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CORRELATION OF THE EARLY MESOZOIC NEWARK SUPERGROUP BY VERTEBRATES, PRINCIPALLY FISHES

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ABSTRACT. New data on the distribution of fossil fish together with floral and tetrapod evidence are used to develop an internal correlation of the strata of the early Mesozoic Newark Supergroup of eastern North America. Within the Newark, we recognize five informal biostratigraphic zones, each characterized by a particular fish fauna. These fish zones are then related to other Mesozoic freshwater deposits, augmented by palynologic and tetrapod data, to the European type area, and to important Early Mesozoic terrestrial sequences elsewhere.

The oldest fish zones are the *Dictyopyge* zone found in the Middle Carnian age rocks of the Richmond, Taylorsville, and Scottsburg Basins and the Middle and Late Carnian *Diplurus newarki* zone represented in the Chatham group, Dan River Group, Gettysburg Basin, and Newark Basin. These two zones correlate with the Chinle Formation and the Dockum Group of the southwestern United States as well as the Middle and Late Carnian rocks of the German basin.

The three youngest zones, early Jurassic in age, are characterized primarily by species groups of the holostean *Semionotus*. Fishes of the "*Semionotus tenuiceps* group" zone are known from the Hettangian Feltville and Towaco Formations of the Newark Basin and the Turners Falls Sandstone of the Deerfield Basin. The "*Semionotus micropterus* group" zone is found in the Late Hettangian-Early Sinemurian rocks of the Shuttle Meadow and East Berlin Formations of the Hartford Basin and the "Midland fish bed" of the Culpeper Basin. Youngest of these semionotid zones is the Sinemurian "*Semionotus elegans* group" representatives of which occur in the Sinemurian Portland Formation of the Hartford Basin and the Boonton Formation of the Newark Basin.

Correlation by these fish zones suggests that all the coal-bearing Newark rocks are divisible into an older and younger sequence both dated palynologically (by others) as Middle Carnian. Further, while the time span over which extrusive basalts were deposited is limited to the Hettangian and Sinemurian of the Early Jurassic, the individual basalt flow formations are not correlative among basins in a simple one to one manner according to the biostratigraphic data. With respect to the rest of the world, the "*Semionotus tenuiceps* group," "*S. micropterus* group," and the "*S. elegans* group" zones correlate with the European Early Jurassic, the Glen Canyon Group of the southwestern United States, the upper Stormberg Group of southern Africa, and the Lower Lufeng of China.

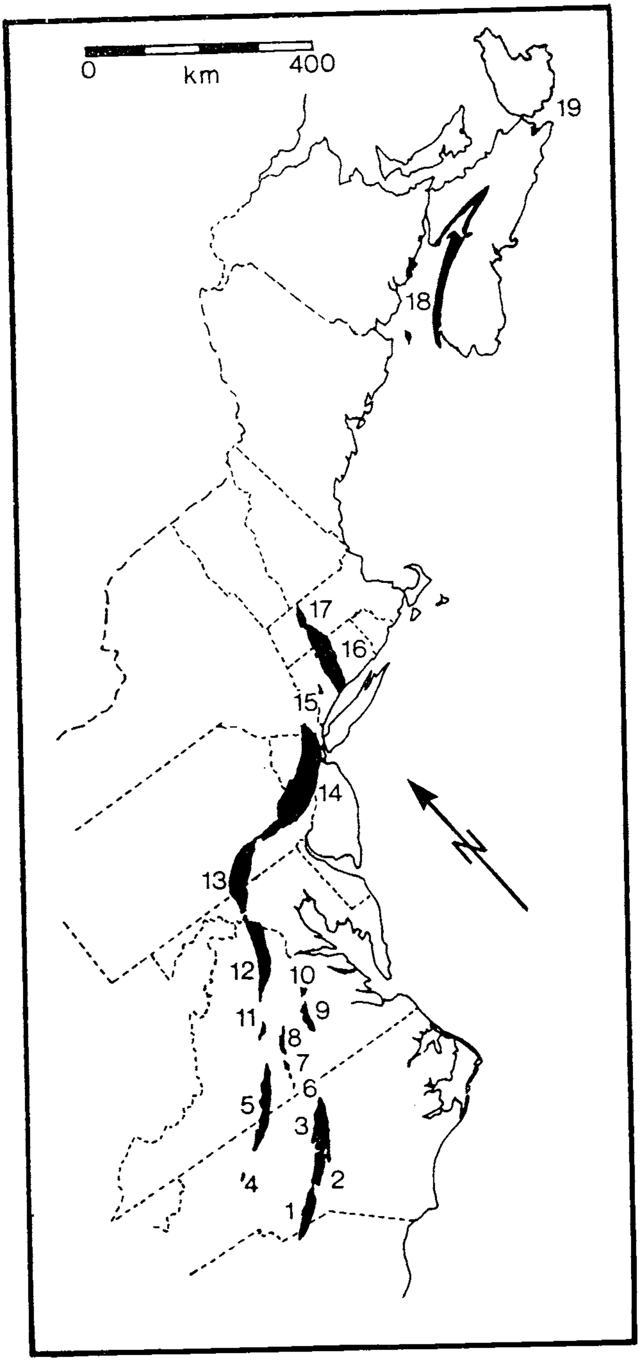
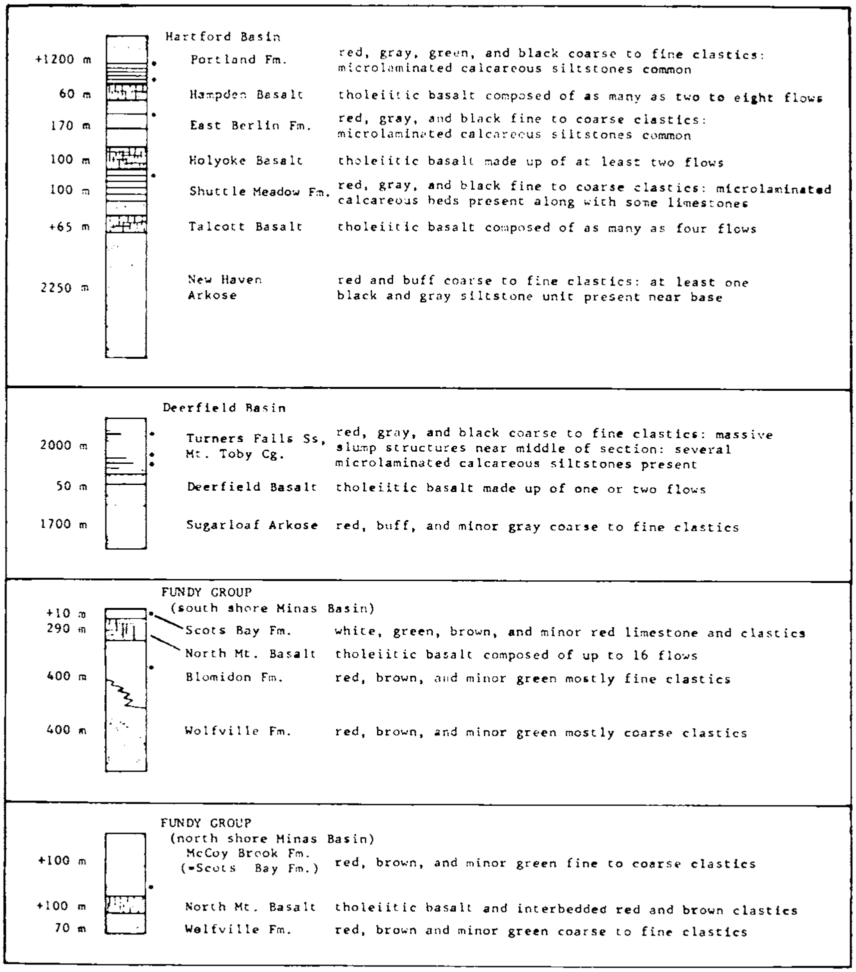


Fig. 1. The Newark Supergroup of eastern North America: (1) Wadesboro Basin (Chatham Group), (2) Sanford Basin (Chatham Group), (3) Durham Basin (Chatham Group), (4) Davie County Basin, (5) Dan River and Danville Basins (Dan River Group), (6) Scottsburg Basin, (7) basins south of the Farmville Basin, (8) Farmville Basin, (9) Richmond Basin, (10) Taylorsville Basin, (11) Scottsville Basin, (12) Culpeper Basin, (13) Gettysburg Basin, (14) Newark Basin, (15) Pomperaug Basin, (16) Hartford Basin and Cherry Brook outlier, (17) Deerfield Basin, (18) Fundy Basin (Fundy Group), (19) Chedabucto Basin (? Orpheus Graben). Data primarily from Calver (1963), Jansa and Wade (1975), King and others (1944), Van Houten (1977), and Olsen (1978).

INTRODUCTION

Just prior to the Jurassic separation of the North American and African continental plates, a series of elongate basins formed in the region around the incipient rifting axis (Van Houten, 1977; Manspeizer, Puffer, and Cousminer, 1978). In eastern North America, these basins developed parallel to the grain of the basement rocks and were filled with thousands of meters of continental sediments and minor tholeiitic volcanics. The faulted, tilted, and deeply eroded remnants are exposed from Nova Scotia to South Carolina and are termed the Newark Supergroup (Van Houten, 1977; Olsen, 1978) (figs. 1 and 2).

Correlation of the ten major and several minor Newark Supergroup basins with each other and with early Mesozoic deposits of the world



Hartford Basin

+1200 m	Portland Fm.	red, gray, green, and black coarse to fine clastics: microlaminated calcareous siltstones common
60 m	Hampden Basalt	tholeiitic basalt composed of as many as two to eight flows
170 m	East Berlin Fm.	red, gray, and black fine to coarse clastics: microlaminated calcareous siltstones common
100 m	Holyoke Basalt	tholeiitic basalt made up of at least two flows
100 m	Shuttle Meadow Fm.	red, gray, and black fine to coarse clastics: microlaminated calcareous beds present along with some limestones
+65 m	Talcott Basalt	tholeiitic basalt composed of as many as four flows
2250 m	New Haven Arkose	red and buff coarse to fine clastics: at least one black and gray siltstone unit present near base

Deerfield Basin

2000 m	Turners Falls Ss, Mt. Toby Cg.	red, gray, and black coarse to fine clastics: massive slump structures near middle of section: several microlaminated calcareous siltstones present
50 m	Deerfield Basalt	tholeiitic basalt made up of one or two flows
1700 m	Sugarloaf Arkose	red, buff, and minor gray coarse to fine clastics

FUNDY GROUP
(south shore Minas Basin)

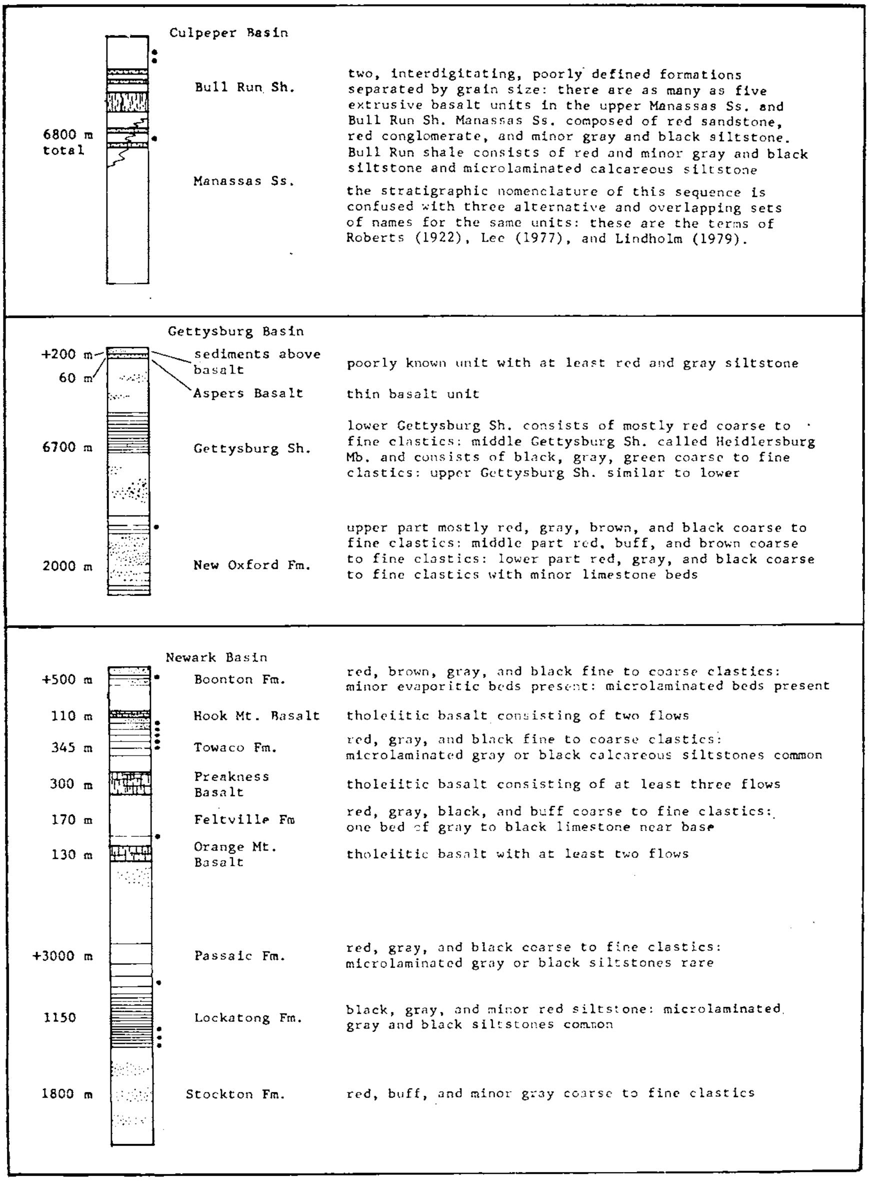
+10 m	Scots Bay Fm.	white, green, brown, and minor red limestone and clastics
290 m	North Mt. Basalt	tholeiitic basalt composed of up to 16 flows
400 m	Blomidon Fm.	red, brown, and minor green mostly fine clastics
400 m	Wolfville Fm.	red, brown, and minor green mostly coarse clastics

FUNDY GROUP
(north shore Minas Basin)

+100 m	McCoy Brook Fm. (=Scots Bay Fm.)	red, brown, and minor green fine to coarse clastics
+100 m	North Mt. Basalt	tholeiitic basalt and interbedded red and brown clastics
70 m	Wolfville Fm.	red, brown and minor green coarse to fine clastics

Fig. 2. Formations and divisions of the Newark Supergroup. Data derived mainly from Bain and Harvey (1977), Cornet and Traverse (1975), Cornet (ms), Emerson (1898), Faill (1973), Glaeser (1966), Klein (1962), Keppie and others (1979), Krynine (1950), Lee (1977), Lehman (1959), Lindholm (1979), McCollum (1971), Olsen (1979, 1980b c, d and in press), Olsen and others (1978), Randazzo and Copeland (1976), Reinemund (1955), Thayer (1970), Shaler and Woodworth (1899), Van Houten (1969), Weems (ms), and personal observation. The dots next to the columns show the position of fish producing units.

