed that *Redfieldius* is limited to the Liassic formations of the Hartford and Newark basins; a similar Liassic age has also been obtained for the *Redfieldius* beds (Midland and Haymarket) in the Culpeper basin (Cornet, Traverse and McDonald, 1973, p. 1247). Similarly, Olsen (personal commun., 1976) has

suggested that *Dictyopyge* is restricted to a middle Carnian age, and thus is only found in the appropriate rocks of the Richmond, Taylorsville, and Scottsburg basins (see correlation chart, page 158). *Synorichthys* and *Cionichthys* are perhaps also restricted to the middle and upper Carnian.

The Newark Supergroup, now known to be part Late Triassic and part Early Jurassic in age (Cornet, Traverse and McDonald, 1973) was regarded as entirely Late Triassic for nearly a century. Aside from the geochronological implications of this new interpretation, which is based essentially on palynological and paleobotanical evidence, there are interesting changes in the time ranges of the Newark fishes. *Redfieldius* has become an exclusively Liassic taxon, whereas the other redfieldiids have remained Late Triassic. *Ptycholepis marshi* is also apparently restricted to the Liassic. At least one of the species presently included in the paraphyletic genus *Semionotus* remains Late Triassic (Carnian?), whereas the others are Liassic. *Diplurus* is the only Newark taxon that crosses the Triassic-Liassic boundary.

These time-stratigraphic changes in the Newark Supergroup raise some interesting questions about the age of the Chinle, Dockum, and Moenave formations in the western United States, which contain fishes related to those from the Newark (Schaeffer, 1967) and to the Triassic-Liassic deposits of Morocco recently discussed by Van Houten (1977). According to present evidence, all the Chinle-Dockum taxa

that are also known from the Newark (*Turseedus*, *Cionichthys*, *Tanaocrossus* and a species of *Semionotus* related to the *Semionotus braunii* group (fide Paul Olsen) support the conclusion, based mostly on phytosaur evidence (Schaeffer, 1967), that the Chinle and Dockum are about the same age as the lower part of the Newark, that is, Upper Triassic. The Moenave Formation has yielded only remains of *Semionotus* that Olsen (personal commun.) relates to Liassic species groups in the Newark. The coelacanths *Diplurus newarki* and *D. longicaudatus* (which may be conspecific) occur in both the Triassic and Liassic parts of the Newark Supergroup. The Chinle-Dockum genus *Chinlea*, which is the sister taxon of *Diplurus*, has not been found in the Moenave, but the Moenave fishes have not been properly collected or studied.

The only fish remains so far reported from the Moroccan Triassic sequence are bones and tooth plates of *Ceratodus* (Dutuit, 1966). These occur in beds that also contain metoposaurs and phytosaurs, which indicates Late Triassic age. *Ceratodus* has not been recovered from the Newark Supergroup, but it is generally present in the Chinle and Dockum in predominantly clay facies that include amphibians and phytosaurs. The apparent absence of *Ceratodus* from the Newark may therefore involve a facies difference. Even so, the differences in these depositional environments in terms of *Ceratodus* ecology are almost impossible to interpret.

LITERATURE CITED

- Agassiz, Louis
1833. Recherches sur les poissons fossiles. Neuchâtel and Soleure, vol. 2, p. 23.
- Aldinger, Hermann
1937. Permische Ganoidfische aus Ostgrönland. Meddel. Grönland, Bd. 102, no. 3, 392 pp.
- Applegate, Sheldon P.
1956. Distribution of Triassic fish in the Piedmont of Virginia [abs.]. Bull. Geol. Soc. Amer., vol. 67, p. 1749.
- Baer, F. M., and W. H. Martin
1949. Some new finds of fossil ganoids in the Virginia Triassic. Science, vol. 110, pp. 684-686.
- Ballard, R. D., and E. Uchupi
1975. Triassic rift structure in Gulf of Maine. Amer. Assoc. Petrol. Geol. Bull., vol. 59, pp. 1041-1072.
- Berg, Leo S.
1940. Classification of fishes both Recent and fossil. Trav. Inst. Zool. Acad. Sci. U.S.S.R., vol. 5, no. 2, 517 pp. (Russian and English texts. Also reprint, Ann Arbor, Michigan, 1947.)
1958. System der rezenten und fossilen Fische.

