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OLD RED CONTINENT FACIES IN THE LATE DEVONIAN AND EARLY CARBONIFEROUS OF APPALACHIAN NORTH AMERICA

by

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(5 figures)

ABSTRACT. - Old Red facies sediments deposited in the Appalachian geosyncline represent a nearly continuous record of plant evolution from Early Devonian to Late Pennsylvanian. Sediments from a tectonic upland (Acadian Mountains) were shed westward into a trough paralleling the southwesterly prograding coastal plain. Closure of the Iapetus Ocean and subsequent collision of Laurentia, Baltica, Avalonia, and Africa are thought to be responsible for this Acadian orogeny. Old Red facies of Late Devonian to Early Carboniferous were deposited in New York, Pennsylvania, West Virginia, and Virginia as a continuously south-westward prograding deltaic complex (Catskill Delta) until terminated by a major Late Famennian (Fa2c = mid-upper Conewangoan) transgression. Deposition of sandy alluvium of the Pocono group was initially transgressive, but eventually became regressive as it continued through the Latest Famennian (= Strunian = Fa2d-Tn1a-lower Tn1b = uppermost Conewangoan), Earliest Tournaisian (upper Tn1b-Tn2 = Kinderhookian), and Late Tournaisian (Tn3 = Osagean). Biostratigraphic analysis of plant mega- and micro-fossils is only just beginning, but indicates that the Old Red facies in the Appalachians can be correlated across the Devonian/Mississippian boundary and that continuous sedimentation occurred at this interval in south central Pennsylvania.

RESUME. - Des sédiments à faciès "Old Red" déposés dans le géosynclinal appalachien représentent un enregistrement presque continu de l'évolution des végétaux depuis le début du Dévonien jusqu'au Pennsylvanien tardif. Des sédiments provenant d'une région en surrection (les Monts Acadiens) furent déversés vers l'ouest dans une fosse parallèle à la plaine côtière progradant vers le sud-ouest. La fermeture de l'Océan Iapetus et la collision qui a suivi entre Laurentia, Baltica, Avalonia et Africa sont considérés comme responsables de cet orogène acadien. Des faciès "Old Red" du Dévonien tardif ou Carbonifère ancien ont été déposés, dans les Etats de New York, de Pennsylvanie, de Virginie occidentale et de Virginie, en un complexe deltaïque (Catskill delta) en progradation continue vers le sud-ouest puis en une transgression majeure à la fin du Famennien (Fa2c = Conewango moyen et supérieur). Le dépôt d'alluvions sableuses du groupe de Pocono fut d'abord transgressif mais redevint régressif tout au long du Famennien terminal (= Strunien = Fa2d-Tn1a-Tn1b inférieur = Conewango le plus supérieur), du Tournaisien le plus ancien (Tn1b supérieur - Tn2b = Kinderhook) et du Tournaisien récent (Tn3 = Osage). L'analyse biostratigraphique des macro- et microfossiles végétaux en est seulement à son début mais indique que les faciès "Old Red" dans les Appalaches peuvent être corrélés près de la limite Dévonien-Carbonifère et qu'une sédimentation continue a existé pendant ce temps dans le sud de la Pennsylvanie centrale.

The Acadian orogeny of North America is interpreted as the Mid Paleozoic closure of the Iapetus Ocean with subsequent collision between the Laurentian, Baltican, Avalonian, and eventually African plates (Scotese *et al.,* 1979; Bambach, Scotese & Ziegler, 1980; Oliver, 1980). A thick wedge of Old Red facies sediments was shed to the west in North America from a rapidly uplifted tectonic highland to the east, known as the Acadian Mountains (Allen & Friend, 1968). These sediments were shed into an elongate trough, the Appalachian geosyncline, that paralleled the western slopes of the coastal plain. Sedimentation into this basin began as Acadian events commenced in the Late Silurian and Early Devonian of Quebec, New Brunswick, and Maine and gradually progressed southwesterly so that the Old Red facies of Virginia are Latest Devonian and Earliest Carboniferous (Oliver, 1980).

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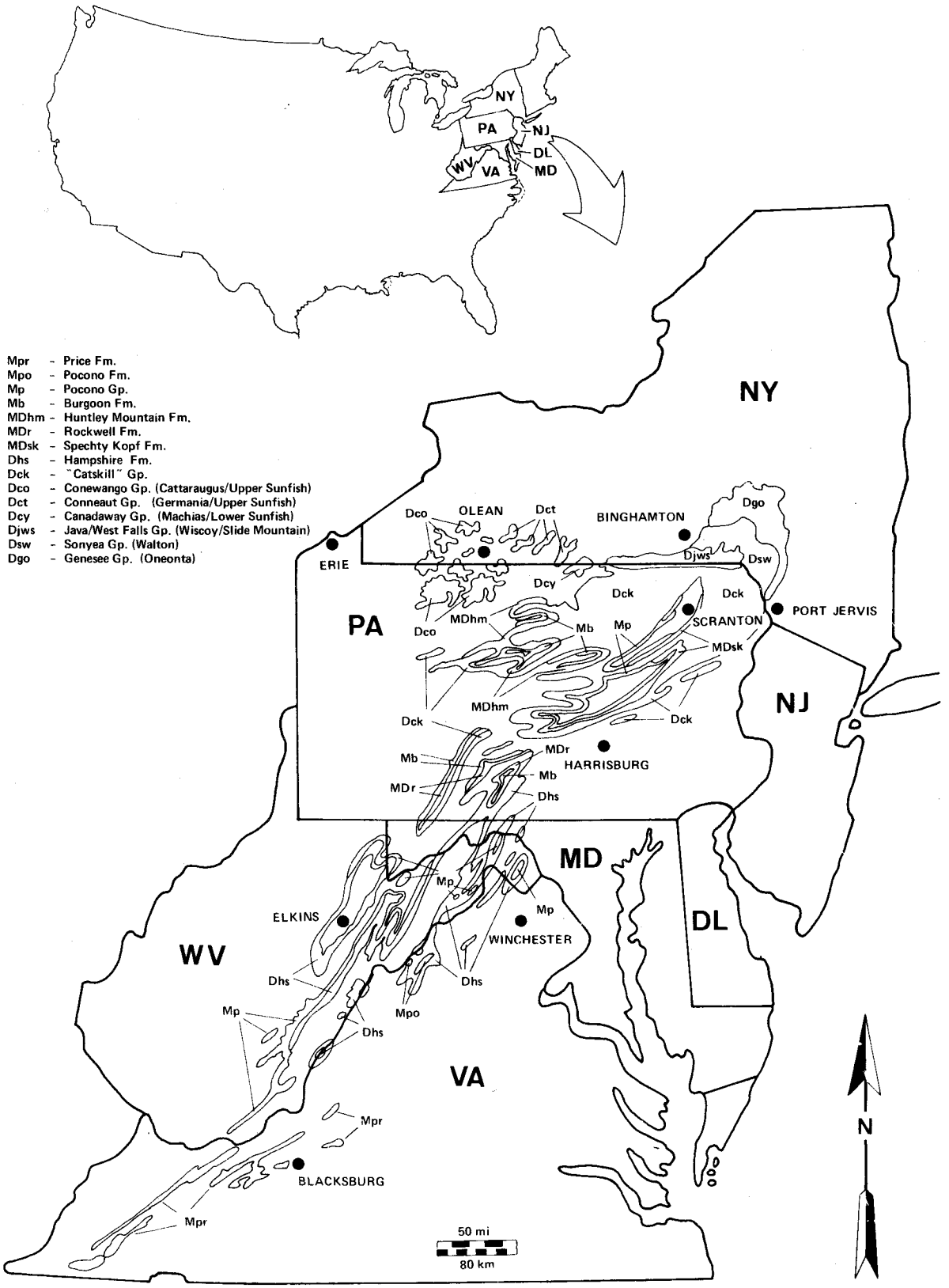


Figure 1. - Outcrops of Late Devonian and Early Carboniferous Old Red coastal plain facies in the central Appalachians of North America NY. New York; PA. Pennsylvania; NJ. New Jersey; MD. Maryland; DL. Delaware; WV. West Virginia; VA. Virginia. Data compiled from Fisher *et al.* (1962), Berg *et al.* (1980), Calver *et al.* (1963) and Price *et al.* (1968).

As Acadian events continued during the Devonian the coastal plain, located in Quebec, New Brunswick, and Maine in Early Devonian, migrated southwestward over earlier marine deposits. By the time that the coastal plain reached New York and Pennsylvania in the Late Devonian, the Old Red facies of Quebec, New Brunswick and Maine were deposited in numerous small and discontinuous, intermontane basins (Schluger, 1971; Woodrow, Fletcher & Ahrnsbrok, 1973). Correlation of these Late Devonian intermontane basins with the coastal plain sediments of New York and Pennsylvania is made difficult by the lack of direct continuity with the adjacent marine sections or with the more southern terrestrial sections. Nor are the mega- and micro-fossil plant assemblages well enough known for any degree of precision in their correlations. Therefore, the analysis here will concentrate on the Late Devonian and Early Carboniferous coastal plain sediments of the central Appalachians where lateral correlation with adjacent marine and terrestrial sections is better documented (fig. 1).

SEDIMENTARY HISTORY

The Appalachian basin is the only place in North America that has continuous terrestrial sedimentation across the Devonian/Mississippian (in south central Pennsylvania) and Mississippian/Pennsylvanian boundaries (in southern West Virginia). This basin extends both in time and place throughout most of the early history of plant life on land and is, therefore, an area of great interest to paleobotanists.