Fig. 2 (continued)



Thickness	Unit	Description
	Culpeper Basin	
6800 m total	Bull Run Sh.	two, interdigitating, poorly defined formations separated by grain size: there are as many as five extrusive basalt units in the upper Manassas Ss. and Bull Run Sh. Manassas Ss. composed of red sandstone, red conglomerate, and minor gray and black siltstone. Bull Run shale consists of red and minor gray and black siltstone and microlaminated calcareous siltstone
	Manassas Ss.	the stratigraphic nomenclature of this sequence is confused with three alternative and overlapping sets of names for the same units: these are the terms of Roberts (1922), Lee (1977), and Lindholm (1979).
	Gettysburg Basin	
+200 m	sediments above basalt	poorly known unit with at least red and gray siltstone
60 m	Aspers Basalt	thin basalt unit
6700 m	Gettysburg Sh.	lower Gettysburg Sh. consists of mostly red coarse to fine clastics: middle Gettysburg Sh. called Heidlersburg Mb. and consists of black, gray, green coarse to fine clastics: upper Gettysburg Sh. similar to lower
2000 m	New Oxford Fm.	upper part mostly red, gray, brown, and black coarse to fine clastics: middle part red, buff, and brown coarse to fine clastics: lower part red, gray, and black coarse to fine clastics with minor limestone beds
	Newark Basin	
+500 m	Boonton Fm.	red, brown, gray, and black fine to coarse clastics: minor evaporitic beds present: microlaminated beds present
110 m	Hook Mt. Basalt	tholeiitic basalt consisting of two flows
345 m	Towaco Fm.	red, gray, and black fine to coarse clastics: microlaminated gray or black calcareous siltstones common
300 m	Preakness Basalt	tholeiitic basalt consisting of at least three flows
170 m	Feltville Fm	red, gray, black, and buff coarse to fine clastics: one bed of gray to black limestone near base
130 m	Orange Mt. Basalt	tholeiitic basalt with at least two flows
+3000 m	Passaic Fm.	red, gray, and black coarse to fine clastics: microlaminated gray or black siltstones rare
1150	Lockatong Fm.	black, gray, and minor red siltstone: microlaminated gray and black siltstones common
1800 m	Stockton Fm.	red, buff, and minor gray coarse to fine clastics

Fig. 2 (continued)

		CHATHAM GROUP (Sanford Basin)	
1500 m		Sanford Fm.	brown, red, and minor gray coarse to fine clastics
260 m		Cumnock Fm.	black and gray fine clastics and minor calcareous beds: two formerly mined coals (.1 - 1.5 m)
1000 m		Pekin Fm	red, brown, and gray coarse to fine clastics: local, thin (.1 m) coal at base
3000 m		CHATHAM GROUP (Wadesboro Basin) Pekin Fm.	brown, red, and minor gray coarse to fine clastics
2000 m		CHATHAM GROUP (Durham Basin) undifferentiated	brown, red, black and gray coarse to fine clastics: some calcareous beds present
		DAN RIVER GROUP	
+500 m		Stoneville Fm.	red and gray coarse to fine clastics
+800 m		Cow Branch Fm.	black and gray fine clastics: many microlaminated beds
500 m		Stoneville and Pine Hall Fms.	
700 m		Cow Branch Fm.	black and gray fine clastics: thin coal near base
700 m		Pine Hall Fm.	gray, buff, and minor red coarse to fine clastics
		Richmond Basin	
		TUCKAHOE GROUP	
+200 m		Otterdale Ss.	gray and red predominately coarse clastics
670 m		Vinita Sh.	black and gray coarse to fine clastics: very thin coals locally present
		CHESTERFIELD GROUP	
170 m		"productive coal measures"	black and gray fine clastics some sandstone present: several formerly mined coals at base (.3 - 5 m)
100 m		"lower barren beds"	black and gray coarse to fine clastics: some red clastics and coarse conglomerate locally present
		TAYLORSVILLE GROUP	
1000 m		Cherrydale Fm.	red and gray mostly coarse clastics
400 m		Falling Creek Fm.	black, gray, and green coarse to fine clastics: minor calcareous beds present as are thin beds of coal
270 m		Poorhouse Fm.	gray and buff coarse clastics
		Scottsburg Basin	
700 m		undifferentiated	black, gray, and buff fine to coarse clastics

Table 1

Distribution of the fish taxa in the Newark. Numbers refer to figure 7.

	FORMS PRESENT												
	Turseodus	Dictyopyge	Synorichthys	Cionichthys	Redfieldius	Ptycholepis	Semionotus sp.	"Semionotus braunii group"	"Semionotus tenuiceps group"	"Semionotus micropterus group"	"Semionotus elegans group"	Diplurus longicaudatus	Diplurus newarki
RICHMOND BASIN													
1 Lower Barren Beds		☒		☒									
2 Productive Coal Measures		☒					?						
3 Vinita Shales		☒					?						
TAYLORSVILLE GROUP													
4 Falling Creek Fm.		☒		?									
SCOTTSBURG BASIN													
5 undifferentiated		☒											
CHATHAM GROUP													
6 Pekin Fm.			☒	☒									
7 Cumnock Fm.	?		☒	☒									☒
8 "Durham Basin fish bed"	☒			☒									☒
DAN RIVER GROUP													
9 lower mb. Cow Branch Fm.			☒	☒									☒
10 upper mb. Cow Branch Fm.	☒		☒	?				☒					☒
CULPEPER BASIN													
11 "Midland fish bed"					☒	☒				☒		☒	
12 "Haymarket fish bed"					☒	☒					☒	☒	
13 "Millbrook Quarry beds"							☒					☒	
GETTYSBURG BASIN													
14 New Oxford Fm.	☒		☒										
NEWARK BASIN													
15 Lockatong Fm.	☒		☒	☒				☒					☒
16 Passaic Fm.			☒					☒					
17 Feltville Fm.						☒			☒				
18 Towaco Fm.									?				
19 Boonton Fm.					☒	☒					☒	☒	
HARTFORD BASIN													
20 Shuttle Meadow Fm.					☒	☒				☒		☒	
21 East Berlin Fm.					☒					?		☒	
22 Portland Fm.					☒						☒	?	
23 upper Portland Fm.							☒						
DEERFIELD BASIN													
24 Turners Falls Ss.									☒				
25 Mt. Toby Cg.							☒						
FUNDY GROUP													
26 Blomidon Fm.							☒						
27 Scots Bay Fm.							☒						

has always posed problems because the Newark lacks the marine fossils traditionally used in most Mesozoic biostratigraphy. Recently, a number of authors (Cornet, Traverse, and McDonald, 1973; Cornet and Traverse, 1975; Cornet, ms and 1977; Cousminer and Manspeizer, 1976, 1977; Dunay and Fisher, 1974; Koob, ms) have partially circumvented this difficulty by using palynomorph (spore and pollen) assemblages preserved in both Newark deposits and marine and paralic sediments; from the data it appears that Newark rocks range from at least Late Triassic through Early Jurassic in age (Cornet, ms). Terrestrial vertebrates have also proven useful for correlating the Newark Supergroup with the European and South African early Mesozoic (Olsen and Galton, 1977). However, fish are the most common and diverse elements of the Newark vertebrate fauna, and vertical changes in the composition of fish assemblages form the basis for our correlation.

Fishes found in the Newark are abundant and well-preserved. Although the species diversity of the fishes is not yet known, many distinct taxa can be easily identified from fragmentary material. From overall fish distribution (table 1), we have been able to discern five biostratigraphic zones (table 2) which we use, along with other data, for correlation.

We propose an internal correlation of the Newark which depends principally on the stratigraphic distribution of morphologically identifiable types of fish. As in all biostratigraphic correlations, faunal similarity is presumed to indicate temporal proximity. More specifically, our correlation assumes: (1) the characters used to discriminate among fish taxa evolved only once; (2) the time needed for taxa to disperse among basins was small compared to the duration of the biostratigraphic

TABLE 2

Informal fish zones of the Newark Supergroup

Dictyopyge zone
Guide fossil: *Dictyopyge macrurus* (W. C. Redfield)
Type area: Richmond Basin
Range in type area: Lower Barren Beds — Vinita Shales

Diplurus newarki zone
Guide fossil: *Diplurus newarki* Bryant
Type area: Newark Basin
Range in type area: ?Stockton — Lockatong

"*Semionotus tenuiceps* group" zone
Guide fossil: fish similar to *Semionotus tenuiceps* Agassiz
Type area: Deerfield Basin
Range in type area: lower Turners Falls Sandstone

"*Semionotus micropterus* group" zone
Guide fossil: fish similar to *Semionotus micropterus* (Newberry)
Type area: Hartford Basin
Range in type area: Shuttle Meadow Formation — ?East Berlin Formation

"*Semionotus elegans* group" zone
Guide fossil: fish similar to *Semionotus elegans* (Newberry)
Type area: Newark Basin
Range in type area: upper Boonton Formation

zone they define; (3) the variability of physical and ecological factors among basins was not sufficient to bias the composition of living faunal associations; (4) taphonomic bias in the fossil assemblages is consistent over major sequences of fish-bearing units; (5) the existing collections of fish from lake sediments are adequate samples of the Newark fossil record. Whether the time-stratigraphic value attached to the proposed fish zones is robust with respect to the above assumptions is uncertain. However, the data derived from the fish are compatible with the more or less independent palynologic and reptile footprint data, as well as independent paleomagnetic evidence and radiometric dates.

The correlations are not proposed as definitive; they are working hypotheses for further analysis, to be tested by additional fossil collecting and evidence from independent sources. In this way we hope to put the tremendous volume of Newark strata into a preliminary stratigraphic perspective while more work is in progress. To this end, we are currently studying large samples of newly collected Newark fishes from areas in which there is excellent physical stratigraphic control. This will allow fine-scale analysis of faunal change and will also supply a wealth of data on which a more refined regional correlation may eventually be based.

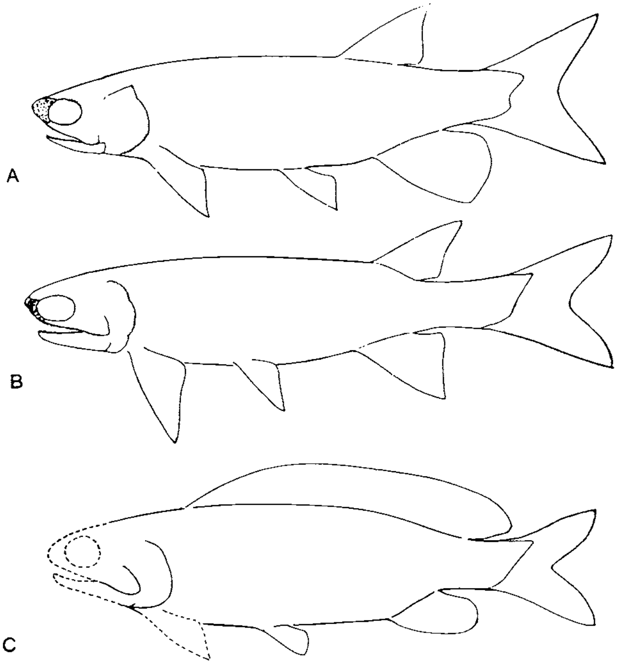


Fig. 3. Fishes of the *Dictyopyge* zone: (A) *Dictyopyge macrurus* (adapted from Schaeffer and McDonald, 1978); (B) *Cionychthys* cf. *greeni* (adapted from Schaeffer, 1967, and YPM 7936); (C) *Tanaocrossus* (drawn from AMNH 5700 figured in Schaeffer, 1967).

INTERNAL CORRELATION OF THE NEWARK SUPERGROUP

The Dictyopyge *and* Diplurus newarki *zones*

The oldest distinct fish assemblage in the Newark is found in the Richmond, Taylorsville, and Scottsburg Basins (figs. 1 and 2) and is dominated by the fish *Dictyopyge* (fig. 3). This redfieldiid has extremely distinctive skull ornamentation and is easily recognized from fragmentary material. In the Richmond Basin, *Dictyopyge* has been found with the redfieldiid *Cionichthys* cf. *greeni,* the odd palaeonisciform *Tanaocrossus* (fig. 3), and a possible semionotid (Schaeffer and McDonald, 1978; Newberry, 1888) (see app.). The biostratigraphic significance of these other fishes, which are known from so few localities, is unclear. Therefore, this assemblage zone is best termed the *Dictyopyge* zone (table 2).

Diplurus newarki is a coelacanth usually found with the redfieldiids *Cionichthys* cf. *dunklei* and *Synorichthys* sp. (fig. 4; app., 4 to 7, 9, 10.1), and their distribution marks the *Diplurus newarki* zone (tables 1 and 2).

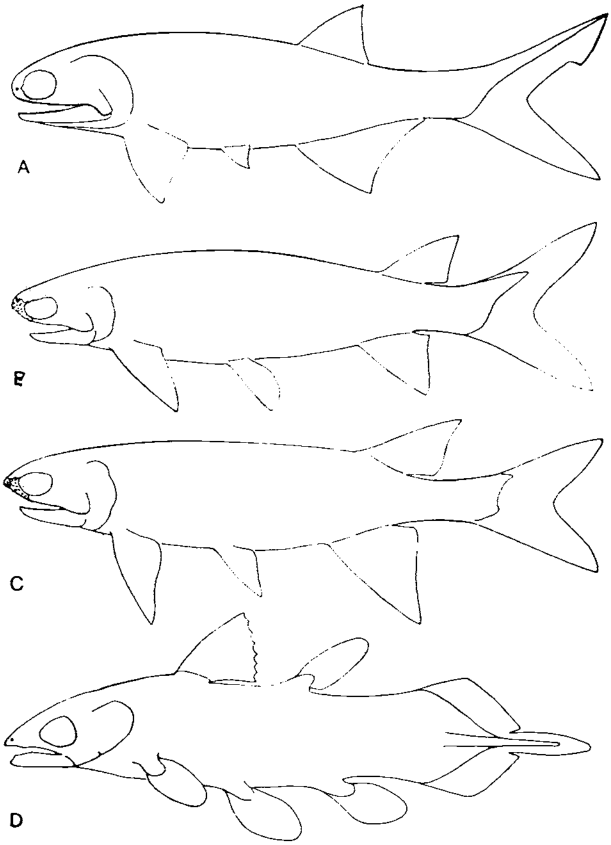


Fig. 4. Biostratigraphically important fishes of the *Diplurus newarki* zone: (A) *Turseodus* (adapted from Schaeffer, 1967); (B) *Synorichthys stewarti* (adapted from Schaeffer, 1967); (C) *Cionichthys dunklei* (adapted from Schaeffer, 1967); (D) *Diplurus newarki* (adapted from Schaeffer, 1952).

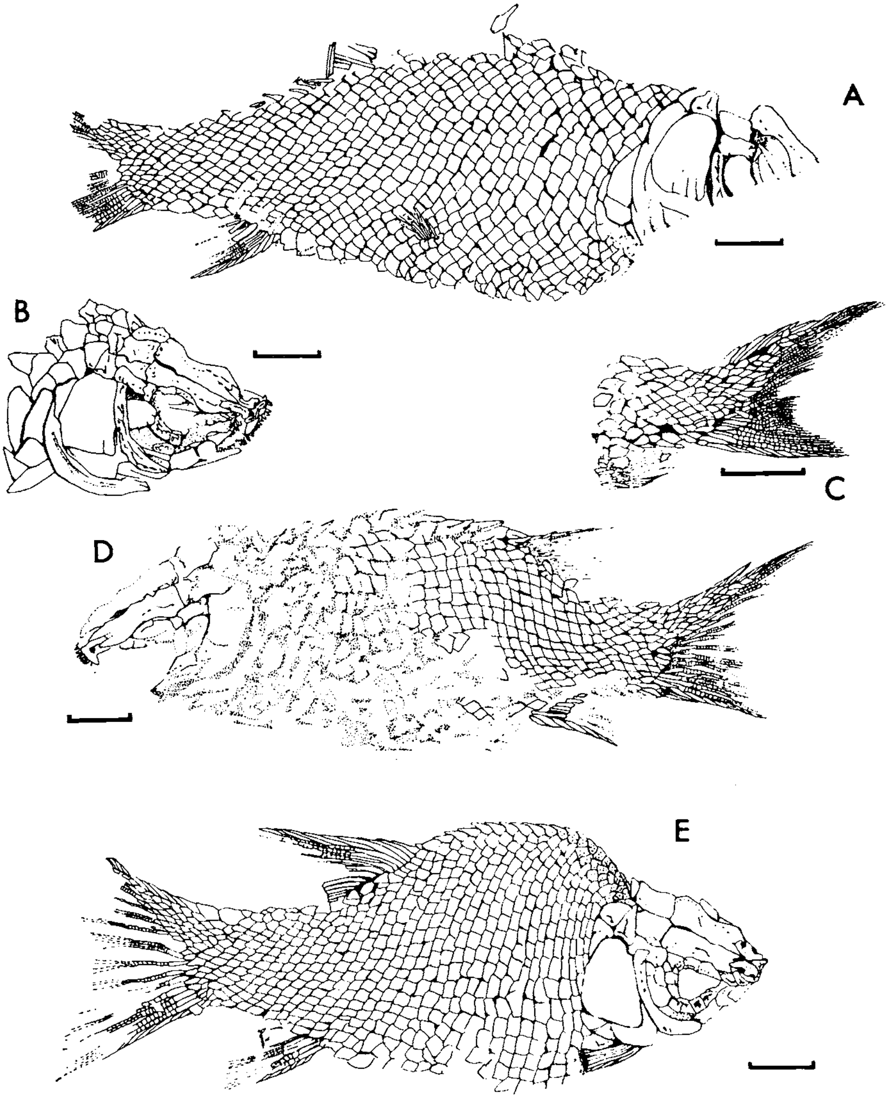


Fig. 5. A, B, C, D. fish of the "*Semionotus brauni* group": (A) YPM 6420, lower Lockatong Formation, Weehawken, N.J.; (B) YPM 6403, lower Lockatong Formation, Weehawken, N.J.; (C) YPM 6405, lower Lockatong Formation, Weehawken, N.J.; (D) YPM 7901, upper member of the Cow Branch Formation, loc. CB-2-D (see Olsen, 1979). Scale 1 cm.