- tigen und Fische. Berlin, VEB Deutscher Verlag der Wissenschaften, 310 pp.
- Berger, H. A. C.
1843. Letter on *Semionotus* and *Thalassides*. Neues Jahrb. Min. Geol. Palaeont., p. 86.
- Bock, Wilhelm
1959. New eastern American Triassic fishes and Triassic correlations. Geol. Center Res. Ser., vol. 1, 184 pp.
- Brough, James
1931. On fossil fishes from the Karroo System, and some general considerations on the bony fishes of the Triassic period. Proc. Zool. Soc. London, pp. 235-296.
1934. On the structure of certain catopterid fishes. *Ibid.*, part 3, pp. 559-571.
1936. On the evolution of bony fishes during the Triassic period. Biol. Rev., vol. 11, pp. 385-405.
- Brown, A., H. L. Berryhill, Jr., D. A. Taylor, and J. V. A. Trumbull
1952. Coal resources of Virginia. United States Geol. Surv. Circular 171, 57 pp.
- Bryant, William L.
1934. New fishes from the Triassic of Pennsylvania. Amer. Phil. Soc. Proc., vol. 73, pp. 319-326.
- Byrnes, J. B., and J. C. Horne
1974. Alluvial fan to marine facies of Connecticut Valley Triassic. Amer. Assoc. Petrol. Geol., Ann. Mtg. Abstr., vol. 1, p. 15.
- Campbell, M. R., and K. W. Kimball
1923. The Deep River Coal Field of North Carolina. North Carolina Geol. and Econ. Surv. Bull., vol. 33, 95 pp.
- Carroll, R. L., E. S. Belt, D. L. Dineley, D. Baird, and D. C. McGregor
1972. Vertebrate paleontology of eastern Canada. XXIV Int. Geol. Congress, Montreal, Quebec, 113 pp.
- Colbert, Edwin H.
1965. A phytosaur from North Bergen, New Jersey. Amer. Mus. Novitates, no. 2230, pp. 1-25.
- Cornet, Bruce
1977. Preliminary investigation of two late Triassic conifers from York County, Pennsylvania. In Romans, R. C. (ed.), Geobotany, Plenum Publ. Corp., New York, New York, pp. 165-172.
- Cornet, Bruce, and A. Traverse
1975. Palynological contributions to the chronology and stratigraphy of the Hartford basin in Connecticut and Massachusetts. Geoscience and Man, vol. 11, pp. 1-33.
- Cornet, Bruce, A. Traverse, and Nicholas G. McDonald
1973. Fossil spores, pollen and fishes from Connecticut indicate Early Jurassic age for part of the Newark Group. Science, vol. 182, pp. 1243-1246.
- Davis, W. M., and S. W. Loper
1891. Two belts of fossiliferous black shale in the Triassic formation of Connecticut. Geol. Soc. Amer. Bull., vol. 2, pp. 415-430.
- Deecke, W.
1889. Ueber Fische aus verschiedenen Horizonten der Trias. Palaeontographica, vol. 35, pp. 97-138.
- Dietz, R. S., and J. C. Holden
1970. Reconstruction of Pangaea: Breakup and dispersion of continents, Permian to Present. Jour. Geophys. Res., vol. 75, pp. 4939-4956.
- Dunkle, David H.
1940. Fishing for fossils. New England Nat., no. 9, pp. 6-9.
- Dutuit, J-M.
1966. Apport des découvertes de vertébrés à la stratigraphie du Trias continental du couloir d'Argana (Haut Atlas occidental, Maroc). Notes. Serv. Géol. Maroc, vol. 26, pp. 29-31.
- Eastman, Charles R.
1905. A brief general account of fossil fishes of New Jersey. Annual Report of the State Geologist, Geol. Surv. of New Jersey, pp. 29-130.
1911. Triassic fishes of Connecticut. Connecticut Geol. and Nat. Hist. Surv. Bull., vol. 18, 75 pp.
- Eavenson, H. N.
1942. The first century and a quarter of American coal industry. Koppers Bldg., Pittsburgh, Pa. Privately printed, pp. 29-131.
- Egerton, Philip
1847. In Lyell, C., On the structure and probable age of the Coal-field of the James River, near Richmond, Virginia. Quart. Jour. Geol. Soc., vol. 3, pp. 261-280.
1858. Palichthyologic notes. No. 10. On *Palaeoniscus superstes*, with a note on the locality of the fossil, by Rev. P. B. Brodie. *Ibid.*, vol. 14, pp. 164-167.
- Emerson, B. K.
1917. Geology of Massachusetts and Rhode Island. United States Geol. Surv. Bull., vol. 597, 289 pp.