Coastal plain and deltaic sedimentation began in Maritime Canada in Early Devonian (Siegenian). As a result of continued mountain uplift to the northeast, vast, relatively flat coastal and deltaic plains were prograded to the southwest. Continued uplift in Mid and Late Devonian shifted the coastal plain into New York and Pennsylvania where the great thickness of Old Red facies (3,000-4,000 m = 9,300-12,400 ft) is called the Catskill Delta. Earlier, the sediment sources and paleocurrent directions were mostly from the northeast. But beginning in Late Devonian and becoming more important in the Carboniferous, was a new sediment source from the southeast. This new sediment is variously interpreted as arising from late Acadian events involving the collision of Laurentia with the southernmost fringe of Baltica or Avalonia (Scotese *et al.*, 1979; Bambach *et al.*, 1980) or from collision with the leading edges of the African plate (Edmunds *et al.*, 1979; Oliver, 1980).

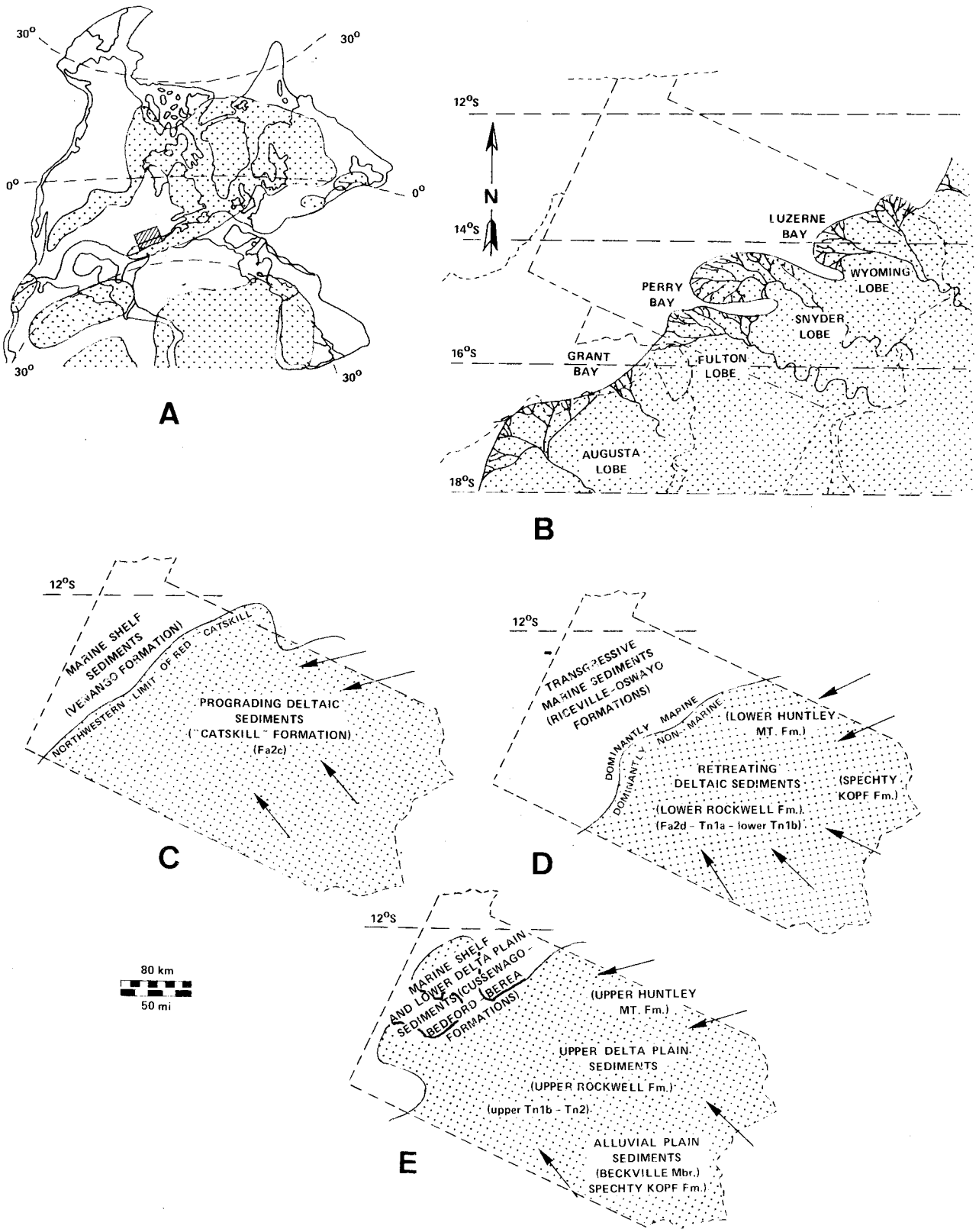
Numerous terrestrial facies are represented in the Late Devonian Catskill Delta ranging from uplands characterized by braided streams and coalesced alluvial fans to lowland interfluves and floodplains cut by meandering streams and dotted with small ponds to the deltaic interfingerings with nearshore marine beds.

Throughout the Late Devonian of New York, Pennsylvania, and West Virginia, the general vertical sequence of beds is nearshore marine overlain by sandy to muddy shore deposits and then by tidal flat and coastal plain sediments as the deltas prograded southwestward. Since the major sources of sediment through this time were from the northeast, the beds in New York are generally coarser than either their facies or time equivalents in Pennsylvania and West Virginia. A southwesterly longshore current (McGhee & Sutton, 1981), however, may have enhanced the accumulation of finer sediments in the more southerly areas.

Frasnian and Famennian are marked by numerous small episodes of transgression and regression which are interpreted (Dennison & Head, 1975) as evidence for small-scale sea level changes. The Catskill deltaic complex achieved its maximum westward progradation during Late Famennian (early Conewangoan), but near the end of Famennian a much larger transgression interupted terrestrial sedimentation in its western portions (Edmunds *et al.*, 1979). During this time and in the succeeding regression (Fig. 2) the gray sands of the Pocono Group were deposited on the upper surface of the Late Devonian Catskill Delta.

As westerly progradation resumed in Latest Famennian (Strunian) and Earliest Tournaisian, the Pocono sands were in many areas disconformably deposited upon the eroded Late Devonian surface. During Early Mississippian (Kinderhook - Early Tournaisian), some westward progradation took place, but in general a stable coastal plain was established in central Pennsylvania (Fig. 2E) dominated by delta lobe development and switching. In the succeeding upper Lower Mississippian (Osage) there was a westward extension of the elongate anastomosing alluvial sand plain (Burgoon) in Pennsylvania and West Virginia and the formation of a barrier protected, deltaic complex in southwestern Virginia from sediments derived mainly from the southeast (Kreisa & Bambach, 1973). Lower Upper Mississippian (Meramec) time saw mild epeirogenic uplift across northwestern Pennsylvania and adjacent New York that ended deposition in that area and that eroded some of the Burgoon equivalents and older rocks. In southeastern Pennsylvania strong sediment influx initiated red bed deposition of the Mauch Chunk delta (Edmunds *et al.*, 1979) that prograded northwestward. To the southwest of Pennsylvania a shallow, restricted embayment extended into this area and deposited lateral equivalents of the Greenbrier limestones (e.g., Loyalhanna) that are sometimes thought to be older than the more western occurrences (Fig. 3-4).

Simultaneous with the epeirogenic uplift in northwest Pennsylvania, there was a downwarping of the flat Price delta so that tidal flat redbeds of the Maccrady transgressed over the former Price surface. Maccrady is predominantly Meramecian, but may include some latest Osagean in the southwest. Near the end of Meramecian time the Maccrady tidal flats were


30°
30°
0°
0°
30°
30°
A
12°S
N
14°S
LUZERNE BAY
WYOMING LOBE
PERRY BAY
SNYDER LOBE
16°S
GRANT BAY
FULTON LOBE
AUGUSTA LOBE
18°S
B
12°S
MARINE SHELF SEDIMENTS (VENANGO FORMATION)
NORTHWESTERN LIMIT OF RED CATSKILL
PROGRADING DELTAIC SEDIMENTS ("CATSKILL" FORMATION) (Fa2c)
C
12°S
TRANSGRESSIVE MARINE SEDIMENTS (RICEVILLE-OSWAYO FORMATIONS)
DOMINANTLY MARINE
DOMINANTLY NON-MARINE
(LOWER HUNTLEY MT. Fm.)
RETREATING DELTAIC SEDIMENTS
(SPECHTY KOPF Fm.)
(LOWER ROCKWELL Fm.)
(Fa2d - Tn1a - lower Tn1b)
D
12°S
MARINE SHELF AND LOWER DELTA PLAIN SEDIMENTS (CUSSEWAGO - BEDFORD - BEREA FORMATIONS)
(UPPER HUNTLEY MT. Fm.)
UPPER DELTA PLAIN SEDIMENTS
(UPPER ROCKWELL Fm.)
(upper Tn1b - Tn2)
ALLUVIAL PLAIN SEDIMENTS
(BECKVILLE Mbr.)
SPECHTY KOPF Fm.)
E
80 km
50 mi

sufficiently drowned (Edmunds *et al.*, 1979) to receive the first units of the Greenbrier limestones (Fig. 3). In Virginia and West Virginia, Early Chester is taken up entirely by Greenbrier limestones. But by Late Chester the continuing uplift begun earlier in the Meramecian of northwest Pennsylvania began to yield a series of mild regressions as shore/deltaic conditions led to marine/non-marine interfingerings of the Bluefield, Hinton, Princeton, and Bluestone formations (Fig. 3). The Bluestone and its Mauch Chunk equivalent in Pennsylvania were themselves overrun from the southeast by coarse alluvial clastics of the Pottsville (basal Pennsylvanian).