E. Semionotid (AMNH 5680) from the upper Chinle Formation of Utah. Specimen described and figured in Schaeffer (1967). Scale 1 cm.

The most common assemblage in the southern Newark Supergroup Basins, it has been identified in the Newark Basin, Gettysburg Basin, and Dan River Group, and in the subbasins of the Chatham Group (collectively the Deep River Basin). In addition, the palaeoniscid *Turseodus* (fig. 4) and the holostean *"Semionotus brauni"* (fig. 5) are present in the Newark Basin, Gettysburg Basin, Dan River Group, and Durham Basin portion of the Chatham Group. Although the fishes collected from this zone number in the thousands, fragmentary specimens have been especially useful in clarifying the distribution of the redfieldiids *Cionichthys* and *Synorichthys.*

Fish characteristic of the *Diplurus newarki* zone have not been found in the same basin as those of the *Dictyopyge* zone, so that the temporal relationship between the two zones must be clarified by other (that is, floral) data. Megafossil assemblages and palynoflorules found near the base of the Pekin Formation in the Sanford Basin (Reinemund, 1955) of the Chatham Group correlate with the upper part of the *Dictyopyge* zone in the Richmond Basin (Cornet, ms). The Cumnock Formation of the Chatham Group, which contains fish typical of the *Diplurus newarki* zone, occurs in the Sanford Basin approx 680 m above this basal Pekin flora (according to outcrop width and local dip). This relationship between the two fish zones can be extended to other basins via a correlation web (fig. 6).

It may be possible to subdivide further the *Diplurus newarki* zone. The Cow Branch Formation of the Dan River Group (figs. 1 and 2) consists of two members (Thayer, personal commun; Olsen and others, 1978; Olsen, 1979): a lower coal-bearing black and gray siltstone and an upper black and gray siltstone unit containing no coal. Disarticulated remains of *Diplurus newarki* and *Cionichthys,* have been found in the lower member (app., 7.1), while in the upper member articulated specimens of *Diplurus newarki, Synorichthys, Turseodus, "Semionotus* cf. *brauni,"* and an unidentified pholidophoridiform are common (app., 7.2) (Olsen and others, 1978). The coal-bearing Cumnock Formation of the Sanford Basin division of the Chatham Group (figs. 1 and 2) has produced an assortment of isolated elements referable to *Diplurus newarki, Synorichthys,* and *Cionichthys* sp., like the lower member of the Cow Branch Formation (app., 5.1). Emmons (1857) described individual scales from the Cumnock as *Amblypterus ornatus.* While these scales are clearly palaeonisciform, possibly *Turseodus,* they are not diagnostic. In addition, our own field work in the Cumnock has failed to reveal any elements diagnostic of *Turseodus* (such as ring centra), and thus this taxon of Emmons' is not useful for correlation. In contrast to both the Cumnock Formation and the lower member of the Cow Branch Formation, the upper middle portion of the New Oxford Formation of the Gettysburg Basin (figs. 1 and 2) has produced definite remains of *Turseodus, Synorichthys* (app., 9) and a palynoflora correlative with the Lockatong Formation of the Newark Basin (Cornet, 1977) (figs. 1 and 2). The Lockatong also contains numerous articulated remains of *Diplurus* *newarki* (Schaeffer, 1952a); *Turseodus* spp. (Schaeffer, 1952b); *Synorichthys* (Schaeffer and Mangus, 1970), *Cionichthys* (app., 10.1), *"Semionotus brauni"* (Newsberry, 1888), and a rare hybodont shark (*Carinacanthus jepseni,* Bryant, 1934). The Lockatong Formation is thus correlative with the upper member of the Cow Branch Formation (Olsen and others, 1978), suggesting that both the lower member of the Cow Branch Formation and the Cumnock Formation are slightly older than the Lockatong (see fig. 6).

Two other *Diplurus newarki* zone faunas require note here. A well bedded gray-green and red siltstone containing disarticulated remains of *Diplurus newarki, Turseodus* sp., *Cionichthys* sp., and *Semionotus* sp. (app., 6) occurs in the upper third of the section preserved in the northern fault block of the Durham Basin (Bain and Harvey, 1977) (figs. 1 and 2). This unit is obviously correlative with the Lockatong Formation. Another rather poorly sampled interval in the lower half of the section in the Wadesboro Basin has produced isolated elements of *Diplurus newarki, Synorichthys* sp., *Cionichthys* sp., a possible hybodont shark (app., 4), and a palynofllora resembling that of the Cumnock Formation (Cornet. ms), and, thus, correlation with the latter formation seems likely. Interest-

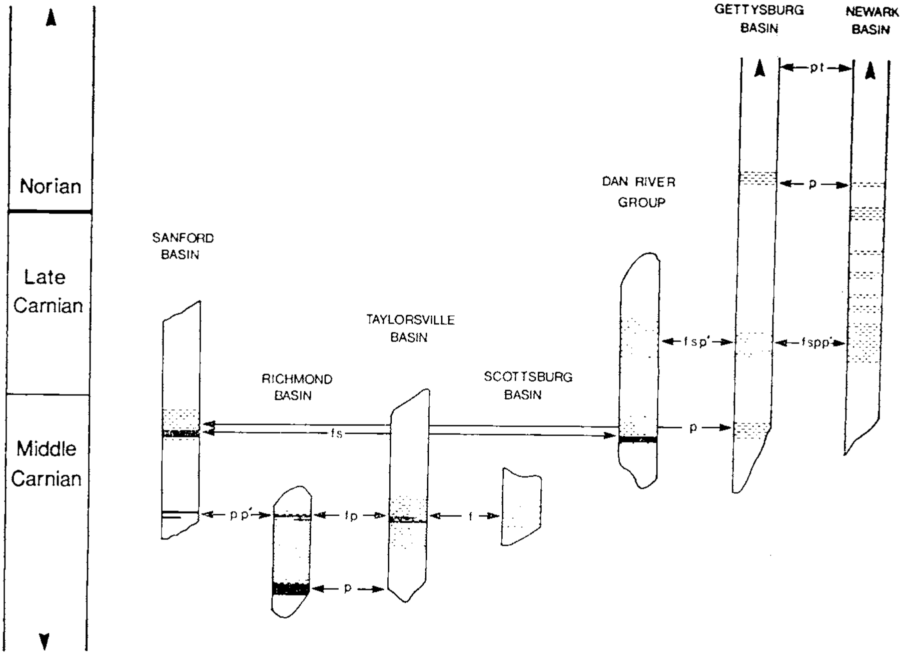


Fig. 6. Correlation web for the older parts of the Newark Supergroup. Arrows show the sources of biostratigraphic data in a column. Abbreviations for the kinds of data present are as follows: f, fish; s, reptile or amphibian skeletal remains; t, reptile footprints; p. palynomorph assemblages; p′, megafossil plant remains. When the letters are placed between columns on a double arrow it indicates that the fossils are from both sections. Black bars represent coals, and dashed pattern, gray and black siltstones. Note that thicknesses of columns are not to scale.

ingly, this Wadesboro exposure makes up part of the type section of Campbell and Kimball's (1923) Pekin Formation.

To recapitulate, it appears that the *Diplurus newarki* zone is younger than the *Dictyopyge* zone (fig. 6). The upper *Turseodus*-bearing portion of the *Diplurus newarki* zone is represented in: (1) the Lockatong Formation, Newark Basin; (2) the upper middle New Oxford Formation, Gettysburg Basin; (3) the upper member of the Cow Branch Formation, Dan River Group; (4) the lacustrine beds in the northern fault block of the Durham Basin. Fish characteristic of the lower part of this zone occur in the coal-bearing lower member of the Cow Branch Formation, of the Dan River Group and the Cumnock Formation of the Sanford Basin. The *Dictyopyge* zone and the *Diplurus newarki* zone correspond to the lower parts of zone 1 of Olsen and Galton (1977).

*Post-*Diplurus newarki, *pre-Jurassic strata of the Newark*

Thick sections (1000-6000 m) of primarily red clastics overlie sediments containing fish of the *Diplurus newarki* zone in the Chatham Group, Dan River Group, Gettysburg Basin, and Newark Basin. Similar units form the lower portions of the column in the Culpeper Basin, Hartford Basin, Deerfield Basin, Pomperaug Basin, and Fundy Group (figs. 1 and 2). While these beds contain very scrappy fossils (app., 10.2) or none at all, they can be correlated (with the exception of the lower Pomperaug Basin beds) by using distribution data of terrestrial vertebrate skeletal remains and footprints and palynomorph assemblages (fig. 7) (Cornet, ms; Olsen, Baird, and Salvia, ms; Olsen, 1980a). Except for the lower parts of the Wolfville Formation of the Fundy Group, these beds are younger than the *Diplurus newarki* zone and older than any of the Jurassic fish zones discussed below. They correspond to the younger parts of zone 1 and all of zone 2 in Olsen and Galton (1977).

The semionotid fish zones

The Culpeper Basin, Gettysburg Basin, Newark Basin, Pomperaug Basin, Hartford Basin, Deerfield Basin, and Fundy Group each contain a sequence of basalt flows and sediments that rests on the primarily red, fish-poor units mentioned above (fig. 2). These intra- and post-basalt flow sediments are commonly rich in fossil fish. Palynological correlation (Cornet and Traverse, 1975; Cornet, ms; Cousminer, 1977), radiometric dates (Armstrong and Besancon, 1970; Dallmeyer, 1975; Sutter and Smith, 1975; Masterson, ms), paleomagnetic data (Reeves and Helsley, 1972; McIntosh, ms) and terrestrial vertebrate correlation (Olsen and Galton, 1977; Olsen, 1980a; Olsen, Baird, and Salvia, ms) all indicate an Early Jurassic age for these beds.

Semionotid fishes are the most common vertebrates in the Newark Early Jurassic, and the restriction of some forms to certain fish-bearing beds in several basins makes them useful for correlation. Unfortunately, taxonomic confusion at both specific and generic levels prevents the use of formal systematic nomenclature at this time.

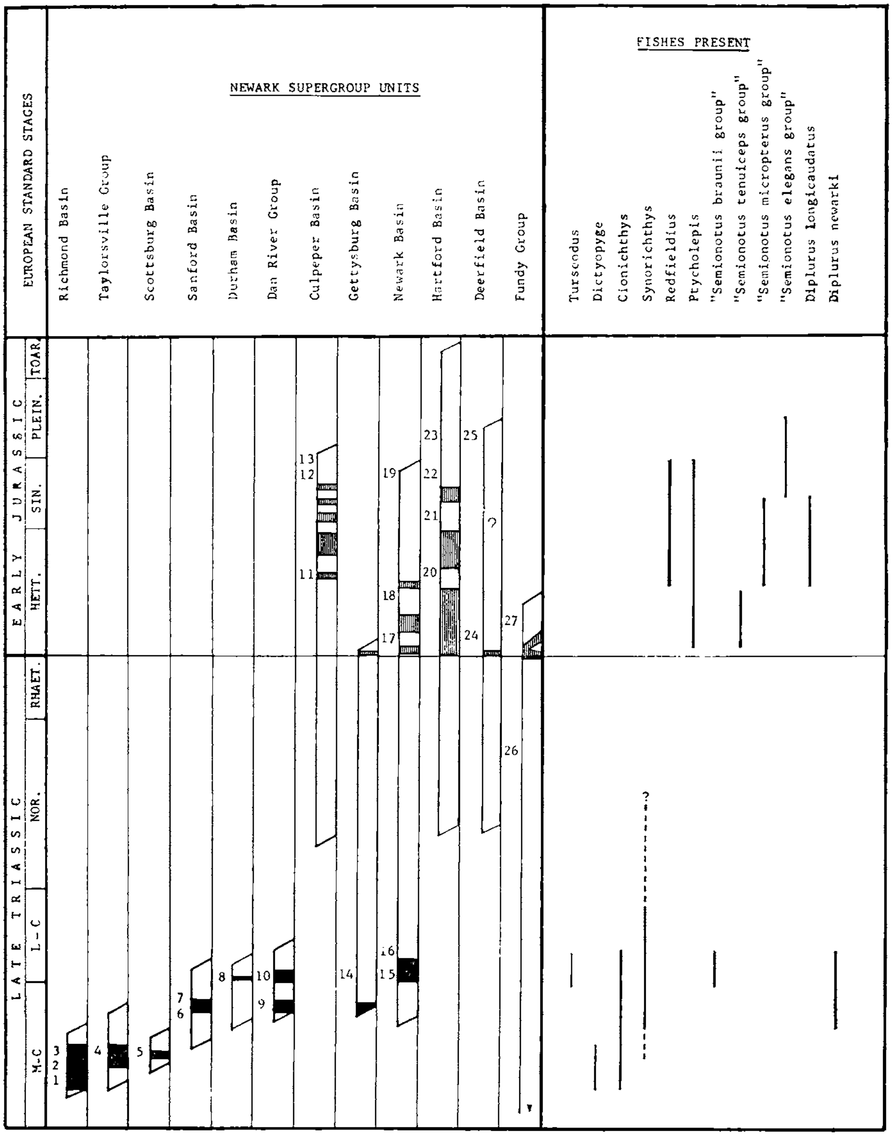


Fig. 7. Summary chart for correlation of the Newark Supergroup by fossil fish. The numbers refer to the fish-producing units in table 1. Vertical ruling indicates extrusive basalt units. The right hand side of the chart shows the ranges of the fish taxa used in constructing this correlation. Thickness of units not to scale. Black portions of columns signify thick black and gray formations. Abbreviations used: M-C, Middle Carnian; L-C, Late Carnian; NOR, Norian; RHAET, Rhaetic; HETT, Hettangian; SIN, Sinemurian; PLIEN, Pliensbachian; TOAR, Toarcian.

Agassiz (1832, 1833-1834) designated the Early Jurassic *Semionotus leptocephalus* the type of the genus *Semionotus,* but for over a century the poorly preserved Late Triassic *S. bergeri* has been mistaken for the type. The haphazard result is that small semionotids have been identified as *Semionotus* on the basis of size, supposed Triassic age, and poor preservation (McDonald, ms), all irrelevant characteristics of *S. bergeri.* What is more important to correlation, however, is that traditionally all Newark semionotids have been called *Semionotus,* and their presence cited as strong evidence of a Late Triassic age for all Newark sediments (Reeside and others, 1957; Klein, 1962).

On the basis of the first well-prepared Newark semionotids, Cornet, Traverse, and McDonald (1973) described the close similarity between Newark forms from the Shuttle Meadow Formation and the Jurassic semionotid *Lepidotes* from European localities. They also noted how little the Newark forms resembled published drawings of "classic" *Semionotus* species, such as *S. capensis* and *S. nilssoni.* Although we believe there are sufficient morphological grounds for the generic separation of all Newark forms from the type species of *Lepidotes (L. elevensis),* certain other members of the genus, such as *L. minor* from the English Purbeck (Late Jurassic), are very similar to Newark forms. Furthermore, most descriptions of semionotid species have been based on unprepared specimens, and some "Triassic" semionotids, in particular *S. kanabensis* and *S. capensis,* are really (like the type of the genus itself) Jurassic (Olsen and Galton, 1977; and see below). For these reasons, we use the term *Semionotus* in an informal sense, recognizing that a later systematic revision may alter the use of the name (see table 2). We attach no more specific time-stratigraphic significance to the presence of *Semionotus* or *Lepidotes* than a Mesozoic age.