- Emmons, Ebenezer
1856. Geological report of the midland counties of North Carolina. New York and Raleigh, 351 pp.
1857. American geology, containing a statement of the principles of the science, with full illustrations of the characteristic fossils. Part 6. Albany, New York. 152 pp.
1858. Fossils of the sandstones and slates of North Carolina. Proc. Amer. Assoc. Adv. Sci., vol. 11, pp. 76-80.
1860. Manual of geology. Philadelphia, 2nd Ed., New York. 290 pp.
- Fairchild, H. L.
1887. A history of the New York Academy of Sciences. Published by the author. 190 pp.
- Glaeser, J. D.
1963. Lithostratigraphic nomenclature of the Triassic Newark-Gettysburg basin. Pennsylvania Acad. Sci. Proc., vol. 37, pp. 179-188.
- Goodwin, B. K.
1970. Geology of the Hylas and Midlothian Quadrangles, Virginia. Virginia Div. Min. Resources, Report Inv. 23, 51 pp.
- Grammer, J. Jr.
1818. Account of the coal mines in the vicinity of Richmond, Virginia. Amer. Jour. Sci., ser. 1, vol. 1, pp. 125-130.
- Hay, Oliver P.
1899. On some changes in the names, generic and specific, of certain fossil fishes. Amer. Nat., vol. 33, pp. 783-792.
1902. Bibliography and catalogue of the fossil Vertebrata of North America. United States Geol. Surv. Bull., no. 179, 868 pp.
- Heinrich, O. J.
1878. The Mesozoic formation in Virginia. Trans. Amer. Inst. Mining and Metall. Engin., vol. 6, pp. 227-274.
- Hobbs, W. H.
1901. The Newark system of the Pomperaug Valley, Connecticut. United States Geol. Surv., Ann. Rept., no. 21, pt. 3, pp. 7-162.
- Hubert, J. F., A. A. Reed, and P. J. Carey
1976. Paleogeography of the East Berlin Formation, Newark Group, Connecticut Valley. Amer. Jour. Sci., vol. 276, pp. 1183-1207.
- Hutchinson, Peter
1973. A revision of the redfieldiiform and perleidiform fishes from the Triassic of Bekker's Kraal (South Africa) and Brookvale (New South Wales). Bull. British Mus. (Nat. Hist.), Geol., vol. 22, pp. 233-354.
- Jansa, L. F., and J. A. Wade
1975. Geology of the continental margin off Nova Scotia and Newfoundland. In Van Der Linden and Wade (eds.), Offshore Geology of Eastern Canada. Geol. Surv. Canada, Paper 74-30, vol. 2, pp. 51-105.
- Johnson, M. E., and D. B. McLaughlin
1957. Triassic formations in the Delaware Valley. In Dorf, E. (ed.), Geol. Soc. Amer., Guidebook for field trips, Atlantic City. Field trip #2, pp. 31-68.
- Klein, G. deV.
1962. Triassic sedimentation, Maritime Provinces, Canada. Geol. Soc. Amer. Bull., vol. 73, pp. 1127-1146.
- Krynine, Paul D.
1950. Petrology, stratigraphy and origins of the Triassic sedimentary rocks of Connecticut. Connecticut Geol. Nat. Hist. Surv. Bull., no. 73, 247 pp.
- Kümmel, H. B.
1897. The Newark System, [New Jersey]. New Jersey Geol. Survey, Annual Rept. of the State Geologist for 1896, pp. 25-88.
1898. The Newark System or Red Sandstone Belt. New Jersey Geol. Survey, Annual Rept. of the State Geologist for 1897, pp. 23-159.
- Lehman, Jean-Pierre
1952. Etude complémentaire des Poissons de l'Eotrias de Madagascar. K. Svenska Vetenskapsakad. Handl., ser. 4, vol. 2, no. 6, 201 pp.
1966. Actinopterygii. In Piveteau, J. (ed.), Traite de paléontologie. Tome 4, vol. 3, Paris, Masson et Cie, 242 pp.
- Lehmann, E. P.
1959. The bedrock geology of the Middletown Quadrangle, [Connecticut] with map. Connecticut Geol. Nat. Hist. Surv. Quad. Rept. no. 8, 40 pp.
- Lyell, Charles
1847. On the structure and probable age of the Coal-field of the James River, near Richmond, Virginia. Quart. Jour. Geol. Soc. London, vol. 3, pp. 261-280.
- McCollum, M. B.
1971. Basalt flows in the Triassic Culpeper basin, Virginia. Geol. Soc. Amer. Bull., vol. 82, pp. 2331-2332.
- McKee, Edwin D., et al.
1959. Paleotectonic maps of the Triassic system. United States Geol. Survey, Misc. Geol. Inv. Map. 1-300, 33 pp.