STRUCTURAL GEOLOGY

The Appalachian basin was filled under relatively stable conditions and contains in the Late Devonian and Early Carboniferous little of the penecontemporaneous folding, rifting, and volcanic intrusions or exhalations that characterize many of the contemporaneous Old Red beds of Great Britain (Allen, 1979). Some tectonic movement along a Precambrian basement fault zone (38th parallel lineament) occurred periodically throughout the Phanerozoic (Yeilding *et al.*, 1985). To the east some Devonian volcanics occur and to the west local thinning, truncation, and facies changes, suggesting minor upwarps or folding, occur in the late Devonian and Mississippian beds with a maximum of tectonic activity in the middle Mississippian (Meramecian : Yeilding *et al.*, 1985).

More extensive collisions of the African plate with eastern Laurentia resulted in the Alleghenian orogeny of Latest Carboniferous, Permian, and Triassic. This event uplifted and terminated the Appalachian geosyncline as a sedimentary basin and folded and deformed many of the beds. This folding is most severe in the Valley and Ridge province of south central to southeastern Pennsylvania and eastern West Virginia and western Virginia and is accompanied by numerous low angle thrust faults. Farther southwest in Virginia, west in West Virginia and northwest in Pennsylvania, the beds are much less deformed. In New York and adjacent northern Pennsylvania, the beds are much less deformed. In New York and adjacent northern Pennsylvania, the rocks west of Port Jervis (Fig. 1) are generally undeformed.

STRATIGRAPHIC CORRELATIONS

These are shown in Fig. 3 and 4 which attempt (Fig. 3) to correlate the Old Red facies of the progressively southwestward prograding deltaic systems of New York, Pennsylvania, West Virginia, and Virginia and (Fig. 4) to correlate a portion of the Pennsylvania Old Red facies, where terrestrial deposition was continuous in Latest Devonian and Earliest Mississippian, with the marine equivalents which are well dated in New York and Ohio.

Present biostratigraphic zonation and correlation of these Old Red facies is still tentative and incomplete. Few palynological studies like that of Streel & Traverse (1978) have been published for the relevant strata. Plant megafossil zonation is useful, but lacks the precision that we might hope for. Nearshore bivalves and brachiopods are only of broad value for biostratigraphy since the varying ecology of this environment produces quite different community assemblages of relatively persistent organisms (e.g., McGhee & Sutton, 1981). Conodont, foraminifera, and ammonoid stratigraphy of the more westerly basinal facies is yieiding promising results (Manger & Saunders, 1982; Thompson, 1984; Sutherland & Manger, 1984), but the problem here is correlation of the western units with the eastern terrestrial beds.

In New York, where the Old Red facies beds are undeformed, specific wedges of terrestrial deposits can be correlated with nearby datable marine units (e.g., Slide Mt., Mansfield, Wiscoy, and Hannover shale of the latest Frasnian Java Group) (Rickard, 1975; Mc Ghee & Sutton, 1981) by following lateral contacts above and below "marker" beds of black shale (Pipe Creek at Base and Dunkirk at top of Java Group). Unfortunately, the prograding delta front passed beyond New York into central Pennsylvania and adjacent West Virginia and Virginia (Fig. 1) by the latest Famennian and earliest Tournaisian and this interval is a vast erosional disconformity in New York and eastern Pennsylvania (Fig. 3).

Figure 2. - Paleogeographic reconstructions of the Old Red Continent and portions of the central Appalachians during Late Devonian and Early Carboniferous.

A. Laurentia, Baltica, Avalonia, and Africa shown in proximity to the Old Red and other land areas (shaded). Study area shown by the lined rectangle. Modified from Scotese *et al* (1979), Heckel & Witzke (1979), Bambach *et al.* (1980), and McGhee & Sutton (1981).

B. Early Famennian reconstruction of a portion of the shore and coastal plain of New York, Pennsylvania, Maryland, West Virginia and Virginia. Data modified from Willard (1934, 1939), Dennison & de Witt (1972), and McGree and Sutton (1981).

C, D, E. Reconstructions of a portion of the shoreline and coastal plain of Pennsylvania during Late Famennian to Early Tournaisian. Modified from Edmunds *et al.* (1979).

C. Maximum extent of the Catskill deltaic complex in Late Famennian (Fa2c).

D. Major transgression during Latest Famennian (Fa2d-Tn1a-lower Tn1b).

E. Regression which by Early Tournaisian (upper Tn1b-Tn2) had achieved a stable coastline with active delta building and switching.

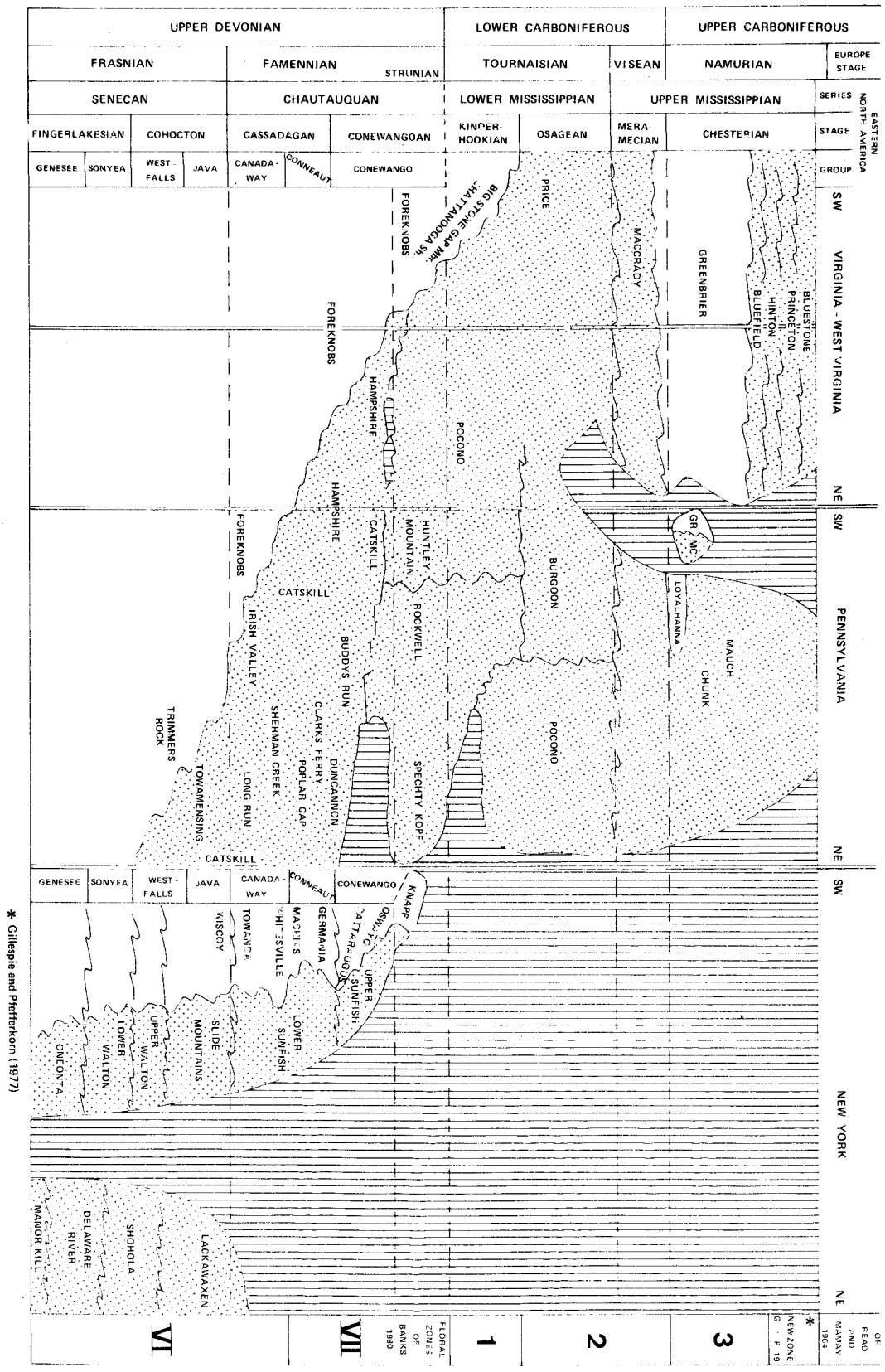


Figure 3. - Stratigraphic correlations of the Old Red facies (shaded) of Late Devonian and Early Carboniferous along a line parallel to the main southwestern progradation of the Catskill delta (parallel to a line drawn from Binghamton, NY to Blacksburg, VA as in Fig. 1). Data primarily from Rickard (1975), Berg *et al.* (1983), and Price *et al.* (1968), with modifications from Arkle *et al.* (1979), Englund (1979), Englund & Henry (1984), Edmunds *et al.* (1979), Oliver *et al.* (1968, 1969).
Vertical lines indicate non-deposition or erosion.