For specific determinations of Newark semionotids, paleontologists have in the past relied primarily on the early descriptions by the Redfields (1836, 1841, ms, and 1856) and J. S. Newberry (1888). Unfortunately, reliable indentification of specimens on the basis of these authors' criteria is impossible because their descriptions are vague and overlapping. Confusion at this level is understandable, because morphological diversity of Newark forms is unexpectedly great (Olsen, 1980c). In most fish-bearing beds, body form ranges from fusiform to cycloid among all but extreme size classes. Some skull-bone proportions, scale and skull ornamentation, and meristic characters vary, but not necessarily in accord with each other. Significantly, the majority of semionotids at single horizons do share certain distinguishing characters including morphology of dorsal-ridge scales (fig. 8), shape of frontal bone (figs. 9 and 10), and the degree of heterocercality of the caudal fin (figs. 5 and 8 to 12). Despite the taxonomic disarray of Newark semionotids (a revision is in progress), these characters can be used tentatively to recognize six distinct groups of semionotids, four of which are used in interbasin correlation.

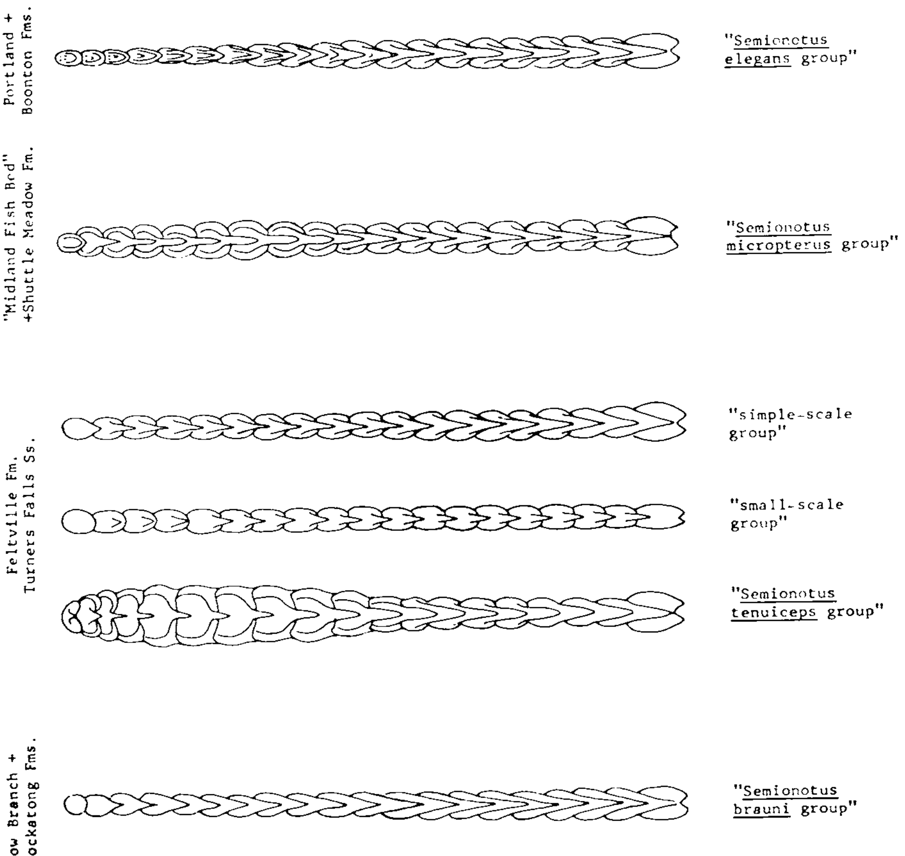


Fig. 8. Dorsal views of dorsal ridge scales for the Newark semionotids described in this paper. These drawings are generalizations representative of many specimens such as those in figures 10 to 13.

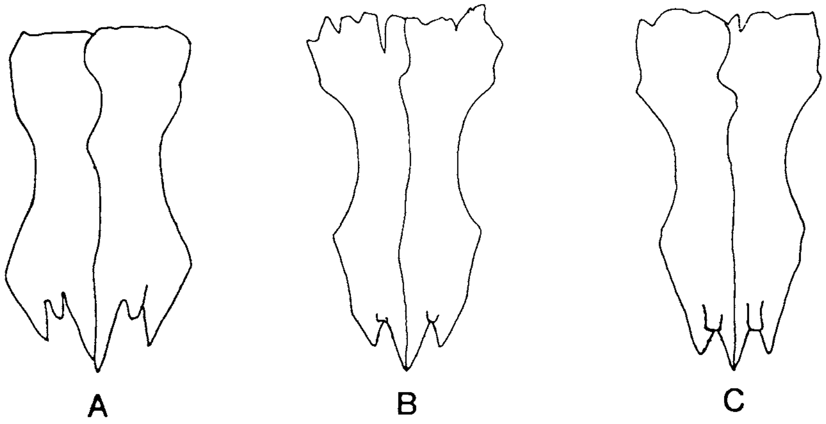


Fig. 9. General patterns of Newark semionotid frontals: (A) the *"Semionotus brauni* group," (B) the *"Semionotus tenuiceps* group," (C) the *"Semionotus micropterus* group."

Certain "species" of Newark semionotids that belong to some of these groups have already been described, and the name of the best known of each of these will be used here in an informal way to designate groups (table 1). For the purposes of this paper, the following are recognized: the "*Semionotus brauni* group" (figs. 5 and 9), the "*Semionotus tenuiceps* group" (figs. 8, 9, and 11), the "*Semionotus micropterus* group" (figs. 8, 9 and 12, and the "*Semionotus elegans* group" (figs. 8 and 10). There are also two groups for which no names are available, which we will call the "small scale group" and the "simple scale group" (figs. 8 and 13).

The "Semionotus brauni *group" zone.*—The oldest definite Newark semionotids are found in the upper (*Turseodus*-bearing) part of the *Diplurus newarki* zone. Several specimens of semionotids from this zone in the Lockatong Formation were designated *Semionotus (Ischypterus)* by Newberry (1888) (see fig. 5). As a rule, the fishes of this "*Semio-*

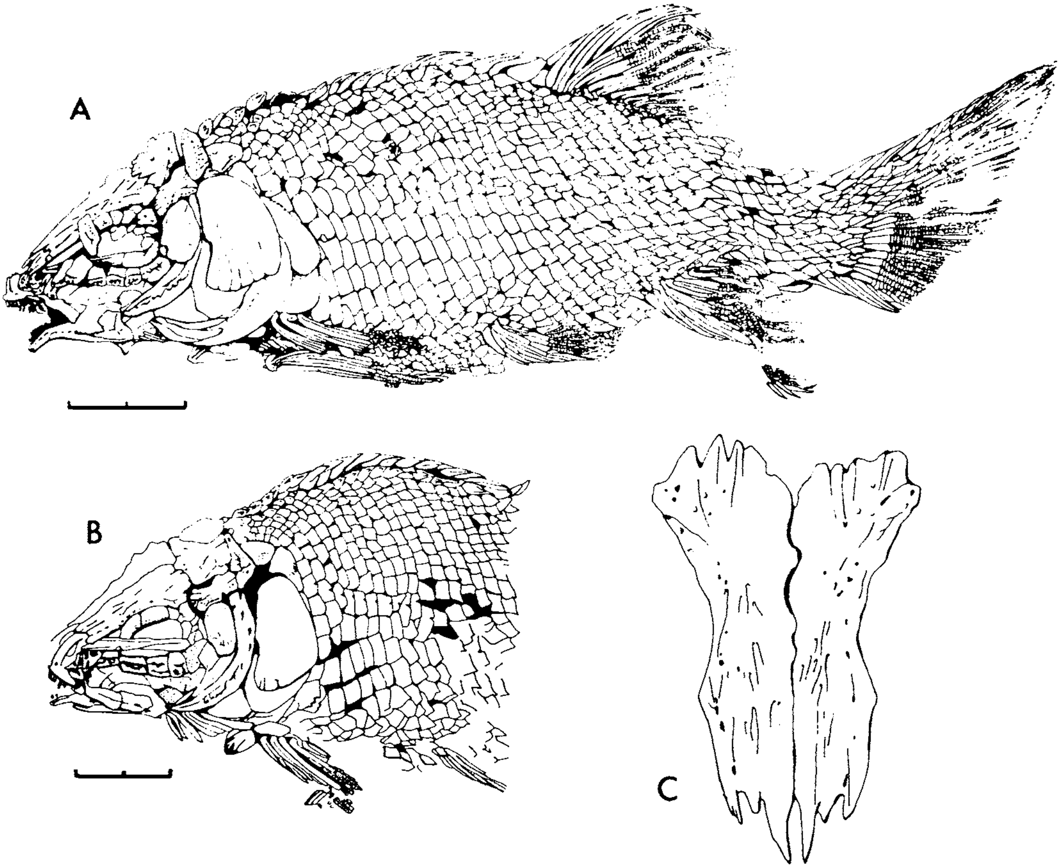


Fig. 10. Fish of the "Semionotus elegans group": (A) YPM 6567, "Boonton Fish Bed" of the Boonton Formation, Boonton, N.J.; (B) YPM 8163, lower Portland Formation, Middlefield, Conn.; (C) frontals in dorsal view from YPM 8601 and 6567. Scale for (A) and (B), 2 cm.

notus brauni group" show less morphologic diversity than other, Newark forms. They are characterized by a strongly heterocercal tail, frontals with a preorbital portion as broad as or broader than the postorbital portion (fig. 9), and paddle-shaped dorsal-ridge scales (fig. 8). Numerous well-preserved "*Semionotus brauni* group" fish have been recovered from the Lockatong Formation (Newark Basin) and the upper member of the Cow Branch Formation (Dan River Group) (Newberry, 1888; Olsen and others, 1978; see app., 7.2, 10.1 and figs. 7 and 5). Much less complete remains have been found in the *Turseodus*-bearing beds (Bain and Harvey, 1977) of the Durham Basin portion of the Chatham

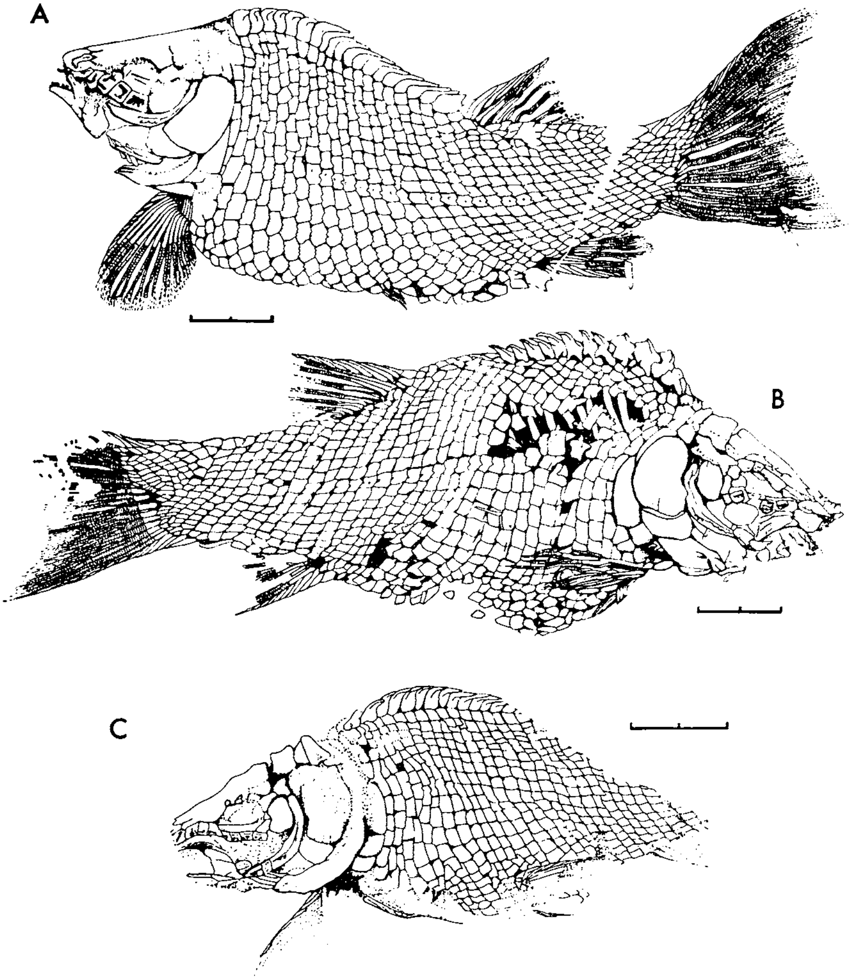


Fig. 11. Fish of the "*Semionotus tenuiceps* group": (A) YPM 7763, Feltville Formation, Martinsville, N.J.; (B) YPM 8162, Turners Falls Sandstone, Sunderland, Mass.; (C) YPM 8671, Member D, middle Towaco Formation, loc. Pom 1, Pomption, N.J. Scale 2 cm.

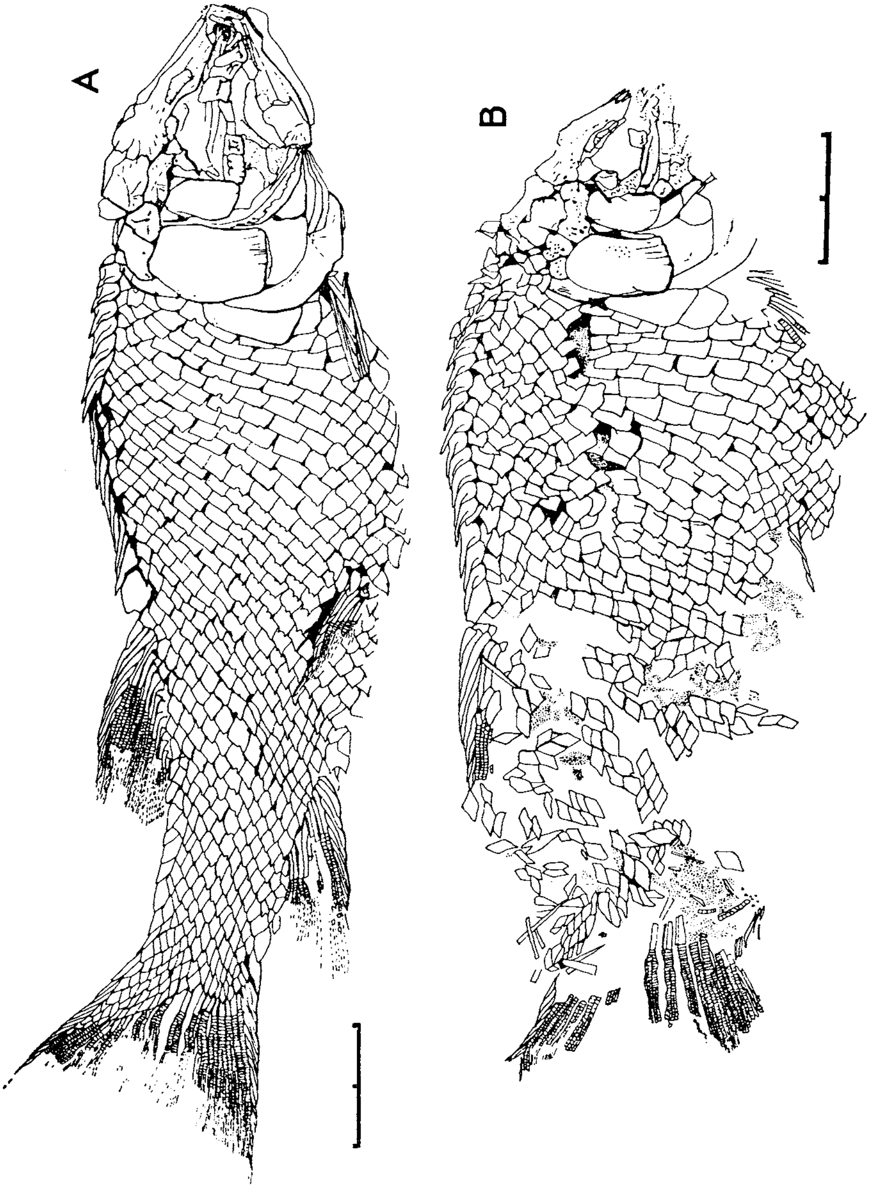


Fig. 12. Fish of the "*Semionotus micropterus* group:" (A) YPM 8604, Shuttle Meadow Formation, North Guilford, Conn.; (B) YPM 8608, "Midland Fish Bed," Midland, Va. Scale 2 cm.