- Marine, W., and G. E. Siple
1974. Buried Triassic basin in the central Savannah River area, South Carolina and Georgia. *Geol. Soc. Amer. Bull.*, vol. 85, pp. 311-320.
- Meyertons, C. T.
1963. Triassic formations of the Danville basin. Virginia Div. Min. Res. Rept. Inv. 6, 65 pp.
- Newberry, John S.
1888. Fossil fishes and fossil plants of the Triassic rocks of New Jersey and the Connecticut Valley. *United States Geol. Surv., Monogr.*, vol. 14, 152 pp.
- Olsen, Paul E.
[MS] On the use of the term Newark for Triassic and Early Jurassic rocks of eastern North America.
- Ørvig, Tor
1957. On the structure of the bone tissue in the scales of certain Palaeonisciformes. *Arkiv for Zoologi*, ser. 2, vol. 10, pp. 481-490.
- Packard, A. S.
1871. [Remarks on *C. gracilis* at Sunderland, Massachusetts]. *Essex Inst. Bull.*, vol. 3, no. 1, pp. 1-2.
- Parrott, W. T., and D. H. Dunkle
1949. A new occurrence of vertebrate fossils in the Triassic of Virginia (abs.). *Proc. Virginia Acad. Sci.*, p. 135.
- Redfield, John H.
1837. On the fossil fishes of Connecticut and Massachusetts, with a notice of an undescribed genus. *Ann. Lyceum Nat. Hist.*, vol. 4, pp. 35-40.
- Redfield, William C.
1841. Short notices of American fossil fishes. *Amer. Jour. Sci. and Art*, vol. 41, pp. 24-28.
- Reinemund, J. A.
1955. Geology of the Deep River coal field, North Carolina. *United States Geol. Surv., Prof. Paper*, no. 246, 159 pp.
- Roberts, J. K.
1928. The geology of the Virginia Triassic. *Virginia Geol. Surv. Bull.*, no. 29, 205 pp.
- Rogers, W. B.
1839. Report of the progress of the Geological Survey of the State of Virginia for the year 1839. In *The Geology of the Virginias* [Reprint, 1884], New York, D. Appleton and Co., 832 pp.
- Sanders, J. E.
1970. Stratigraphy and structure of the Triassic strata of the Gaillard Graben, south-central Connecticut. *Connecticut Geol. and Nat. Hist. Surv., Guidebook no. 3*, 15 pp..
- Schaeffer, Bobb
1952. The Triassic coelacanth fish *Diplurus*, with observations on the evolution of the Coelacanthini. *Bull. Amer. Mus. Nat. Hist.*, vol. 99, pp. 25-78.
1954. *Pariostegus*, a Triassic coelacanth. *Notulae Naturae, Acad. Nat. Sci. Philadelphia*, no. 261, pp. 1-5.
1955. *Mendocinia*, a subholostean fish from the Triassic of Argentina. *Amer. Mus. Novitates*, no. 1737, pp. 1-23.
1967. Late Triassic fishes from the western United States. *Bull. Amer. Mus. Nat. Hist.*, vol. 135, pp. 287-342.
- Schaeffer, Bobb, and Marlyn Mangus
1970. *Synorichthys* sp. (Palaeonisciformes) and the Chinle-Dockum and Newark (U. Triassic) fish faunas. *Jour. Paleo.*, vol. 44, pp. 17-22.
- Schaeffer, Bobb, D. H. Dunkle, and N. G. McDonald
1975. *Prycholepis marshi*, Newberry, a chondrosteian fish from the Newark Group of Eastern North America. *Fieldiana: Geol.*, vol. 33, pp. 205-233.
- Scott, R. B.
1974. The Bedrock geology of the Southbury Quadrangle. *Connecticut Geol. and Nat. Hist. Surv. Quad. Rept.*, no. 30, 63 pp.
- Sedgwick, Adam, and R. I. Murchison
1828. On the old conglomerates, and other secondary deposits on the north coasts of Scotland. *Proc. Geol. Soc. London*, vol. 1, pp. 77-80.
- Shainin, Vincent E.
1943. New coelacanth fishes from the Triassic of New Jersey. *Jour. Paleo.*, vol. 17, pp. 271-275.
- Shaler, N. S., and J. B. Woodworth
1899. The geology of the Richmond basin, Virginia. *United States Geol. Survey, Ann. Rept.*, no. 19, pt. 2, pp. 385-519.
- Silliman, Benjamin
1821. [Note on the finding of a fossil fish at Sunderland, Massachusetts.] *Amer. Jour. Sci.*, vol. 3, pp. 365-366.
- Smith, J. H.
1900. Fish four million years old. *Metropolitan Magazine*, vol. 12, pp. 498-506.
- Stensiö, Erik
1921. Triassic fishes from Spitzbergen. Part I, Vienna, Adolf Holzhausen, xxviii + 307 pp.