The strata in southern Pennsylvania have been highly deformed by the Alleghenian orogeny. The Famennian terrestrial and nearshore beds are defined entirely by lithology with only limited attempts to correlate these with the better dated more westerly marine beds. The latter are far away in the undeformed northwestern part of the state and fossils are few and not much studied.

The wedge of Old Red sediments that enclose an essentially complete record of the Late Frasnian and entire Famennian (formerly the Catskill formation) is now subdivided into numerous members based on facies (Walker, 1971; Walker & Harms, 1971; Glaeser, 1974). These may maintain their relative positions as the Catskill delta prograded to the southwest in the Late Devonian, but they become progressively younger as the beds are traced south or west and they eventually lose their distinctness as they are replaced by western equivalents (Fig. 3-4). The Hampshire formation of southwest Pennsylvania, West Virginia and Virginia is the youngest continuation of the prograding Catskill deltaic system. These beds were formerly called "Catskill" also, but were renamed Hampshire (see Reger, 1931) in recognition of their younger age. These relations are shown in Figure 1, 3-4.

The sharp transgression/regression that is marked by the sandy Pocono group provides one of the very few correlatable series of beds in this Late Devonian-Mississippian sequence. The lowest Pocono sands in the east have long been correlated with the transgressive Oswayo formation and they are now known to carry a similar Late Famennian spore flora (Fa2c-Fa2d; Streel & Traverse, 1978; Gillespie, Rothwell & Scheckler, 1981). Similarly, the long established correlation of the Berea sandstone (Fig. 4) with the higher Lower Pocono beds is confirmed by spore analyses that indicate they carry a Latest Famennian (Fa2d-Tn1a-lower Tn1b) flora (Eames, 1974; Streel & Traverse, 1978). The overall relations of the various portions of the Old Red prograding deltaic system (Fig. 3) are thus in reasonable accord. The problem comes in attempting to correlate them more precisely with the European sequence or with the adjacent marine sections.

Figure 4 shows the attempted correlation of the marine and non-marine beds in Pennsylvania. The marine beds are correlated with the more fossiliferous ones in New York and Ohio which are securely dated by their faunas and a few palynological studies (Eames, 1974). This figure is modified from that of Berg *et al.* (1983) by raising the Conewangoan to include the Berea sandstone and its easterly equivalents and by restricting the Kinderhookian to the Cuyahoga Group and Shenango formation and their lateral equivalents. This follows the palynological report of Eames (1974), which indicates a Late Devonian age for the Cleveland, Bedford, and Berea and an Early Mississippian age for the overlying Cuyahoga Group and is in agreement with the observations of Streel & Traverse (1978) and McGregor (1979) on the distribution of the *lepidophytus* spore zone. Figure 3 is similarly adjusted. This has the effect of bringing the Devonian-Mississippian boundary in Appalachian North America into closer accord with the paleontological evidence.

Except for the Berea and Oswayo equivalents of the Pocono, correlation of these northwestern marine units into the southeastern Old Red facies is difficult (Fig. 4) and relies greatly on general lithological similarities. The southeasternmost strata are based entirely on facies that are indisputably time-transgressive.

TRANSGRESSIONS AND REGRESSIONS

Numerous small transgressions and regressions occur throughout the Late Devonian (Dennison & Head, 1975). These are thought to indicate widespread eustatic changes in sea level that provide useful stratigraphic markers. Beginning in the mid Conewangoan (Late Famennian Fa2c) when the southwest progradation of the Catskill delta was at its maximum (Fig. 2C), a major, relatively abrupt and widespread transgression terminated the Catskill deltaic complex, overrunning its upper surface by 80-160 km (50-100 mi) and deposited the Riceville and Oswayo formations (Fig. 3-4) of Pennsylvania and New York (Edmunds *et al.*, 1979). The relatively abrupt onset and vast extent of this transgression would have required a land/sea level adjustment of 16-110 m (50-350 ft) since the paleogeomorphology of the Catskill coastal plain was one of very minor relief (Woodrow *et al.*, 1973), judged by the morphology and petrology of stream deposits, with a surface slope of between 0.2-0.7 m per km (1-3 ft per mile). Initiation of the transgression is dated as Fa2c at the Hampshire/Pocono contact near Elkins, West Virginia, the distalmost edge of the delta system, near the Hampshire/Pocono contact at Valley Head, West Virginia, and at the basal Pocono of Altoona, Pennsylvania, on the upland alluvial plain (Streel & Traverse, 1978; Clendening, Eames & Wood, 1980; Gillespie, Rothwell & Scheckler, 1981; Gillespie, pers. com. 1980). No explanation for this dramatic transgression can be found in the Appalachians themselves, but it may be related to some northward movement of Laurentia toward the paleoequator (Bambach *et al.*, 1980) and melting of glaciers in nearby orogenic highlands to the east (Sevon, 1969; Woodrow *et al.*, 1973). One effect of this transgression was the loss of most of the typical Catskill characteristics, especially the red colors of the older terrestrial rocks (Edmunds *et al.*, 1979) in the non-marine lower Pocono members.

Although major, the transgression was short lived. By Latest Famennian (Strunian : Fa2d-Tn1a-lower Tn1b) delta building has resumed (Fig. 2D) so that by Earliest Tournaisian (upper Tn1b-Tn2 : Kinderhook) a stable shore, dominated by delta switching (Fig. 2E), was established in Pennsylvania where Upper Rockwell

and Upper Huntley Mt. formations developed on the sandy alluvial and upper delta plain (Streel & Traverse, 1978; Edmunds *et al.*, 1979). That this regression was diachronitic is documented by the sequence of arrival of deltaic and coastal plain sediments of Upper Pocono (Tn2) in Pennsylvania and of Price (Tn3) in Virginia. A similar short term transgressive pulse followed by a diachronitic regression is recorded for the Belgian Fa2c to Fa2d-Tn1a-lower Tn1b interval which suggests the possibility of intercontinental correlation. This requires further exploration in the Appalachians, however.

PALEOGEOGRAPHY AND PALEOCLIMATE

The Old Red Continent is reconstructed to various shapes and dispositions, but generally conforms to something like Figure 2A. The topography of the Appala-

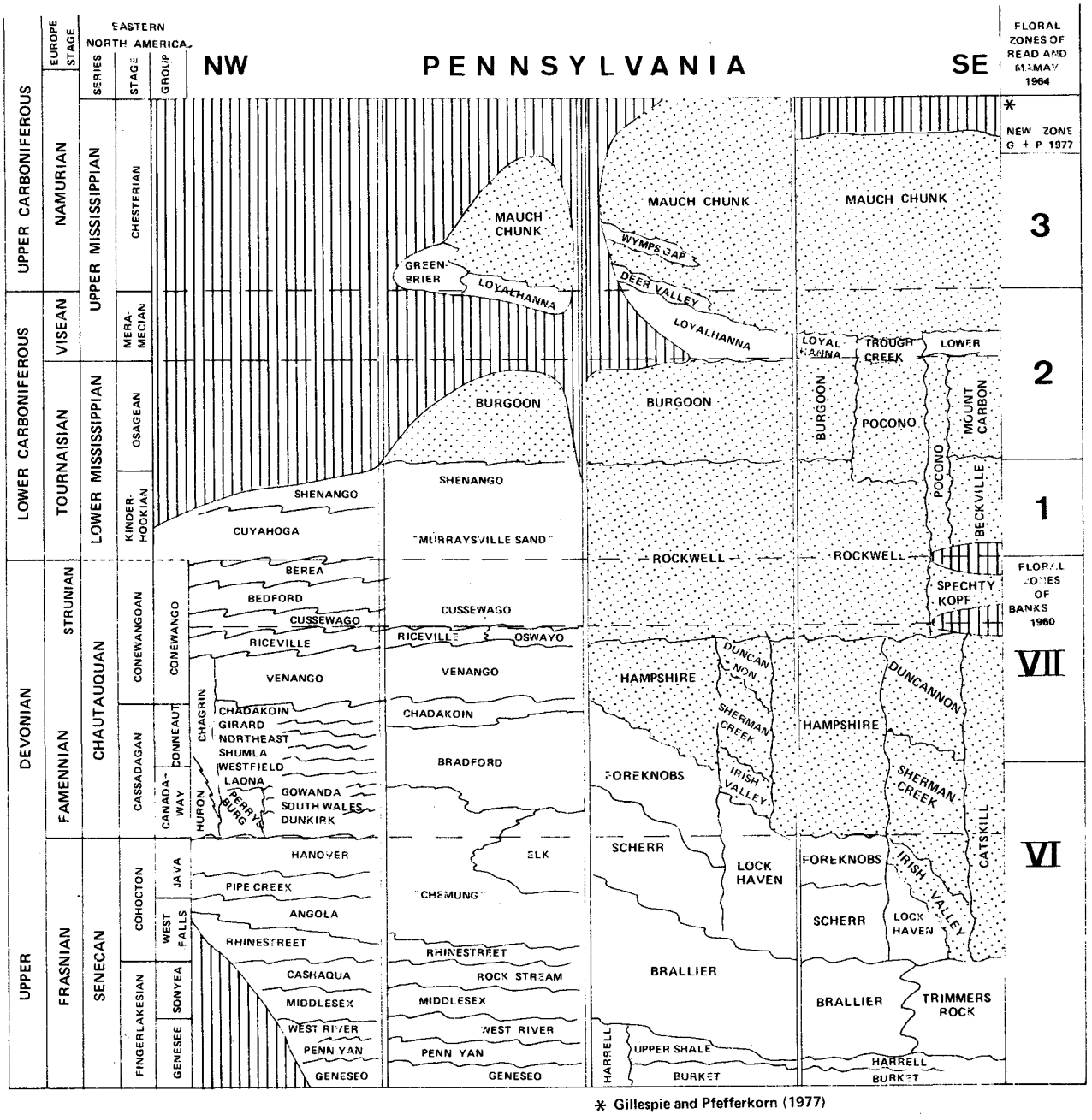


Figure 4. - Stratigraphic correlations of the Old Red facies (shaded) of Late Devonian and Early Carboniferous of Pennsylvania along a line perpendicular to the shore (from Harrisburgh to Erie, PA, Fig. 1).
Data from Berg *et al.* (1983). Vertical lines indicate non-deposition or erosion.

chian coastal plain is concluded to have been rather flat, based upon stream bed loads and sinuosity of meanders (Woodrow *et al.*, 1973). The generalized shoreline is often reconstructed as a muddy, indistinct one of low slope (Woodrow & Fletcher, 1968; Allen & Friend, 1968; Sutton *et al.*, 1970; Walker, 1971, 1972; Walker & Harms, 1971) without sandy barrier bars or shoals except for the Frasnian of New York (Allen & Friend (1968).