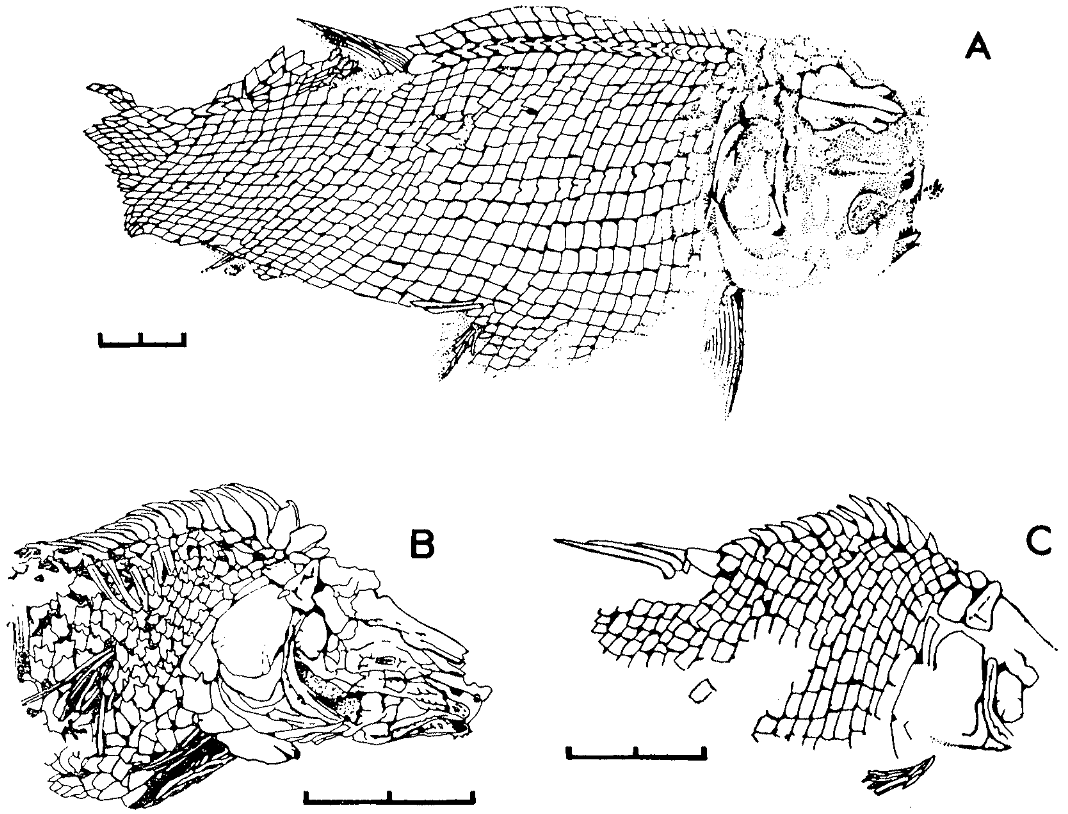


Fig. 13. (A) Semionotids of the "small scale group" (YPM 6898) from the Turners Falls Sandstone, Sunderland, Mass.; (B) fish of the "*Semionotus tenuiceps* group" (6960) from the Turners Falls Sandstone, Turners Falls, Mass.; (C) semionotid from the Scots Bay Formation, Five Islands Park, Nova Scotia. Scale 2 cm.

Group (see app., 6). Fish of this sort are unknown above the *Diplurus newarki* zone.

The "Semionotus tenuiceps *group" zone.*—The Jurassic rocks of the Feltville and Towaco Formations of the Newark Basin and the Turners Falls Sandstone of the Deerfield Basin contain a predominantly semionotid fish assemblage (figs. 1 and 2) (Olsen, 1980c). In these semionotids the preorbital portion of the frontals is as broad as or narrower than the postorbital portion (fig. 9), and the heterocercal tail is more abbreviated than in the *"Semionotus brauni* group" (fig. 11). The most common fish present have large, elaborate dorsal-ridge scales (figs. 8 and 11) and belong to what we call the *"Semionotuus tenuiceps* group" (fig. 11; app., 10.3 and 13.1) after Agassiz's *Semionotus (Eurynotus) tenuiceps* (table 2). Other semionotids present are separable into two rather poorly defined groups. One group, exemplified by Newberry's *S. latus* (1888, pl. 13, fig. 13), which we call the "simple scale group", has relatively simple-looking dorsal-ridge scales (fig. 8 and app., 10.3). The other, the "small-scale group", is poorly known but has especially small and simple dorsal ridge scales (fig. 13). The high diversity of semionotids in this zone stands in marked contrast to the low diversity of other fishes; the subholostean *Ptycholepis* cf. *marshi* (see app., 10.3) is the only other fish taxon known from these beds (Schaeffer and McDonald, 1978).

The "Semionotus micropterus *group" zone.*—The Hartford Basin (figs. 1 and 2) is situated between the Deerfield and Newark Basins and like the latter two basins, the sediments (Shuttle Meadow Formation) above the lowest basalt formation (Talcott) are rich in fossil fish. Even casual examination of the Shuttle Meadow assemblage — the range of which we term the *"Semionotus micropterus* group"—zone reveals a fauna very different from that of the *"Semionotus tenuiceps* group" zone. The Shuttle Meadow is dominated by semionotids with distinct "banjo-shaped" dorsal ridge scales (table 1 and fig. 8). There are also the redfieldiid *Redfieldius* sp., the subholostean *Ptycholepis marshi,* and the large coelacanth *Diplurus* cf. *longicaudatus* (Schaffer and McDonald, 1978; Schaeffer, 1948 — see fig. 14 and app., 12). That the Shuttle Meadow fishes show so little resemblance to those of the Feltville Formation is especially interesting in light of the supposed physical connection between the two basins. The "Broad Terrain Hypothesis," as it is called, has been linked historically to a one-to-one correlation between the three major extrusive units in the Hartford and Newark Basins (Russell, 1878; Longwell, 1922, 1928; Sanders, 1960, 1963, 1974; Hubert and others, 1978). Such a correlation is not supported by the biostratigraphic data, but, of course, no correlation can preclude the Broad Terrain Hypothesis.

About 500 km to the southwest of the Hartford Basin is the Culpeper Basin. Here, in the "Midland Fish Bed" (Baer and Martin, 1948; Schaeffer and McDonald, 1978) are found all the fishes typical of the Shuttle Meadow Formation including *"Semionotus micropterus* group" forms (see app., 8.1). This fish-bearing unit is above the lowest of five major extrusive units in the Culpeper Basin (McCollum, 1971; Lee, 1977, 1980; Lindholm, 1979), but because there are five units rather than three, a simple correlation with the extrusives of the Hartford and Newark Basins is not possible.

Cornet (ms) suggests that the palynofloras of the Shuttle Meadow Formation and the Midland Fish Bed are slightly younger than those of the Feltville Formation, Towaco Formation, and Turners Falls Sandstone, though the evidence is not very strong (Cornet, personal commun.). Additional support for a probable younger age of the "*S. micropterus* group" zone is provided by fishes found in higher positioned units in the Newark and Hartford Basins described below.

The "Semionotus elegans *group" zone.*—The upper Boonton Formation of the Newark Basin (Olsen, 1980d) contains the famous "Boonton Fish Bed," one of the best sampled units in the Newark Supergroup. Semionotids, *Redfieldius* spp, *Diplurus longicaudatus,* and *Ptycholepis* sp. (Schaeffer, Dunkle, and McDonald, 1975) have been recovered from this unit mostly as articulated specimens (app., 10.5). The semionotids are distinguished from the "*Semionotus tenuiceps* group" and the "*S. micropterus* group" by the shape of their anterior dorsal ridge scales (figs. 7 and 11), frontals in which the preorbital portion is almost always narrower than the postorbital portion, and strongly abbreviated het-

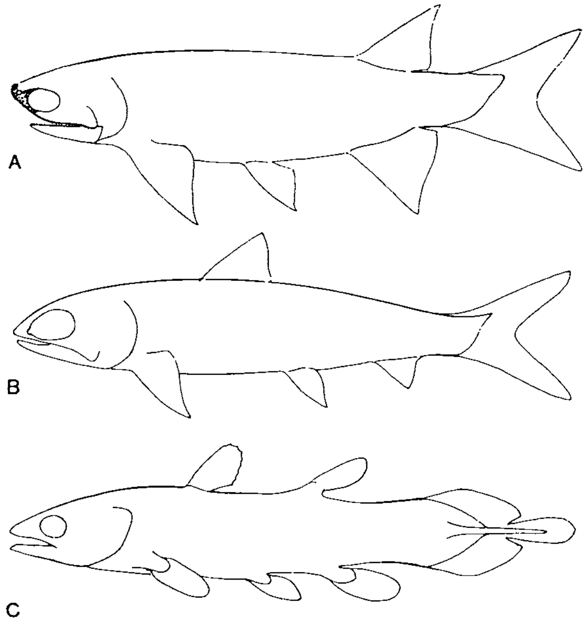


Fig. 14. Non-semionotid fishes found in the Jurassic semionotid zones: (A) *Redfieldius* (adapted from Schaeffer and McDonald, 1978) about 1/3 X, (B) *Ptycholepis marshi* (adapted from Schaeffer, Dunkle, and McDonald, 1975) about 1/3 X, (C) *Diplurus longicaudatus* (adapted from Schaeffer, 1948) about 1/15 X. Of these fishes, only *Ptycholepis* is present in the "*Semionotus tenuiceps* group" zone.

erocercal tail. The most common name used to describe fish of this type is *Semionotus (Ischypterus) elegans* (Newberry, 1888), and thus we refer to both the species group and its range zone by that name (table 1). The "Boonton Fish Bed" is probably contemporaneous with the lower Portland Formation as they have both produced the *"Semionotus elegans* group", *Redfieldius* (app., 12.3) and similar palynomorph assemblages (Cornet, ms). In addition, a unit above the highest extrusive basalt in the Culpeper Basin (the "Haymarket Fish Bed" — see app., 8.2) has produced semionotids of the *"S. elegans* group," *Redfieldius* spp., *Ptycholepis* sp., and *Diplurus* cf. *longicaudatus*. The fish and the palynoflorule from these beds (Cornet, personal commun.) suggest correlation with the lower Portland and upper Boonton formations. The simplest hypothesis relating all three of the Newark Jurassic semionotid zones is that the *Redfieldius*-bearing beds are closer to each other in time than the units without *Redfieldius* (that is, the *"S. tenuiceps* group" zone), and thus, the *"Semionotus tenuiceps* group" zone is older than the *"S. micropterus* group" zone, which in turn, is older than the *"S. elegans* group" zone (figs. 6, 7, and 15). As yet, fish of the *"Semionotus tenuiceps* group" zone have not been identified in the Hartford or Culpeper Basins, perhaps for a number of reasons, not the least of which are that the

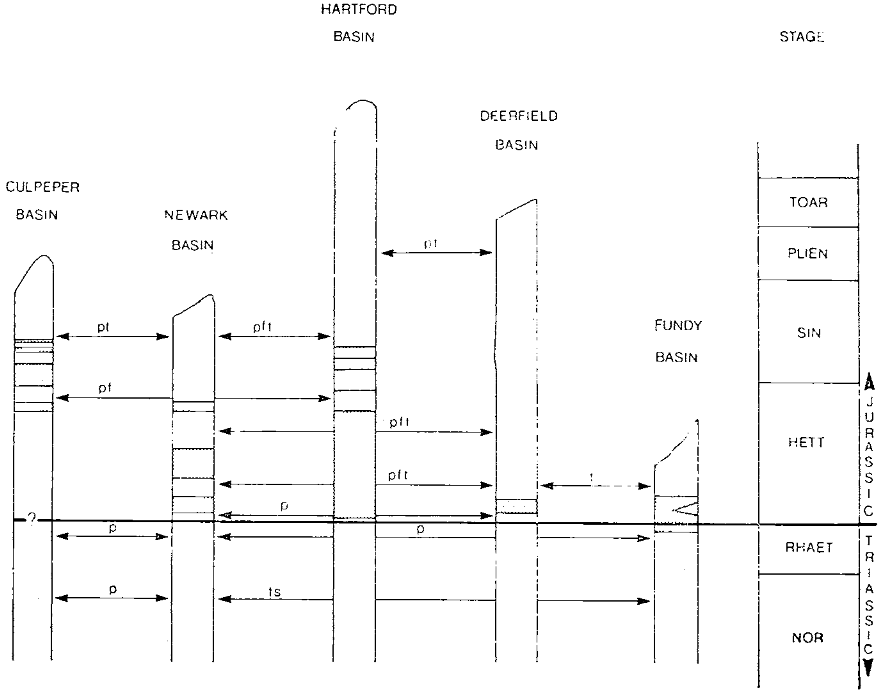


Fig. 15. Correlation web for the younger parts of the Newark Supergroup. Arrows show the sources of biostratigraphic data in a column. Abbreviations for the kinds of data present are as follows: f, fish; s, skeletal remains of tetrapods; t, reptile footprints; p, palynomorph associations. Note that the thickness of units are not to scale and that gray areas represent extrusive basalts. The use of the letters is the same as in figure 6.

proper units may not yet be sampled, or lakes may not have existed at appropriate times.

The hypothesis diagrammed in figure 15 is one that involves the least separation in time of the data-producing levels in each basin. Simply stated, the data suggest that the Feltville and Towaco Formations and the lower Turners Falls Sandstone are older than the Shuttle Meadow Formation and the sediments above the lowest extrusive basalt unit in the Culpeper Basin (see fig. 2). The data also suggest that the upper Bonton Formation, the lower Portland Formation, and the "Haymarket Fish Bed" (of the beds above the highest extrusive unit in the Culpeper Basin) (see app., 8.2) correlate. Providing the Feltville and Towaco formations are, in fact, younger than the upper New Haven Arkose (a hypothesis supported only by the presence of a phytosaur about 80 m below the Talcott Basalt — Olsen, 1980c), the interval of time represented by the Feltville through Towaco Formations and lower Turners Falls Sandstone should fall somewhere between the top of the New Haven Arkose and the base of the Shuttle Meadow Formation. A large number of individual arrangements of formations are possible within these constraints.

No other pair of Newark Supergroup Basins share the same diversity of classes of time-correlative data as the Newark and Hartford basins, and it is important to see how the different data compare in detail. In addition to the paleontologic data, there are paleomagmatic data (deBoer, 1968); K/Ar dates (Armstrong and Besancon, 1970; Reesman, Filbert, and Kruger, 1973; Masterson, ms); and basalt geochemical data (Puffer and Lechler, 1980). Each class of data has its own simplest hypothesis of correlation; for the paleomagnetic data, deBoer (1968) suggests that all three Newark Basin basalt formations correlate with the Holyoke Basalt of the Hartford Basin; for the K/Ar data, Masterson (ms) suggests that the Orange Mountain and Preakness basalts are older than the Talcott Basalt and that the Hook Mountain Basalt and the Hampden Basalt correlate; and for the geochemical data, Puffer and Lechler (1980) suggest that each of the three basalt formations of the Newark Basin correlates with each of three of the Hartford Basin. But these are only the simplest hypotheses; many others, each fully consistent with the data, are possible. The basalt-geochemical data may be used as an illustration. Because there are no data for each of the sedimentary formations around the basalt units, the data for the Preakness Basalt, for example, allow correlation with either the Holyoke Basalt, the Shuttle Meadow Formation, or the East Berlin Formation, or in fact any interval between the top of the Talcott and the bottom of the Hampden; likewise, the data for the Hook Mountain Basalt allow correlation with any interval above the Holyoke Basalt. Thus, by allowing more complex correlations, we can combine disparate lines of data, which at first appear incompatible, into reasonable correlations (fig. 16).