- Stose, G. W., and F. Bascom
1929. Description of the Fairfield and Gettysburg Quadrangles, Pennsylvania. United States Geol. Survey, Geol. Atlas of the United States, Fairfield-Gettysburg Folio, Folio no. 225, 22 pp.
- Strüver, J.
1864. Die fossilen Fische aus dem Keupersandstein von Coburg. Zeitschr. Deutsch. Geol. Ges., vol. 16, pp. 303-330.
- Stuckey, J. L.
1965. North Carolina: Its geology and mineral resources. North Carolina Dept. of Conservation and Development, Raleigh, 550 pp.
- Thayer, P. A.
1970. Stratigraphy and geology of Dan River Triassic basin, North Carolina. Southeastern Geol., vol. 12, pp. 1-31.
- Traquair, Ramsey H.
1877. On the Agassizian genera *Amblypterus*, *Palaeoniscus*, *Gyrolepis* and *Pygopterus*. Quart. Jour. Geol. Soc. London, vol. 33, pp. 548-578.
- Van Houten, Franklin B.
1962. Cyclic sedimentation and the origin of analcime-rich Upper Triassic Lockatong Formation, west-central New Jersey and adjacent Pennsylvania. Amer. Jour. Sci., vol. 260, pp. 561-576.
1964. Cyclic lacustrine sedimentation, Upper Triassic Lockatong Formation, central New Jersey and adjacent Pennsylvania. In Merriam, D. F. (ed.), "Symposium on Cyclic Sedimentation." Kansas Geol. Survey, Bull. 169, vol. 2, pp. 497-531.
1977. Triassic-Liassic deposits of Morocco and Eastern North America: Comparison. Amer. Assoc. Petrol. Geol. Bull., vol. 61, pp. 79-99.
- Wanner, H. E.
1921. Some faunal remains from the Triassic of York County, Pennsylvania. Proc. Acad. Nat. Sci. Philadelphia, vol. 73, pp. 25-37.
- Weems, Robert E.
1972. The Taylorsville Triassic Basin of Virginia (abs.). In Southeastern Section, 21st Ann. Mtg. Geol. Soc. Amer. Abstr., vol. 4, pp. 112-113.
- Wheatley, Charles M.
1861. Remarks on the Mesozoic red sandstone of the Atlantic slope, and notice of the discovery of a bone bed therein, at Phoenixville, Pennsylvania. Amer. Jour. Sci., ser. 2, vol. 32, pp. 41-48.
- Willard, M. E.
1951. Bedrock geology of the Mt. Toby Quadrangle, Massachusetts. United States Geol. Survey, Geol. Quad. Map, GQ8.
1952. Bedrock geology of the Greenfield Quadrangle, Massachusetts. United States Geol. Survey, Geol. Quad. Map, GQ20.
- Woodward, Arthur S.
1890. The fossil fishes of the Hawkesbury series of Gosford,. Mem. Geol. Surv. New South Wales, Paleont., no. 4, pp. 1-55.
- Woodworth, J. B.
1901. The Atlantic coast Triassic coal field. United States Geol. Surv., Ann. Rept., no. 22, part 3, pp. 27-53.
- Zittel, Karl A. von
1887. Handbuch der Palaeontologie, I. Abth. Palaeozoologie, band 3, Munich and Leipzig, p. 203.