On a more local scale, in the Frasnian and early Famennian a number of river systems and delta lobes (Fig. 2B) have been identified (Willard, 1934, 1939; Dennison & de Witt, 1972; McGhee & Sutton, 1981). However this morphology changed quite rapidly as the Latest Devonian/Earliest Carboniferous transgression and regression occurred (Fig. 2C-E).

The aerial extent of the coastal plain fluctuated through time but at its maximum in Late Famennian (Fig. 2C) probably extended no more than 100-150 km (ca. 125 mi) northwest from its easternmost outcrops near Port Jervis, New York (Fig. 1; Woodrow *et al.*, 1973). The western shoreline is easily perceived, but the eastern edge of the coastal plain is not certain. Petrology of Catskill sandstones along the eastern outcrops suggests that they were derived from source rocks located within a few km or tens of km of the present exposures (Allen & Friend, 1968; Woodrow *et al.*, 1973).

Streams are mostly meandering and not particularly numerous. Few, if any, major streams have been located. The interfluves of some lowland areas have calcareous accumulations (calcrete ?) that suggest this surface was stable for long periods of time (ca. 5,000-50,000 years; Woodrow *et al.*, 1973). Lowland topography is estimated to have been flat with a surface of fine sediments and a slope of no more than 0.2-0.7 m/km (1-3 ft:mi). Upland topography is more varied with braided streams, shorter lived interfluves (less than 5,000 years) and coarse-grained surface materials. Surface slopes are thought to be only slightly greater than those of the lowland coastal plain and elevations at the upland boundary of the coastal plain probably did not exceed 200 m (600 ft) and were usually less than 100 m (300 ft) (Woodrow *et al.*, 1973).

Paleoclimate is partly deduced from the continental reconstructions which place this area of the Appalachians at about 10-20° south of the equator (Fig. 2A). Study of evaporites, paleosols, calcretes, trace fossils of aestivating dipnoan fishes, and the structures of stream and floodplain deposits all lead to the conclusions that during the Late Devonian and Earliest Carboniferous the Appalachian region of the Old Red Continent was an area characterized by a hot climate with an annual precipitation of circa 75 cm (30 in), but with a distinct wet season/dry season rainfall pattern (Woodrow *et al.*, 1973). Allen (1979) has made similar conclusions for the Old Red Continent of Great Britain. The occurrence of *in situ* coal beds in the Late Famennian of West Virginia and Virginia (Fig. 5A; Scheckler, 1986) and in the Late Tournaisian of Virginia (Fig. 5B; Scheckler & Beeler, in prep.) suggests that at least some local areas had high enough water tables to prevent the oxidation of peats so that, after burial, they could be preserved as coal.

PLANT MEGA- AND MICRO-FOSSIL BIOSTRATIGRAPHY OF APPALACHIAN LATE DEVONIAN AND EARLY CARBONIFEROUS

Through the activities of many individuals we have a reasonable understanding of the megafossil assemblages of the Late Devonian and Early Carboniferous of Appalachian North America. In particular the Late Famennian Hampshire formation of West Virginia and Virginia is well known (Kräusel & Weyland, 1941; Andrews & Phillips, 1968; Phillips, Andrews & Gensel, 1972; Gillespie *et al.*, 1981; Scheckler, this volume). Beds of equivalent age in Pennsylvania have been virtually unsampled except by Arnold (e.g., 1939). Similarly, the Earliest Carboniferous Pocono and Price formations of Pennsylvania, Maryland, West Virginia and Virginia are well known through the work of Read (1955). Additions to the Price flora have more recently been made (Gensel, 1973; Jennings, 1975; Gensel and Skog, 1977; Skog & Gensel, 1980; Scheckler, 1984; Scheckler & Beeler, 1984; Scheckler & Jennings, in press).

Our understanding of the significance of these plant assemblages has been greatly aided by the descriptions of floral zones for the Appalachian Carboniferous by Read & Mamay (1964) and by Banks (1980) for worldwide Devonian correlations and by Wagner (1984) who has attempted to correlate the Carboniferous coal basins of Europe and North America. These attempts are only starting points that will be modified as more information on plant distributions, their geological circumstances, and microfossil associates accumulate.

Banks subdivided the Late Devonian into two floral zones, his VI in which *Archaeopteris* first appears and VII in which *Rhacophyton* first appears. As a general scheme this is quite adequate. For finer subdivision, however, one must look at the plant assemblages more carefully. Banks' floral zone VI begins with the first appearance of indisputable *Archaeopteris* in basal Frasnian. This plant is rare in basal Frasnian, though, where aneurophytalean progymnosperms, fern like plants with cladoxylalean anatomy, and herbaceous lycopods are more common. These latter taxa, however, were also common in the preceding Givetian. *Archaeopteris* has its last appearance at the end of Banks' floral zone VII during which it often codominated with *Rhacophyton*. Floral zone VI thus is also defined by the absence of *Rhacophyton* and extends from basal Frasnian to about the Famennian 1-2 bound-

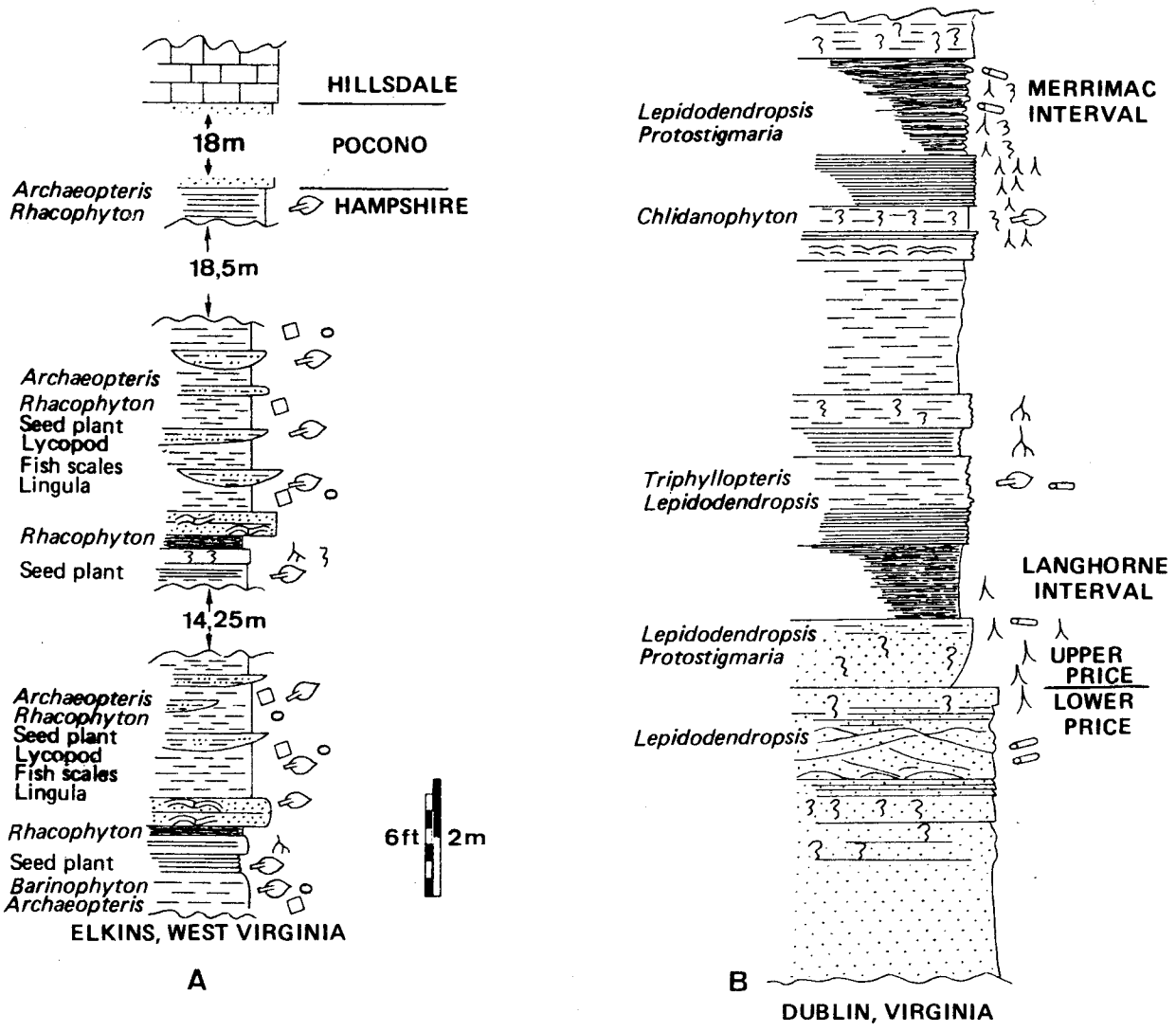


Figure 5. - Geological cross sections from Late Devonian (A) and Early Carboniferous (B) outcrops in the central Appalachians.
A. Outcrop of Hampshire formation from near Elkins, West Virginia representing the pre-transgression Catskill sediments of Fa2c. Data from Gillespie *et al.* (1981) and Scheckler (this volume).
B. Outcrop of Price formation from near Dublin, Virginia representing the post-regression Pocono sediments of Tn3. Data from Scheckler & Beeler (in prep.).