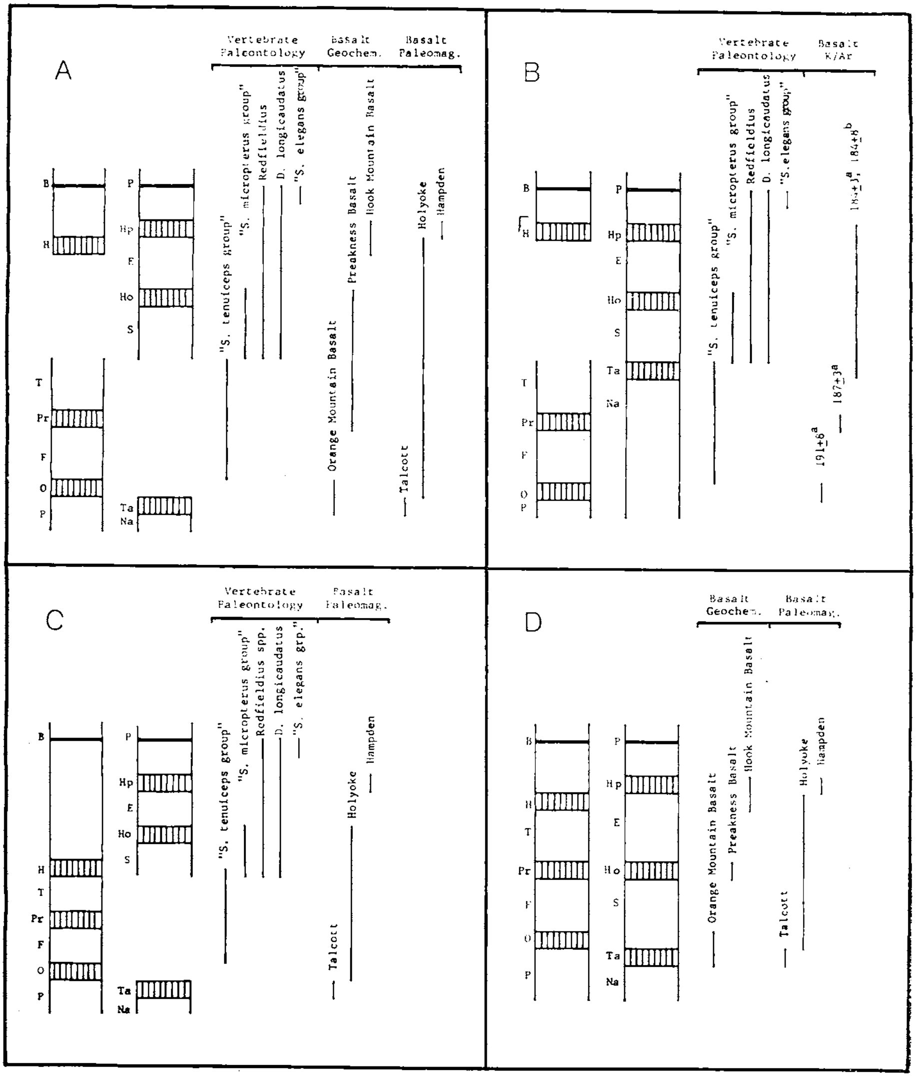


Fig. 16. Comparison of internally consistent alternative correlations based on vertebrate paleontology, basalt geochemistry, basalt paleomagnetics, and K/Ar dates: (A) correlation based on vertebrate paleontology, basalt geochemistry, and basalt paleomagnetics; (B) correlation based on vertebrate paleontology and basalt K/Ar dates (a, data from Masterson, ms and personal commun., b, data from Reesman, Filbert, and Krueger, 1973); (C) correlation based on vertebrate paleontology and basalt paleomagnetics (this is essentially the correlation given by Cornet and Traverse, 1975 and Cornet, 1977); (D) correlation based on basalt geochemistry and basalt paleomagnetics.

Abbreviations as follows: P, Passaic Formation; O, Orange Mountain Basalt; F, Feltville Formation; Pr, Preakness Basalt; T, Towaco Formation; H, Hook Mountain Basalt; B, Boonton Formation; Na, New Haven Arkose; Ta, Talcott Basalt; S, Shuttle Meadow Formation; Ho, Holyoke Basalt; E, East Berlin Formation; Hp, Hampden Basalt; P, Portland Formation. In all the correlations the Newark Basin section is on the left, while the Hartford Basin section is on the right.

Non-vertebrate data from deBoer (1968), Puffer and Lechler (1980), Reesman, Filbert, and Krueger (1973), and Masterson (ms).

Cornet and Traverse (1975) and Cornet (ms) use both vertebrate data and the paleomagnetic data of deBoer (1968) for their proposed correlation of the extrusives and interbedded sediments of the Newark, Hartford, and Deerfield Basins (as shown in fig. 16C). Olsen (1980a), on the other hand, uses only vertebrate data for correlation. In both cases, the Feltville and Towaco Formations are thought to be older than the Shuttle Meadow Formation. Based on the vertebrate data alone, the Talcott Basalt could correlate with the entire interval from the base of the Orange Mountain Basalt to the top of the Towaco Formation (as in fig. 15), or a hiatus can be postulated either between the Shuttle Meadow Formation and the Talcott Basalt or between the Talcott Basalt and the New Haven Arkose (as in Olsen, 1980a). If the hiatus is placed above the Talcott, the correlation is consistent with deBoer's paleomagnetic data (see fig. 16C). Only other lines of evidence can resolve ambiguities in the correlation; however, while other forms of data reduce the number of possible correlations, they do not necessarily improve the reliability of any particular correlation.

In fact, of the pair-wise combinations possible, the fish-zone data prove consistent with each of the other classes of data (fig. 16). In addition, the basalt geochemical data and the paleomagnetic data are compatible, and together consistent with the fish data. The K/Ar data, while consistent with the fish data, do not agree with either the basalt geochemical or the paleomagnetic data. While this could be taken as support for the fish-zone correlation, we lack confidence that any one class of data is to be preferred over any other. No relevant geophysical or paleontological data are free of compromising assumptions and technical difficulties. Agreement among three independent lines of data does not add reliability to the correlation if the data are equivocal.

In summary, the Jurassic strata in the Newark Supergroup can be correlated by three semionotid fish zones. A fourth semionotid zone forms the upper part of the Triassic *Diplurus newarki* zone. Paleomagnetic, basalt geochemical, radiogenic, palynological, and non-fish-vertebrate evidence are consistent with the correlation web based on the fish zones (fig. 15). The oldest of the semionotid zones is of Late Triassic age (the "*Semionotus brauni* group" zone). Above that the three Jurassic fish zones are (from oldest to youngest) the "*Semionotus tenuiceps* group" (Feltville Formation, Towaco Formation, Turners Fall Sandstone), the "*Semionotus micropterus* group" zone (Shuttle Meadow Formation, "Midland Fish Bed") and the "*Semionotus elegans* group" zone (Boonton Formation, lower Portland Formation). The biostratigraphic data are not consistent with a simple correlation of the individual extrusive basalts of the various Newark Supergroup Basins, though all the extrusive units appear to be restricted to the older Early Jurassic (Hettangian-Sinemurian).

In addition to the fishes from the formations already discussed, fish have been found in other formations and basins. Because the relation of these fish assemblages does not as yet add directly to the correlation (though they are not inconsistent with it) they are discussed separately below.

Other Newark fishes

Hartford Basin.—The East Berlin Formation (fig. 2) is a sedimentary unit overlying the Shuttle Meadow Formation (and the Holyoke Basalt) but under the lower Portland Formation (and the Hampden Basalt). This formation has produced a large number of poorly preserved *Redfieldius, Diplurus* cf. *longicaudatus* (McDonald, 1975), and possibly fishes of the "*Semionotus micropterus* group" (see app., 12.2). On the basis of existing information the fauna of the East Berlin is indistinguishable from that of the Shuttle Meadow Formation.

Above the "*Semionotus elegans* group" zone in the Portland Formation are beds with palynological assemblages indicating Pleinsbachian and Toarcian ages (Cornet, 1977). Fossil fish known from the Toarcian age beds in Massachusetts include some poorly preserved 'holosteans' of unknown affinities called "*Acentrophorus*" (Newberry, 1888). Unfortunately, the semionotids present are also too poorly preserved to compare with other semionotids, but the absence of *Redfieldius* in the middle and upper Portland beds probably has time-stratigraphic value.

Pomperaug Basin.—The Pomperaug Basin (figs. 1 and 2) lies directly between the Newark and Hartford Basins. Black and gray limestones of the Pomeraug Basin (fig. 2) have produced fragmentary remains of semionotids and *Redfieldius* (Schaeffer and McDonald, 1978; see app., 11). Unfortunately, the geology of the fish-producing beds is so poorly understood that it is not possible to locate their position relative to the basalts. All we can say is that palynomorph assemblages from the fish-bearing beds indicate correlation with the Shuttle Meadow Formation, and the fish do not contradict this.

It has been common practice to use the rock-stratigraphic terms applied to the Hartford Basin for the beds of the Pomperaug Basin (Cornet, ms; Hubert and others, 1978), but this habit presumes the correctness of the Broad Terrain Hypothesis. Since neither the biostratigraphic relations nor the stratigraphic sequence of the Pomperaug Basin have been satisfactorily explored, we note that correlations with individual units of the Hartford Basin are only speculative.

Deerfield Basin.—A fish-bearing horizon high in the Deerfield Basin section (Mt. Toby Conglomerate — fig. 2) produces only semionotids (app., 13.2) (Bain, 1932). This unit is well above beds of Pleinsbachian age, and, though there may be structural complications, it seems to correlate with the middle Portland Formation assemblage described above (Cornet, ms).

Culpeper Basin.—A fish-bearing horizon higher than the "Haymarket Fish Bed," "the Millbrook Quarry Fish Bed" (Baer and Martin, 1948), has produced semionotids, *Diplurus* cf. *longicaudatus* (see app., 8.3), and a palynoflorule of Pliensbachian age (Cornet, personal commun.). The middle Portland Formation and Upper Mt. Toby Conglomerate contain no redfieldiids. These poorly known faunas of Cornet's (ms) "post-redfieldiid zone" make up the youngest of all Newark Supergroup fish assemblages (figs. 7 and 15).

The Fundy Group.—Semionotids have been found in four areas of the Fundy Group (figs. 1 and 2). The first occurrence is in the middle Blomidon Formation (Carroll and others, 1972) approx 130 m below the North Mountain Basalt. Though existing specimens (see app., 14.1) are too fragmentary to be meaningfully compared with other forms, they are important because of their age as deduced from other data. The fish-bearing unit lies about 125 m below a palyniferous horizon correlative with the Rhaetic portion of the upper Passaic Formation (Cornet and Traverse, personal commun.) in the Newark Basin (that is, zone 2 of Olsen and Galton, 1977). At about the same level, 113 km to the south, the phytosaur *Rutiodon* (see app., 15.2) has been found along with footprints comparable to those of the upper Middle Passaic Formation (see app., 15.2), thought to be Norian or Rhaetic in age (Cornet, ms). About 275 m below the Blomidon fish bed, in the same section, are found footprints (see app., 5.1) typical of Carnian and early Norian beds of the lower Passaic Formation (Cornet, ms). It seems likely that the Blomidon fish bed corresponds to the middle Passaic Formation, which means that the fish are, uniquely, in the Newark, Norian, or Rhaetic in age.

Semionotids have also been found in the type Scots Bay Formation (fig. 2) above the North Mountain Basalt (Powers, 1916). These fish (app., 14.2) although abundant in some beds are not well enough preserved for definitive identification, though they look most like semionotids present in the beds along the north shore of the Minas Basin described below.

Well preserved semionotids are common (figure 12 and app., 14.3 and 14.4) in the lower part of the McCoy Brook Formation (Scots Bay equivalent) on the north shore of the Minas Basin portion of the Bay of Fundy. Semionotids from the McCoy Brook and Scots Bay Formation are different from all other Newark semionotids, though they resemble fishes of the "simple scale group" from the *"Semionotus tenuiceps* group" zone. The diverse reptile footprint assemblage (see app., 15.3) in this unit, which corresponds to Olsen and Galton's (1977) zone 3, suggests that the Scots Bay and McCoy Brook Formations are Jurassic in age (see Olsen and Donohue, ms, for a detailed discussion of these beds).

Finally, disarticulated semionotids are abundant in an interflow sedimentary unit of the North Mountain Basalt (locally called the McKay Head Basalt). Associated remains include a prosauropod dinosaur, ornithischian dinosaur, other small reptiles, a hybodont shark, and a possible redfieldiid (see app., 14.4 and 15.3).

CORRELATION OF THE NEWARK SUPERGROUP TO OTHER EARLY MESOZOIC SECTIONS

Relating the Newark Supergroup section to the European early Mesozoic is difficult, not only because large portions of the classic sections are marine while the exposed Newark is continental, but also because the Newark terrain is so distant (even in pre-drift postions) from the European deposits. An additional problem is that critical geophysical data are lacking for the European section. There is, for example, no information on the radiogenic age of the Triassic-Jurassic boundary from within the Germanic basin, and comparison of Newark radiometric dates with the European section depends entirely on a complex biostratigraphic correlation web.

Vertebrate and floral data still provide the best means of correlating the Jurassic Newark and European sections. Unfortunately, the fossil fishes of the European early Mesozoic are little help, because like invertebrates they seem tied to either marine or fresh-water sediments. A survey of the literature on the distribution of Mesozoic fishes (Brough, 1931; Woodward, 1895, 1916-1919; Wenz, 1967; Schmidt, 1928; Romer, 1969; Schaeffer, 1967; Agassiz, 1833-1844; Schaeffer and McDonald, 1978) shows that marine Triassic assemblages closely resemble marine early Jurassic assemblages on generic and familial levels. These marine fishes are very different from contemporaneous continental assemblages, however, which prevents time-stratigraphic comparisons between Newark fishes and the marine Jurassic of Europe. For the Jurassic, correlation with the European section can be based only on tetrapod (skeletal and footprint) and floral data. Although all forms of terrestrial vertebrate and megafossil plant remains are rare in the marine sediments of the Lias, the limited data available are useful (Olsen and Galton, 1977).

Correlation of the lower parts of the Newark with the European section can be more direct because both sections are primarily continental and share similar kinds of fossils. That the vertical changes in vertebrate assemblages from the European Middle through Late Keuper are nearly identical to those seen in the early Newark lends credibility to a Jurassic age for the upper Newark. Continental beds of other areas, such as the southwestern United States and southern Africa, are, for the same reasons, more easily compared to the Newark section than to the Early Jurassic of Europe.

The limited biostratigraphic data from the *Dictyopyge* zone makes correlation with other areas difficult since *Dictyopyge* itself is unique to the Newark (Schaeffer, 1967; Schaeffer and McDonald, 1978). A single specimen (the type) of *Tanaocrossus* is known from the upper Chinle Formation of Colorado (Schaeffer, 1967); another is known from the "productive coal measures" of the Richmond Basin (Schaeffer and McDonald, 1978). Saint-Seine and Casier's (1962) *Macrosemius maeseni* from the Kimmeridgian of Songa, Zaire, has recently been referred to *Tanacrossus* by Bartram (1977), but this seems unjustified in light of the admitted differences between the Kimmeridgian form and the Chinle genus. The only other well preserved fish from the *Dictyopyge* zone are rare specimens of *Cionichthys* (see app., 1.1), which resemble *C. greeni* from the lower Dockum Group more than *C. dunklei* from the upper Chinle Formation. Finally, the only recognizable tetrapod from the *Dictyopyge* zone is a very peculiar reptile from the Taylorsville Basin (Weems, ms). As this reptile probably belongs to its own order and is unique, it offers no aid in correlation.