ary where *Rhacophyton* first appears. Banks' (1966) floral list and my own observations suggest that floral zone VI could be further subdivided since the aneurophytes and herbaceous lycopods become scarce and disappear near the Sonyea/West Falls Group boundary (Fig. 3) so that the rest of this floral zone is occupied almost entirely by *Archaeopteris* and tree lycopods.

Similarly, floral zone VII, characterized throughout by *Rhacophyton* (or its near equivalent *Cephalopteris*) and *Archaeopteris,* shows the introduction of new tree lycopods (especially *Cyclostigma*) near the beginning of Tn1a. When floras of this age are better known, the possibility exists for further resolution of Banks' two Late Devonian floral zones into four with durations more comparable to those of the Carboniferous. One must be careful, however, because local ecology or taphonomy can drastically alter floral composition. There are now several floras of Fa2d-Tn1a-lower Tn1b span (the upper floral zone VII of Banks) that are dominated by early seed plants (which first appear in lower floral zone VII) and that have little or no *Rhacophyton, Archaeopteris,* or *Cyclostigma,* such as the Baggy Beds of England, Taff Gorge of Wales, and Kerry Head and Ballyheigue of Ireland (Arber & Goode, 1915; Rogers, 1926; Gayer, Allen, Bassett & Edwards, 1973; Bridge, Van Veen & Matten, 1980; May & Matten, 1983).

The Carboniferous floral zones of Read & Mamay (1964) have also proved to have great utility. They have recently been revised in part by Gillespie & Pfefferkorn (1977, 1979) and Wagner (1984) and improved by descriptions of floral ranges by Jennings (1984) and of microfossil assemblages at the base of the sequence (Streel & Traverse, 1978).

The Pocono/Price flora of Read (1955) and its subsequent division into floral zones 1 and 2 by Read and Mamay is of special concern here. The Pocono

group was deposited during the initial phases of the major transgression that marked the end of Famennian time in the Appalachians and lasted throughout the period of slow westward progradation during Latest Famennian and Earliest Tournaisian time and into the active deltaic complexes of Latest Tournaisian (Fig. 3) in southwest Virginia.

Floral zone 1 is characterized by *Adiantites, Alcicornepteris, Rhodeopteridium* and *Lagenospermum* and a few other plants. The latter two also occur in floral zone 2. The *Rhacopteris* reported by Read (1955) and Read and Mamay (1964), a plant more characteristic of uppermost floral zone 2 of Britain where *Triphyllopteris* is absent, is almost certainly a misidentified *Archaeopteris* that was collected just once from a horizon in the lowermost Pocono of Horseshoe Curve, Altoona, Pennsylvania that has a spore flora (Streel & Traverse, 1978) equivalent to the upper part of Banks' floral zone VII where it is to be expected.

Floral zone 2 is characterized by *Triphyllopteris, Rhodeopteridium, Neurocardiopteris* and *Lepidodendropsis.* Many other plants also occur in floral zone 2, but they have local distributions apparently reflecting their original ecology (Scheckler & Jennings, in press) or are too scarce for general use.

Streel & Traverse (1978) analyzed the spore assemblages of 5 samples coming from the Lower sandstone member, just above at the base of the Middle sandstone member, and farther above in the middle of the Middle member of the Pocono formation at Horseshoe Curve, Altoona, Pennsylvania. Here the Pocono lies directly upon "Catskill red beds" of presumed Late Famennian age and the Middle member is overlain by the Burgoon member of the Upper Pocono. They found spore assemblages that indicated an age of Late Famennian (Fa2c) for the Lower member, Latest Famennian (Strunian : Fa2d-Tn1a-lower Tn1b) for the lower and mid levels of the Middle member and Early Tournaisian (upper Tn1b-Tn2) for the upper part of the Middle member. The "*Rhacopteris*" (= *Archaeopteris*) of Read (1955) came from the lower Late Famennian parts of the section and the first accurately dated *Adiantites* came from the Early Tournaisian part of the section. The excellent descriptions of localities, sections, and floras of Read (1955) show that his *Adiantites* flora occurs only in the Lower Pocono (Upper Rockwell and Upper Huntley Mtn.) and only in Pennsylvania while the *Triphyllopteris* floras occur only in the Upper Pocono (Burgoon and equivalents) of Pennsylvania and West Virginia and the Price of Virginia.

Although floral zone 2 in Europe (Wagner, 1984) does not contain *Triphyllopteris* in its upper part, the Appalachian beds assigned to this zone always have this plant and *Lepidodendropsis.* Both of these taxa occur throughout the Upper Price and into the overlying Maccrady. The known ranges of these mega- and micro-fossil assemblages (Streel & Traverse, 1978; Wagner, 1984) support the interpretation that the Appalachian Kinderhook (floral zone 1) is equivalent to upper Tn1b-Tn2 and that the Osage (lower part of floral zone 2) is Tn3. The Pocono/Price, therefore, contains beds of Late Famennian (Fa2c) to Late Tournaisian (Tn3), which spans the Devonian-Mississippian boundary, but can be subdivided by megafossil plant assemblages into Upper Conewangoan, Kinderhookian and Osagean.

The resolution of the Devonian-Mississippian boundary in the Old Red facies of North America lies in continued study of the 3,550 m (11,000 ft) of Famennian and Tournaisian "Catskill" and "Pocono" beds along the Lehigh and Susquahanna Rivers of Pennsylvania using spore assemblages for correlation with the European marine sequence and megafossil plants for widespread correlation of units within these Old Red sediments. The work of Streel & Traverse (1978) is very promising but needs to be continued on a far larger scale.

Just as the placement of the Devonian-Mississippian boundary is controversial, so also is correlation of the Mississippian-Pennsylvanian boundary (Manger & Saunders, 1982; Englund & Henry, 1984) with an equivalent European zone. At present this boundary, based on megafloral correlations in the area of continuous deposition in the central Appalachians, is placed at a level close to the Namurian A-B boundary in England (Gillespie & Pfefferkorn, 1979; Sutherland & Manger, 1984).

SECTIONS NEAR THE DEVONIAN-MISSISSIPPIAN BOUNDARY

The Hampshire formation (Fig. 1, 3, 4, 5A) of West Virginia is the youngest and most westerly portion of the Catskill deltaic complex deposited just before the Late Famennian transgression. Because of this the Hampshire is here only about 170-235 m (560-770 ft) thick. The section at Elkins, West Virginia (Fig. 5A) is in the upper, abundantly fossiliferous, part of the Hampshire which is sometimes designated as the Saxton shale member (Reger, 1931) and is only some 20 m (22.5 m or 70 ft from the upper coal bed to the base of the Pocono) from the Pocono. The Pocono is here 21-59 ft (6.4-18 m) thick depending on whether it is identified by a change in color (from red to gray) or by the presence of intraformational conglomerate wedges. The Pocono, which contains no recognizable megafossils, appears to lie conformably upon the Hampshire without any obvious sedimentological break and is unconformably overlain by the Denmar Formation of the Greenbrier Limestone Group (Late Meramecian - equivalent to the Loyalhanna Ls. of Western Maryland and South-Central Pennsylvania). The Maccrady and basal unit of the Greenbrier (Hillsdale) are absent here, presumably by post depositional erosion (Yeilding *et al.*, 1984).

The Hampshire section represents lower delta plain and delta lobe sedimentation interbedded with shoaled delta lobe and marine storm beds of a low energy, mud dominated shore, followed upwards by rebuilt deltas and lower delta plain. Two autochthonous coal beds (*Rhacophyton* swamps) are preserved on delta tops that were drowned and buried by storm beds as delta lobes were abandoned. The flora of the Hampshire beds consists predominantly of *Archaeopteris* and *Rhacophyton* (Banks' floral zone VII) and contains many other minor components, some of which are shown in Figure 5A (Gillespie *et al.*, 1981; Scheckler, 1986). The microfossil flora of these beds suggests an age of lower Fa2c (Gillespie *et al.*, 1981). The same mega- and micro-fossil assemblages occur all the way up to the Pocono contact. Preliminary analysis of the basal Pocono bed (W.H. Gillespie, pers. com., 1980) suggests a Fa2c-Fa2d assignment for these beds also. This gives us further corroboration for a Late Famennian, pre-Strunian, age for the sudden transgression that ushered in the beginnings of Pocono deposition.

The only richly fossiliferous beds of the Pocono/Price are the Price beds of southwestern Virginia (Fig. 1, 3). Figure 5B illustrates a section showing a portion of the marine Lower Price followed by the terrestrial Upper Price. The Lower Price is strictly marine in Virginia and carries no floras despite its inclusion with the Lower Pocono *Adiantites* flora by Read (1955). The fauna relates it to the undoubted Mississippian Cuyahoga group of Ohio (Englund, 1979). The Upper Price begins here and elsewhere in the type area of Montgomery and Pulaski Counties, Virginia, as a sandy, back beach barrier sequence on which an autochthonous coal bed (Langhorne Interval) was deposited. This is overlain by tidal flat and low energy sediments of the lower delta plain. Sediments of the upper delta plain, showing higher energy fluvial sedimentation carry numerous small backswamps, such as the one shown here (Fig. 5B, Merrimac Interval). These are frequently parted or split by crevasse splays indicative of periodic floods and are eventually overlain by more high energy floodplain sediments as the delta continued to prograde to the northwest. Although two coal seams with this structural relationship commonly occur in the type area of the Upper Price, they represent the leading edge of a rapidly prograding deltaic system and are diachronous, even if laterally continuous.

The coal beds contain *Lepidodendropsis* and the floodplain sediments contain mostly *Triphyllopteris* fragments, with other plants (*Rhodeopteridium, Neurocardiopteris,* etc.) being locally common. These beds are the oldest Mississippian terrestrial rocks in Virginia, but the flora indicates assignment to floral zone 2 of probable Tn3 equivalence. No microfossil studies have been done with these beds.

Although the Hampshire and Price were formerly thought to be close to the Devonian-Mississippian boundary, these studies demonstrate that they are not. The only terrestrial rocks close to the boundary are those of the Lower Pocono of Pennsylvania.

REFERENCES

ALLEN, J.R.L., 1979. Old Red Sandstone facies in external basins, with particular reference to southern Britain, *in* M.R. House, C.T. Scrutton & M.G. Bassett (Eds.) "The Devonian System", Sp. Pap. Palaeontol. 23, Palaeontol. Assoc. : 65-80.

ALLEN, J.R.L. & FRIEND, P.F., 1968. Deposition of the Catskill facies, Appalachian region : with notes on some other Old Red Sandstone basins. Geol. Soc. Amer. Spec. Pap. 106 : 21-74.

ANDREWS, H.N. & PHILLIPS, T.L., 1968. *Rhacophyton* from the Upper Devonian of West Virginia. J. LInn. Soc. Bot. 61 : 37-64.

ARBER, E.A.N. & GOODE, R.H., 1915. On some fossil plants from the Devonian rocks of North Devon. Phil. Soc. Proc. 18 (3) : 89-104.

ARKLE, T., BEISSEL, D.R., LARESE, R.E., NUHFER, E.B., PATCHEN, D.G., SMOSNA, R.A., GILLESPIE, W.H., LUND, R., NORTON, C.W. & PFEFFERKORN, H.W., 1979. The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States-West Virginia and Maryland. U.S. Geol. Surv. Prof. Pap. 1110 D : D1-D35.

ARNOLD, C.A., 1939. Observations on fossil plants from the Devonian of eastern North America. IV. Plant remains from the Catskill Delta deposits of northern Pennsylvania and southern New York. Contrib. Mus. Paleontol. Univ. Mich. 5 : 271-314.

BAMBACH, R.K., SCOTESE, C.R. & ZIEGLER, A.M., 1980. Before Pangea : the geographies of the Paleozoic world. Amer. Sci. 68 : 26-38.

BANKS, H.P., 1966. Devonian flora of New York State. Empire St. Geogram, 4 : 10-24, Albany, N.Y.

BANKS, H.P., 1980. Floral assemblages in the Siluro-Devonian, *in* L. Dilcher & T.N. Taylor (Eds.) "Biostratigraphy of fossil plants : successional and paleoecological analyses", Dowden, Hutchinson & Ross, Inc. Stroudsburg, PA : 1-24.

BERG, T.M., EDMUNDS, W.E., GEYER, A.R., GLOVER, A.D., HOSKINS, D.M., MACLACHLAN, D.B., ROOT, S.I., SEVON, W.D., SOCOLOW, A.A., MILES, C.E. & KUCHINSKI, J.G., 1980. Geologic Map of Pennsylvania. Topograph. Geol. Surv. Harrisburg PA.

BERG, T.M., McINERNEY, M., WAY, J.H. & MACLACHLAN, D.B., 1983. Stratigraphic correlation chart of Pennsylvania. Topograph. Geol. Surv. Harrisburg, PA.

BRIDGE, J.S., VAN VEEN, P.M. & MATTEN, L.C., 1980. Aspects of the sedimentology, Palynology, and palaeobotany of the Upper Devonian of southern Kerry Head, Co. Kerry, Ireland. Geol. Journ. 15 : 143-170.

CALVER, J.L., HOBBS, C.R.B., MILICI, R.C., SPIKER, C.T. & WILSON, J.M., 1963. Geologic Map of Virginia. Va. Div. Miner. Res. Charlottesville, VA.

CLENDENING, J.A., EAMES, L.E. & WOOD, G.D., 1980. *Retusotriletes philipsii* n. sp., a potential Upper Devonian guide palynomorph. Palynology, 4 : 15-22.

DENNISON, J.M. & de WITT, W., 1972. Redbed zone produced by a sea level drop at the beginning of Devonian Cohocton Stage delimits Fulton and Augusta lobes of Catskill Delta complex, *in* "Stratigraphy, Sedimentology and Structure of Silurian and Devonian rocks along the Allegheny Front in Bedford County, Pennsylvania, Allegheny County, Maryland, and Mineral and Grant Counties, West Virginia. Ann. Field. Conf. Penna. Geol. Guidebook No. 37 : 109-114.

DENNISON, J.M. & HEAD, J.W., 1975. Sealevel variations interpreted from the Appalachian basin Silurian and Devonian. Amer. J. Sci. 275 : 1089-1120.

EAMES, L.E., 1974. Palynology of the Berea Sandstone and Cuyahoga Group of northeastern Ohio. Ph. D. Dissert. Michigan St. Univ. Lansing, Mich.

EDMUNDS, W.E., BERG, T.M., SEVON, W.D., PIOTROWSKI, R.C., HEYMAN, L. & RICKARD, L.V., 1979. The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States - Pennsylvania and New York. U.S. Geol. Surv. Prof. Pap. 1110B : B1-B33.

ENGLUND, K.J., 1979. The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States - Virginia. U.S. Geol. Surv. Prof. Pap. 1110-C : C1-C21.

ENGLUND, K.J. & HENRY, T.W., 1984. The Mississippian-Pennsylvanian boundary in the central Appalachians, *in* Sutherland, P.K. & Manger, W.L., "9th Intern. Congr. Strat. Geol. Carbon. 1979, vol. 2, Biostratigraphy": 330-336.

FISHER, D.W., ISACHSEN, Y.W., RICKARD, L.V., BROUGHTON, J.G. & OFFIELD, T.W., 1962. Geologic map of New York 1961. Map and Chart Ser. 5. N.Y. St. Mus. Sci. Ser. Geol. Surv. Albany, NY.

GAYER, R.A., ALLEN, K.C., BASSETT, M.G. & EDWARDS, D., 1973. The structure of the Taff Gorge area, Glamorgan, and the stratigraphy of the Old Red Sandstone-Carboniferous Limestone transition. Geol. Journ. 8 : 345-374.

GENSEL, P.G., 1973. A new plant from the Lower Mississippian of southwestern Virginia. Palaeontographica B. 142 : 137-153.

GENSEL, P.G. & SKOG, J.E., 1977. Two Early Mississippian seeds from the Price formation of southwestern Virginia. Brittonia 29 : 332-351.

GILLESPIE, W.H. & PFEFFERKORN, H.W., 1977. Plant fossils and biostratigraphy at the Mississippian-Pennsylvanian boundary in the Pennsylvanian System stratotype area, West Virginia - Virginia. Bot. Soc. Amer. Misc. Ser. Publ. 154 : 41.

GILLESPIE, W.H. & PFEFFERKORN, H.W., 1979. Distribution of commonly occurring plant megafossils in the proposed Pennsylvanian stratotype, *in* Englund, K.J. *et al.*, "Proposed Pennsylvanian stratotype, Virginia and West Virginia." Amer. Geol. Inst. Select. Guidebook. Ser. 1, Falls Church, VA : 87-96.

GILLESPIE, W.H., ROTHWELL, G.W. & SCHECKLER, S.E., 1981. The earliest seeds. Nature 293 : 462-464.

GLAESER, J.D., 1974. Upper Devonian stratigraphy and sedimentary environments in northeastern Pennsylvania. Penn. Geol. Surv. Gener. Geol. Rep. 63 : 1-89.

HECKEL, P.H. & WITZKE, B.J., 1979. Devonian world palaeogeography determined from distribution of carbonates and related lithic palaeoclimatic indicators, *in* House, M.R., Scrutton, C.T. & Bassett, M.G. (Eds.). "The Devonian System". Sp. Pap. Palaeontol. No. 23 :99-123.

JENNINGS, J.R., 1975. *Protostigmaria,* a new plant organ from the Lower Mississippian of Virginia. Palaeontology, 18 : 19-24.