Cornet's (ms) palynomorph data are more helpful in correlating the *Dictopyge* zone with non-Newark deposits (fig. 16). He shows the whole of this zone to be correlative with late Middle Carnian rocks of the Alpine section and the lowermost Chinle and lower Dockum Group of the southwestern United States. Interestingly, the Schilfsandstein of the Germanic basin contains vertebrates very similar to those of the lower Dockum (Schmidt, 1928; Gregory, 1969) and is Middle Carnian (Kozur, 1975; Gall, Durand, and Muller, 1977), thus substantiating the palynomorph data on the lower Dockum and strengthening Newark correlation.

Schaeffer and Mangus (1973) have shown that the lower Newark and the Chinle Formation and Dockum Group have very similar fish assemblages. When only the upper Chinle Formation assemblage (described by Schaeffer (1967) and the fishes of the *Diplurus* zone are compared this similarity is greatly increased; four out of the six genera present in the sediments of the *Diplurus newarki* zone are present in the upper Chinle. Well preserved specimens of *"Semionotus sp."* have been described from the upper Chinle Formation (Schaeffer, 1967), and these more closely resemble the *"Semionotus brauni* group" than any other known forms (fig. 8), although they are clearly a distinct taxon. The important points of resemblance include caudal fin and frontal bone morphology; the Chinle forms differ only in having marked tuberculation of the anterio-dorsal trunk scales and a strong positive allometric trend toward a disk-like shape. This high degree of overall fish resemblance suggests a correlation between the *Diplurus newarki* zone of the Newark Supergroup and the upper Chinle.

Evidence from the tetrapod fauna and palynomorph assemblages further substantiates correlation between the *Diplurus newarki* zone and the upper Chinle Formation. The metoposaur amphibian *Metoposaurus* (= *Eupelor* = *Buettneria;* Gregory, 1972; Olsen, Baird, and Salvia, ms), the large dicynodont *Placerias,* the aetosaur thecodont *Typothorax,* the phytosaur *Rutiodon,* and the tanystropheid *Tanytrachelos* are known from both the Chinle and the *Diplurus newarki* zone of the Newark (Baird and Patterson, 1967; Jacobs and Murry, 1980; Olsen, Baird, and Salvia, ms). In addition, palynomorph assemblages from both the Chinle Formation and the *Diplurus newarki* zone correlate with the Middle-Late Carnian as shown by Cornet (ms and 1977).

The relative age and correlation of the largely non-fish-bearing redbed sequences above beds included in the *Diplurus newarki* zone and below what we believe to be Jurassic strata must be determined by tetrapod, floral, and geophysical data. On the basis of reptile skeletal remains and footprints, Olsen and Galton (1977) divided the terrestrial vertebrate faunas of the Newark Basin into three zones (fig. 16) with, as mentioned, the lower part of zone 1 broadly corresponding to the

Diplurus newarki zone. The upper part of zone 1 corresponds to the non-fish-bearing red beds and appears to be Norian on the basis of abundant palynomorph assemblages described by Cornet (ms). These Newark red beds have also produced skeletal remains of phytosaurs, aetosaurs, and procolophoids, as well as abundant footprints (Olsen and Galton, 1977) similar to those found in the Norian Stubensandstein and Knollenmergel (that is, Steinmergelkeuper) of the Germanic Basin (Gall, Durand, and Muller, 1977; Olsen, Baird, and Salvia, ms; Olsen and Galton, 1977; Olsen 1980a). Above the upper part of zone 1 in the Newark Basin is another series of non-fish-bearing beds which appear to be Rhaetic on the basis of palynomorphs (Cornet, ms). These same beds produce reptile footprints comparable to forms described by deLapparent and Montenat (1967) from the French Infralias (= latest Triassic or oldest Jurassic) (Olsen and Galton, 1977). Beds correlating with zone 2 of the Newark Basin (Rhaetic age) occur in the Culpeper, Gettysburg, Hartford, Deerfield, and Fundy Basins. Zone 3 of the Newark Basin (Olsen and Galton, 1977) appears to be early Jurassic (Cornet, 1977a). Correlative beds are found in all Newark Supergroup basins that contain extrusive basalts (figs. 2, 7 and 15).

Correlation of the Early Jurassic fish zones outside the Newark Supergroup is hampered by the marine nature of most Jurassic fish faunas, but three continental deposits have produced what appear to be Early Jurassic fish. A small semionotid from the Moenave Formation of the Glen Canyon Group (southwestern United States) is described as *Semionotus kanabensis* (Schaeffer, 1950). This fish has frontal bones with the markedly narrow preorbital portion characteristic of the Newark Early Jurassic forms. Comparison beyond this, however, is not possible because the body is inadequately preserved. The palynoflora from the Moenave Formation (Cornet, personal commun.; Olsen and Galton, 1977) indicates an Early Jurassic age, probably Sinemurian or Pliensbachian. Olsen and Galton (1977) correlate the entire Glen Canyon Group with their zone 3 of the Newark Basin on the basis of terrestrial vertebrates, which again is consistent with the fish and floral evidence (fig. 17).

Another fish assemblage is from the lower Clarens Formation (Cave Sandstone Upper Stormberg Group) of southern Africa. The vast majority of these fishes are semionotids which Woodward (1888) named *Semionotus capensis*. The only other fish found in these deposits is *Endemichthys* (Forey and Gardiner, 1973 and Jubb and Gardiner, 1975) which may be a redfiediid. A re-examination of Clarens Formation semionotids (Olsen and McCune ms) shows that they are similar to the youngest Newark forms in skull morphology, especially frontal bone shape and caudal fin morphology. The dorsal-ridge scales are very distinctive, however, and it is clear *S. capensis* is not represented in the Newark. The Upper Stormberg Group appears to correlate with the Early Jurassic on the basis of radiometric dates of the overlying Drakensberg Volcanics and the Upper Stormberg reptile skeletal and footprint assemblage (Olsen and Galton, 1977; Clemens and others, 1979). No floral data are

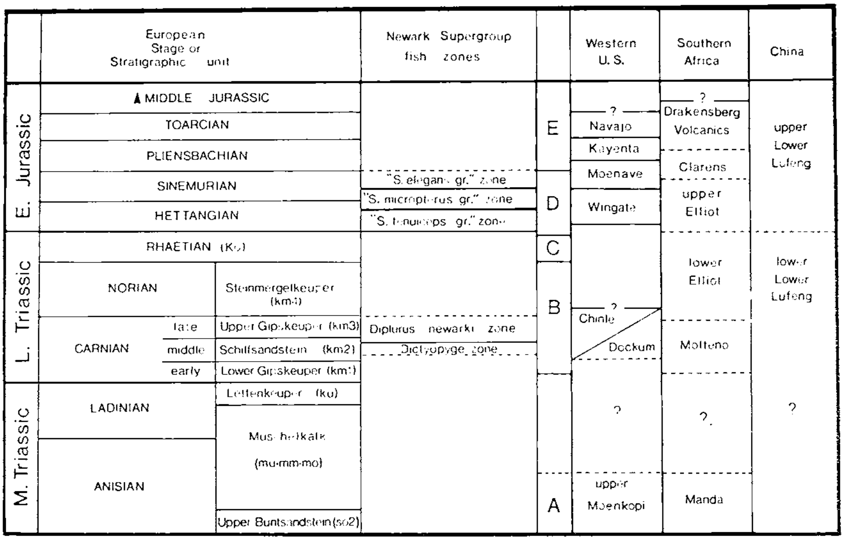


Fig. 17. Correlation of the Newark Supergroup with other areas. The abbreviations (km 4, ko, ku, et cetera) are the standard European notation for Triassic stratigraphic units. The correlation between the German stratigraphic units and the European standard stages is largely from Kozur (1975). The column to the right of the Newark Fish zones shows the major faunal zones of the Newark: (A) Middle Triassic fauna from the Lower Economy beds; (B) zone typified by the presence of *Chirotherium*-type footprints corresponding to Olsen and Galton's (1977) zone 1; (C) zone typified by the earliest appearance of *Batrachopus*-type footprints — corresponds to Olsen and Galtan's (1977) zone 2; (D) zone typified by the earliest appearance of *Anomoepus*-type footprints; it contains all the Jurassic fish zones described in this paper and is associated with extrusive volcanics in the Newark — this and the following zone correspond to Olsen and Galton's (1977) zone 3; (E) zone without redfieldiids and well-defined semionotid zones — this zone is entirely post-extrusive.

available for the Upper Stormberg (Anderson, personal commun., 1979; Anderson and Anderson, 1970) (fig. 17).

Finally, fish occur in the upper part of the Lower Lufeng Series of China. Although at this time, we have been able to examine only fragments (FMNH-CUP 2325, 2323), semionotids and paleonisciforms are present. Of greatest interest is a fragment of a very large fish clearly allied to the *"Semionotus tenuiceps"* group. Associated diverse reptile and mammal remains are very similar to those of the Upper Stormberg (Anderson and Anderson, 1970), and the age of the lower Lufeng is thought to be Early Jurassic, probably Hettangian, on the basis of floral remains (Cui, 1976). While the possible presence of a Chinese member of the *"S. tenuiceps"* group is of great interest, we are not suggesting that the semionotid fish zones defined in eastern North America will be useful for inter-continental correlation.

CONCLUSIONS

Correlation with the Newark Supergroup

The stratigraphic ranges of fish taxa within individual Newark Supergroup basins provide the basis for the informal recognition of five fish zones. These fish zones permit an internal correlation of most Newark Supergroup deposits as follows:

1. The Richmond, Taylorsville, and Scottsburg Basins all contain fish typical of the *Dictyopyge* zone. Correlation by palynomorph assemblages (Cornet, ms) shows that the lowest beds of the Sanford Basin of the Chatham Group correlate with the upper part of the *Dictyopyge* zone, and both are Middle Carnian in age.
2. The Wadesboro, Sanford, and Durham Basins of the Chatham Group contain fishes typical of the *Diplurus newarki* zone as do the Cow Branch Formation of the Dan River Group, the New Oxford Formation of the Gettysburg Basin, and the Lockatong Formation of the Newark Basin. This zone can be further subdivided by the presence or absence of *Turseodus* and the *"Semionotus brauni* group." On the basis of Cornet's (1977) palynomorph data, the upper half (*Turseodus-Semionotus* bearing part) of this zone is Late Carnian and the lower part late Middle Carnian.
3. The Feltville and Towaco Formations of the Newark Basin appear to be correlatives of the Turners Falls Sandstone of the Deerfield Basin as both have produced representatives of the Hettangian (Early Jurassic) *"Semionotus tenuiceps* group."
4. The Shuttle Meadow Formation of the Hartford Basin and the "Midland fish bed" of the Culpeper Basin are of Late Hettangian-Early Sinemurian age and contain the *"Semionotus micropterus* group" zone. This zone and the one succeeding are distinguished by the presence of *Redfieldius* spp.
5. The youngest fish zone presently definable is the Sinemurian *"Semionotus elegans* group" zone which includes the lower part of the Portland Formation of the Hartford Basin, the upper Bonton Formation of the Newark Basin, and from pollen and spore evidence the lower part of the Waterfall Formation of the Culpeper basin (Lindholm, 1980; = post Sander Basalt portions of the Bull Run Formation of Lee, 1980 or the "Haymarket Fish Bed" of Baer and Martin, 1948.
6. Younger Newark rocks (Pliensbachian-Toarcian) have produced a suite of poorly preserved semionotids and other holosteans. Redfieldiids, are absent.

Correlation outside the Newark

The fish zones, defined for the Newark, have little applicability outside the Newark where pollen and spore and tetrapod data provide the chief biostratigraphic foundation for correlation. An exception is that the fish fauna of the Chinle Formation, especially the upper Chinle, bears a remarkably close resemblance to that of the *Diplurus newarki* zone, which substantiates the correlation between the Chinle-Dockum and the *Diplurus newarki* zone based on palynofloras and tetrapods.

Tetrapod and pollen and spore data correlate the *"Semionotus tenuiceps* group" zone (and hence the younger semionotid zones as well) with the European early Jurassic, the Glen Canyon Group of the southwestern United States, the upper Stormberg Group of southern Africa, and the Lower Lufeng of China.

Lithostratigraphy

1. All the coal-bearing-rocks of the Newark occur in the lowest zones: within the *Dictyopyge* and the lower half of the *Diplurus newarki* zones. The upper part of the *Diplurus newarki* zone, where *Turseodus* and *Semionotus brauni* occur, does not contain coal beds.

2. The *"Semionotus tenuiceps* group," *"S. micropterus* group," and *"S. elegans* group" zones are associated with sediments either interbedded with or overlying extrusive basalts. The distribution of fish taxa shows that while all the basalt flows of Newark basins were deposited over a limited interval of time (Hettangian-Sinemurian of the Early Jurassic), individual basalt formations do not correlate between basins in a simple manner. We conclude that the three basalt formations of the Newark and Hartford basins were not the result of synchronous volcanic events as has been widely held.

We feel that some of the correlations proposed in this paper are more tentative than others and may be ranked in order of decreasing reliability as follows: (1) the correlation of all the pre-extrusive sediments and the basin sections that lack extrusives, on the one hand, and of all the syn- and post- extrusive sections, on the other; (2) the correlation of pre-extrusive beds and basin sections lacking extrusives with the European Upper Triassic and of syn- and post-extrusive deposits with the European lower Jurassic, (3) the correlation of individual formations or parts of formations with the European stages of the early Mesozoic, and (4) the detailed correlation of individual formations between basins such as the individual extensive basalts and interbedded sediments of the Newark and Hartford basins (figs. 5, 15, and 16). Tests of these preliminary correlations by comparison with other forms of data, further collecting, and further analysis will determine the value of the assumptions used in the construction of the correlations themselves and will provide insight into the patterns of evolution and biogeography of Mesozoic life.

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APPENDIX

Specimen and locality data for taxa discussed in the text

Abbreviations

AMNH	American Museum of Natural History, New York
ANSP	Academy of Natural Sciences, Philadelphia
CM	Carnegie Museum, Pittsburgh
FMNH	Field Museum of Natural History, Chicago
NMNH	United States National Museum of Natural History, Washington
NSPM	Nova Scotia Museum, Halifax
PU	Princeton University Museum, Princeton
WPMM	William Penn Memorial Museum, Harrisburg
YPM	Peabody Museum, Yale University, New Haven

Fish data

1. Richmond Basin
   - 1.1 Lower Barren Beds

     Dictyopyge macrurus: AMNH 4765, 4766, well preserved skulls, from the Boscobel Quarry, Manakin, Va.; collected by P. Olsen, N. McDonald, and R. Demicco, 1976.

     Cionichthys cf. *C. greeni:* YPM 7121, well preserved skull, and YPM, 7936, complete fish; same locality and collectors as above.
   - 1.2 Productive Coal Measures

     Dictyopyge macrurus: YPM 3207, slab containing about 11 fish including the lectotype from an unknown coal mine in Chesterfield County, Va.; obtained by Sir Charles Lyell, 1845; YPM 8024, fragmentary fish, from the mine dumps of the Old Blackheath Coal Mine, Midlothian, Va.; collected by P. Olsen and A. Litt, 1977.

     Tanaocrossus sp.: AMNH 1427, fragmentary specimen, unknown locality most likely from the Productive Coal Measures (Schaeffer and McDonald, 1978).
   - 1.3 Vinita Shales

     Dictyopyge macrurus: YPM 7802, complete fish, from road cut, south side of Route 6, 0.6 km west of Tuckahoe Creek, Va.
2. Taylorsville Basin (Taylorsville Group, Weems, ms)
   - 2.1 Middle sedimentary unit (Falling Creek Formation of Weems, ms).

     Dictyopyge sp.: NMNH 243984 & 248992, fragmentary fish from south bank of the South Anna River, south of Taylorsville, Va. (Schaeffer and McDonald, 1978; Weems, ms).
3. Scottsburg Basin
   - 3.1 unit about 300 m above base of section present in basin

     Dictyopyge macrurus: YPM 8070, posterior half of fish from Wolf Trap, Va.; collected by P. Olsen and A. Litt, 1977.
4. Chatham Group (Wadesboro Basin)
   - 4.1 Pekin Formation (type Pekin of Campell and Kimball, 1923)

     Synorichthys sp.: YPM 7760, 8534, 8536, isolated skull bones, cut on Route 714, east of Pekin, North Carolina; collected by P. Olsen, R. Salvia, A. Litt, B. Cornet, N. McDonald, R. Demicco, 1975-1977.