JENNINGS, J.R., 1984. Distribution of fossil plant taxa in the Upper Mississippian and Lower Pennsylvanian of the Illinois Basin, *in* Sutherland, P.K. & Manger, W.L. "9th Intern. Congr. Strat. Geol. Carbon. 1979, vol. 2. Biostratigraphy" : 301-312.

KRÄUSEL, R. & WEYLAND, H., 1941. Pflanzenreste aus dem Devon von Nord-Amerika. II. Die Oberdevonischen Floren von Elkins, West Virginien, und Perry, Maine mit Berucksichtigung einiger von der Chaleur-Bai, Canada. Palaeontographica, B 86 : 1-78.

KREISA, R.D. & BAMBACH, R.K., 1973. Environments of deposition of the Price formation (Lower Mississippian) in its type area, southwestern Virginia. Amer. J. Sci. Cooper vol. 273 A : 326-342.

MANGER, W.L. & SAUNDERS, W.B., 1982. An ammonoid-based Middle Carboniferous boundary, *in* Ramsbottom, H.C., Saunders, W.B. & Owens, B. (Eds.). "Subcommission on Carboniferous stratigraphy. Biostratigraphic data for a Mid-Carboniferous boundary". Leeds, England : 95-100.

MAY, B.I. & MATTEN, L.C.,1983. A probable pteridosperm from the Uppermost Devonian near Ballyheigue, Co. Kerry, Ireland. Bot. J. Linn. Soc., 86 : 103-123.

McGHEE, G.R. & SUTTON, R.G., 1981. Late Devonian marine ecology and zoogeography of the central Appalachians and New York. Lethaia, 14 : 27-43.

McGREGOR, D.C., 1979. Spores in Devonian stratigraphical correlation, *in* House, M.R., Scrutton, C.T. & Bassett, M.G. (Eds.). "The Devonian System". Sp. Pap. Palaeontol. No. 23. : 163-184.

OLIVER, J., 1980. Exploring the basement of the North American continent. Amer. Sci. 68 : 676-683.

OLIVER, W.A., de WITT, W., DENNISON, J.M., HOSKINS, D.M. & HUDDLE, J.W., 1968. Devonian of the Appalachian Basin, United States, *in* Oswald, D.H. (Ed.). "The Devonian System". Alberta Soc. Petrol. Geol. Calgary, Alta, 1967 : 1001-1040.

OLIVER, W.A., de WITT, W., DENNISON, J.M., HOSKINS, D.M. & HUDDLE, J.W., 1969. Correlation of Devonian rock units in the Appalachian Basin. Oil and Gas Invest. Chart OC-64. U.S. Geol. Surv. Reston, VA.

PHILLIPS, T.L., ANDREWS, H.N. & GENSEL, P.G., 1972. Two heterosporous species of *Archaeopteris* from the Upper Devonian of West Virginia. Palaeontographica B, 139 : 47-71.

PRICE, P.H., CARDWELL, D.H., ERWIN, R.B., WOODWARD, H.P. & LOTZ, C.W., 1968. Geologic map of West Virginia. W. Va. Geol. Surv. Morgantown, WV.

READ, C.B., 1955. Floras of the Pocono Formation and Price Sandstone in parts of Pennsylvania, Maryland, West Virginia, and Virginia. U.S. Geol. Surv. Prof. Pap. 263 : 1-32.

READ, C.B. & MAMAY, S.H., 1964. Upper Paleozoic floral zones and floral provinces of the United States. U.S. Geol. Surv. Prof. Pap. 454 K : 1-35.

REGER, D.B., 1931. Randolph County. W. Va. Geol. Surv. Morgantown, WV.

RICKARD, L.V., 1975. Correlation of the Devonian rocks in New York State. Map and Chart Ser. 4, N.Y. St. Mus. Sci. Serv. Geol. Surv. Albany, NY.

ROGERS, I., 1926. On the discovery of fossil fishes and plants in the Devonian rocks of North Devon. Trans. Devonsh. Assoc. Advt. Sci. Lit. Art. 58 : 223-234.

SCHECKLER, S.E., 1984. Persistence of the Devonian plant group Barinophytaceae into the basal Carboniferous of Virginia, USA, *in* Sutherland, P.K. & Manger, W.L. (Eds.). "9th Internat. Congr. Strat. Geol. Carbon. 1979, vol. 2. Biostratigraphy": 223-228.

SCHECKLER, S.E., 1986. Geology, floristics and paleoecology of Late Devonian coal swamps from Appalachian Laurentia (U.S.A.). *In* Late Devonian events around the Old Red Sandstone, M.J.M. Bless & M. Streel (eds), Ann. Soc. géol. Belg., 109 - 209-222.

SCHECKLER, S.E. & BEELER, H.E., 1984. Early Carboniferous coal swamp floras from eastern U.S.A. (Virginia). 2nd Intern. Org. Paleobot. Conf. Abstr. Edmonton, Alberta : 36.

SCHECKLER, S.E. & BEELER, H.E., in prep. Geology, floristics, and paleoecology of Early Carboniferous coal swamps from Appalachian Laurentia (U.S.A.).

SCHECKLER, S.E. & JENNINGS, J.R. in press. Fossil plants of the Price Formation (Lower Mississippian) in southwestern Virginia, *in* Bartholomew, M.J. (Ed.), "Valley Coal field of Montgomery and Pulaski Counties, Virginia". Va. Div. Miner. Res. Publ. Charlottesville, VA.

SCHLUGER, P.R., 1971. Origin and environment of deposition of the red beds of the Perry Formation, Upper Devonian, of New Brunswick, Canada and Maine. Intern. Sediment. Congr. Progr. 8th Intern. Assoc. Sedimentol. Abstr. : 88-89.

SCOTESE, C.R., BAMBACH, R.K., BARTON, C., VAN DER VOO, R. & ZIEGLER, A.M., 1979. Paleozoic base maps. Journ. Geol. 87 : 217-277.

SEVON, W.D., 1969. The Pocono Formation in northeastern Pennsylvania : Guidebook 34th Ann. Field. Conf. Penna. Geol. Pa. Geol. Surv. Harrisburg, PA. : 129 p.

SKOG, J.E. & GENSEL, P.G., 1980. A fertile species of *Triphyllopteris* from the Early Carboniferous (Mississippian) of southwestern Virginia. Amer. J. Bot. 67 : 440-451.

STREEL, M. & TRAVERSE, A., 1978. Spores from the Devonian-Mississippian transition near the Horseshoe Curve section, Altoona, Pennsylvania, U.S.A. Rev. Palaeobot. Palynol. 26 : 21-39.

SUTHERLAND, P.K. & MANGER, W.L., 1984. The Mississippian-Pennsylvanian boundary in North America, *in* Sutherland, P.K. & Manger, W.L. (Eds.), "9th Intern. Congr. Strat. Geol. Carbon. 1979, vo. 2. Biostratigraphy": 319-329.

THOMPSON, T.L., 1984. Mississippian stratotype - An overview, *in* Sutherland, P.K. & Manger, W.L. (Eds), "9th Intern. Congr. Strat. Geol. Carbon. 1979, vol. 2. Biostratigraphy" : 235-246.

WAGNER, R.H., 1984. Megafloral zones of the Carboniferous, *in* Sutherland, P.K. & Manger, W.L. (Eds.), "9th Intern. Congr. Strat. Geol. Carbon. 1979, vol. 2. Biostratigraphy" : 109-134.

WALKER, R.G., 1971. Non-deltaic depositional environments in the Catskill clastic wedge (Upper Devonian) of central Pennsylvania. Geol. Soc. Amer. Bull. 82 : 1305-1326.

WALKER, R.G., 1972. Upper Devonian marine-nonmarine transition, southern Pennsylvania. Penna. Geol. Surv. Gen. Geol. Rep. 62 : 1-25.

WALKER, R.G. & HARMS, J.C., 1971. The "Catskill Delta". a prograding muddy shoreline in central Pennsylvania. Journ. Geol. 79 : 381-399.

WILLARD, B., 1934. Early Chemung shoreline in Pennsylvania. Geol. Soc. Amer. Bull. 45 : 897-908.

WILLARD, B., 1939. The Devonian of Pennsylvania : Middle and Upper Devonian. Penn. Geol. Surv. Bull. G19 : 1-481.

WOODROW, D.L. & FLETCHER, F.W., 1968. Late Devonian paleogeography in southeastern New York and northeastern Pennsylvania, *in* Oswald, D.H. (Ed.), "The Devonian System". Alberta Soc. Petrol. Geol. Calgary, Alta : 1327-1334.

WOODROW, D.L., FLETCHER, F.W. & AHRNSBRAK, W.F., 1973. Paleogeography and paleoclimate at the deposition sites of the Devonian Catskill and Old Red facies. Geol. Soc. Amer. Bull. 84 : 3051-3064.

YEILDING, C.A., SULLIVAN, E.M., DENNISON, J.M. & TEXTORIS, D.A., 1984. Sedimentation patterns and diagenesis of the Mississippian Greenbrier Group of East-Central West Virginia. Proc. Appalach. bsn. industr. assoc. 7 : 92-106.

YEILDING, C.A., SULLIVAN, E.M., TEXTORIS, D.A. & DENNISON, J.M., 1985. Effects of Mississippian tectonic movement on sedimentation and diagenesis of Greenbrier Group in Eastern Appalachian plateau. Amer. assoc. petrol. geol. bull. 69 : 318.