     Cionichthys sp.: YPM 8157, isolated skull bones, bed of Woodwards Branch, east of Pekin, North Carolina; collected by P. Olsen and R. Salvia, 1976.

     Diplurus cf. *D. newarki*: YPM 8115; isolated gular, same locality and collectors as above.

     cf. *Carinacanthus*: YPM 8154, isolated dorsal spine, same locality and collectors as YPM 8157 above.
5. Chatham Group (Sanford Basin)
   - 5.1 Cumnock Formation

     Synorichthys sp.: YPM 7902, left frontal, mine dump of Carolina mine, Gulf, North Carolina; collected by P. Olsen and R. Salvia, 1975; YPM 7793, isolated supracleithrum, west side of Deep River at Dam for the old Carbonton Power Plant, Carbonton, North Carolina; collected by P. Olsen and R. Salvia, 1975.

     Cionichthys sp.: YPM 7570, 7904, isolated skull bones, same locality and collectors as YPM 7902 above.

Diplurus cf. *newarki*: YPM 7512, isolated scales from exposures along south side of railroad tracks at Bethany Church, Gulf, North Carolina; collected by P. Olsen and R. Salvia, 1975.

6. Chatham Group (Durham Basin)

   6.1 unnamed siltstone sequence (see Bain and Harvey, 1977)

   Turseodus sp.: YPM 8666, dissarticulated fish from main quarry of Triangle Brick Company, Genlee, North Carolina; collected by P. Olsen and A. Litt, 1977.

   Cionichthys sp.: YPM 8121, cleithrum and scales, same locality and collectors as above.

   Semionotus sp.: YPM 8156, diagnostic scale, same locality and collectors as above.

   Diplurus cf. *D. newarki*: YPM 8557, scales, same locality and collectors as above.

7. Dan River Group

   7.1 lower member of Cow Branch Formation

   Cionichthys sp.: YPM 7911, 8012, 8016, 8017, 8019, isolated skull bones, cut along Southern Railroad south of Walnut Cove, North Carolina; collected by P. Olsen, N. McDonald, A. Litt, 1977-1978.

   Diplurus cf. *D. newarki*: YPM 7910, scales, Cranby Roberts' Quarry, Eden, North Carolina; collected by P. Olsen, A. Litt, 1978.

   7.2 upper member of Cow Branch Formation

   Turseodus sp.: YPM 7475, nearly complete fish, locality CB1-2-E, (see Olsen and others, 1978; Olsen, 1979); collected by P. Olsen and R. Salvia, 1975.

   Synorichthys cf. *S. stewarti*: YPM 7573, nearly complete fish, locality CB1-2-A (see Olsen, 1979); collected by P. Olsen and R. Salvia, 1975.

   Semionotus cf. *S. brauni*: YPM 7901, complete fish, locality CB1-2-D (see Olsen, 1979); collected by P. Olsen and R. Broumbaugh, 1977.

   Diplurus cf. *D. newarki*: YPM 7514, disarticulated fish, 88 m east of overpass for Route 770, on north side of Route 14, Eden, North Carolina; collected by P. Olsen and R. Salvia, 1974.

8. Culpeper Group (Cornet, 1977; Lindholm, ms)

   8.1 "Midland Fish Bed" part of sedimentary unit I-II of Lindholm's (1979) Buckland Formation lower sedimentary unit of Basaltic-Flow-Bearing Clastics Member of the Bull Run Formation of Lee (1977), formation I of Cornet (1977).

   Ptycholepis marshi: NMNH 21289, disarticulated skull from bed of Licking Run, 2 km north of Midland, Va.; collected by S. Applegate, ca. 1955.

   Redfieldius sp.: AMNH 4803, partially dissociated skull, same locality and collector as above.

   "*Semionotus micropterus* group" semionotid: YPM 8608, partial fish, locality as above; collected by B. Cornet, 1975.

   Diplurus cf. *longicaudatus*: NMNH 18475, complete skull, same locality and collector as AMNH 4803 above.

   8.2 "Haymarket Fish Bed" is part of lower Waterfall Formation of Lindholm (1979) the upper sedimentary member of the Basaltic-Flow-Bearing-Clastics Member (above Sander Basalt) of Lee (1977) and (1980) lower part of Cornet's (1977) formation A.

   "*Semionotus elegans* group" semionotid: NMNH 18324, complete fish, road bed of Route 55, 5.6 km west of Haymarket, Va.; collected by W. Parrott and D. Dunkle, 1948.

   Redfieldius cf. *G. gracilis*: YPM 8681, anterior ¾ fish, cut along Catletts Branch, 600 m north of Route 55 near Haymarket, Va.; collected by P. Olsen and R. Upright, 1980.

   Ptycholepis sp.: NMNH 18323, partial fish, locality and collectors as NMNH 18324 (above).

   Diplurus cf. *D. longicaudatus*: YPM 8680, nearly complete very small fish, same locality and collectors as YPM 8681 (above).

   8.3 "Millbrook Quarry Fish Bed" is part of middle or upper Waterfall Formation of Lindholm (1979) the upper sedimentary member of the Basaltic-Flow-Bearing-Clastics Member (above Sander Basalt) of Lee (1977, 1980) formation A of Cornet (1977).

   Indeterminate semionotid; NMNH 54, mass of scales, from the Millbrook Quarry, Thoroughfair Gap, Va.; collector not recorded.

Diplurus cf. *D. longicaudatus*: CM 19053, partial skull, locality as above; collected by P. B. Ruhoff, 1953.

9. Gettysburg Basin
   9.1 upper middle New Oxford Formation
   Turseodus sp.: YPM 7063, 7062, isolated scales and skull bones, cut along small tributary on south side of Little Conewago Creek, near York Haven, Pa.; collected by P. Olsen and R. Upright, 1970.
   Synorichthys sp.: WPMM V 90 to 95, isolated scales and skull bones, south bank of Little Conewago Creek at Zions View, Pa.; collected by D. Hoff, 1970-1971.

10. Newark Basin
   10.1 Lockatong Formation (lower part)
   Carinacanthus jepseni: PU 13739, fish missing skull (the type) from cut along former Reading Railroad between North Wales and Gwynedd Valley Gwynedd, Pa.; collected by G. Jepsen, 1933.
   Turseodus acutus: ANSP 14535, mandible (the type) from cut for former Reading Railroad at the Black Rock Tunnel, Phoenixville, Pa.; collected by C. Wheatly, 1918.
   Synorichthys cf. *S. stewarti*: AMNH 3983, complete fish from the Granton Quarry, North Bergen, N. J.; collected by A. Siefger, about 1965; YPM 8682 (Field number WS550-552), partial fish showing characteristic loss of post-rostral, from King's Bluff, Weehawken, N. J.; collected by K. Thomson, P. Olsen, A. McCune, and others, 1978.
   Cionichthys sp.: ANSP 851, complete fish, type of *Redfieldius obari* Bock (1959), same locality as PU 13739 above; collected by W. Bock, about 1950.
   Semionotus brauni: AMNH 3191 and YPM 6420 (part and counterpart), nearly complete specimen (the type), nearly complete fish from cut along west side of railroad tracks 340 m south of Pennsylvania Railroad Tunnel, Weehawken, N. J.; collected by F. Braun about 1886.
   Diplurus newarki: PU 13695, complete fish (the type), same locality and collector as PU 13739, above.
   10.2 Passaic Formation (lower)
   Synorichthys sp.: YPM 7789 and 7790, skull bones, cut along north side of Raritan River, at Nixon, N. J.; collected by P. Olsen, N. McDonald, R. Demicco, 1977.
   10.3 Feltville Formation
   "*Semionotus tenuiceps* group" semionitid: YPM 7763, complete fish from cut along brook 250 m south of Vosseller Road, Martinsville, N. J.; collected by P. Olsen and R. Salvia, 1975.
   "simple scale group" semionotid: AMNH 675, nearly complete fish from the now covered Field's Copper Mine, Watchung, N. J.; collected by J. Newberry, about 1880.
   Ptycholepis sp.: YPM 6283, scales and skull bones, stream cut just north of Field's Copper Mine, Watchung, N. J.; collected by P. Olsen and A. Lessa, 1972.
   10.4 Towaco Formation
   "*Semionotus tenuiceps* group" semionotid: YPM 8671, anterior half of fish; from member D, loc. Pom. 1; collected by W. C. Redfield, about 1853; YPM Field number 1241, complete fish, loc. as YPM 8671, collected by P. Olsen — A. McCune party (1979).
   10.5 Boonton Formation
   "*Semionotus elegans* group" semionotid: YPM 6567, complete fish from cut along Rockaway River at present site of the dam for the Jersey City Reservoir, Boonton, N. J.; collected by New Jersey Geol. Survey, about 1890.
   Redfieldius cf. *R. gracilis*: YPM 7052, complete fish, same loc. and collector as YPM 6567 above.
   Ptycholepis sp.: YPM 6272, complete fish, same loc. and collector as YPM 6567 above.
   Diplurus longicaudatus: AMNH 630, complete fish (the type), same loc. as above; collected by J. Newberry, about 1880.

11. Pomeraug (Southbury) Basin
   11.1 black and white limestone and siltstone beds, probably between first and second basalt flow units of Pomeraug section.
   Redfieldius sp.: YPM 8673, isolated skull bones and scales, the old "Red

Spring" locality of Hobbs, 1901 — cut along small stream 0.5 km northeast of Rattlesnake Hill, near South Britain, Ct.; collected by J. H. Redfield, about 1870.

Semionotus sp.: YPM 6958, fragmentary fish, small exposure along same stream as YPM 6958 above, about 0.3 km east of South Britain, Ct.; collected by P. Olsen, 1973.

12. Hartford Basin

12.1 Shuttle Meadow Formation

Ptycholepis marshi: AMNH 575, complete fish (the type), small stream cut along west face Totoket Mountain, Durham, Ct.; collected by S. Loper about 1878.

Redfieldius sp.: AMNH 6701, complete fish, bed of small stream below Bluff Head on Totoket Mountain in North Guilford, Ct.; collected by N. McDonald and B. Cornet, 1971.

Semionotus micropterus: AMNH 591, nearly complete fish (the type) from the same loc. and collector as AMNH 575 above.

Diplurus cf. *longicaudatus*: AMNH 627, partial fish, same loc. and collectors as AMNH 575 above.

12.2 East Berlin Formation

cf. "*Semionotus micropterus* group" semionotid: YPM 6713, complete fish, cut along small brook entering southern end of Lake Saltonstall, East Haven, Ct.; collected by C. E. Beecher and G. R. Wieland.

Redfieldius sp.: YPM 7159, complete fish, same loc.. and collectors as YPM 6713 above.

Diplurus cf. *longicaudatus*: NMNH 17095, caudal fin from cut at Westfield Falls, Westfield, Ct.; collected by S. Loper, about 1890.

12.3 lower Portland Formation

Redfieldius gracilis: YPM 3206, complete fish (the type), cut along Laurel Brook, Middlefield, Ct.; collected by W. C. Redfield, about 1860.

"*Semionotus elegans* group" semionotid: YPM 8163, anterior half of fish, loc. and collector as above.

12.4 middle-upper Portland Formation ("Chicopee Fish Bed")

"*Acentrophorus*" *chicopensis*: YPM 6528, complete fish in dorsal view from along the Chicopee River, in Chicopee, Mass.; collected by P. Olsen, 1973.

Indeterminate semionotid: YPM 8045, complete fish, same loc. as above; collected by P. Olsen, N. McDonald, and R. Demicco, 1975.

13. Deerfield Basin

13.1 Turners Falls Sandstone

"*Semionotus tenuiceps* group" semionotid: YPM 8162, complete fish, cut along east bank of Connecticut River at Whitmore's Ferry; collected by W. C. Redfield, about 1860.

"small scale group" semionotid: YPM 6897, fish missing tail; loc. and collector as above.

13.2 Mount Toby Conglomerate

Indeterminate semionotid: YPM 8204, partial fish from exposures along north slope of Mount Toby at the "Sunderland Caves"; collected by P. Olsen, N. McDonald, and B. Cornet, 1977.

14. Fundy Group

14.1 Blomidon Formation

Indeterminate semionotids: NSPM MS 976. 6. 52. 4, fish fragment from a rock fall along Lyons Cove, Kings County, Nova Scotia, Canada; collected by W. Take and E. Colbert, 1962.

14.2 Scots Bay Formation (type area)

Indeterminate semionotids: YPM 7309, 7310, 7524, PU21707, 21798, fragments and partial skulls of several specimens from the cliff exposures, third cove northeast of Ross Creek, Kings County, Nova Scotia; collected by P. Olsen, D. Baird, R. Salvia, 1974-1976.

14.3 McCoy Brook Formation Scots Bay Formation equivalent

Indeterminate semionotid: PU 21706, partial fish from the cliff exposures in Five Islands Provincial Park, Nova Scotia; collected by P. Olsen and D. Baird, 1976.

14.4 North Mountain Basalt interbed (interbed of McKay Head Basalt)

Indeterminate semionotid: YPM 7797, frontal bones and scales, cliff exposures at Wasson's Bluff, Greenhill, Nova Scotia; collected by P. Olsen, A. Litt, and V. Roth, 1977.

hybodont shark: YPM 8665, tooth, same locality as YPM 7797 above; collected by P. Olsen and D. Simanek, 1978.

Reptile data

15. Fundy Basin

15.1 Wolfville Formation (upper). The following forms are also found in the lower Passaic Formation of the Newark Basin (see Baird, 1957).

"Anchisauripus" cf. *A. milfordensis*: PU 21713a, 21808, series of trackways and individual tracks showing characteristic tulip-shaped pes and three toed manus from Paddy's Island, Kings County, Nova Scotia; collected by P. Olsen and D. Baird, 1976.

Rhynchosauroides: PU 21712, 217236; same loc. and collectors as above.

15.2 Blomidon Formation (middle) approximately the same horizon as 14.1 above. The following forms are also found in the middle-upper Passaic Formation of the Newark Basin (see Olsen and Galton, 1977).

Anchisauripus cf. *hitchcocki*: YPM 8664, from Red Head, on north shore of St. Mary's Bay, near Rossway, Digby County, Nova Scotia; collected by P. Olsen and A. Litt, 1978.

Rutiodon carolinensis: YPM 7920, skull anterior to nares and several dorsal scutes; loc. as above; collected by P. Olsen, R. Salvia, and A. Heimlick, 1975.

15.3 Interflow sedimentary unit of North Mountain Basalt (locally called McKay Head Basalt of Klein, 1962).

plateosaurid prosauropod cf. *Ammosaurus*: PU 22196, isolated elements including partial femur, cervical, dorsal, and caudal vertebrae, metatarsals, and ribs; cliff exposures of eolian sandstone at Wassons Bluff, Greenhill, Nova Scotia; collected by P. Olsen, A. Litt, V. Roth, D. Simanek, A. McCune, D. Baird, and J. Horner, 1976-1980.

ornithiscian dinosaur: YPM 8670, tooth from the same loc. as above.

15.4 McCoy Brook Formation (lateral equivalent of Scots Bay Formation).

Anomoepus sp.: YPM 8665, natural casts of left and right pes footprints, shore exposures east of Moose River, near Blue Sac, Nova Scotia; collected by P. Olsen and D. Simanek, 1978.

Otozoum sp.: YPM 8669, polyester resin cast of left pes impression; same loc. and collectors as above.

Anchisauripus sillimani: YPM 8668, natural cast of impressions of right pedes of two individuals, shore exposures at McKay Head (type McCoy Brook Formation); collectors as above.

Batrachopus spp.: YPM 8666, 8667, natural casts of trackways of several individuals, loc. and collectors as above.

Eubrontes sp.: YPM 7769, plaster cast of left pes impression from the shore exposures at Five Islands Provincial Park, Nova Scotia; collected by P. Olsen, V. Roth, and A. Litt, 1977.

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