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 (= Strunien = 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 appalachiens représentent un enregistrement presque continu de l'évolution des végétaux depuis le début du Dévonien jusqu'au Pennsylvien 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 États 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 sablées 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 = Osagean). 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 corréllés 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 & Ahrensbrok, 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 interfluvies 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 Cornawangoan), but near the end of Famennian a much larger transgression interrupted 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 westward progradation resumed in Latest Famennian (Strunian) and Earliest Tournaian, the Pocono sands were in many areas disconformably deposited upon the eroded Late Devonian surface. During Early Mississippian (Kinderhook – Early Tournaian), 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 (Burgoo) 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 epeiric uplift across northwestern Pennsylvania and adjacent New York that ended deposition in that area and that eroded some of the Burgoo 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 epeiric 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
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 south-east 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 (Yielding 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 : Yielding et al., 1985).

More extensive collisions of the African plate with eastern Laurentia resulted in the Alleghenian orogeny of Late 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 yielding 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; McGhee & 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 unconformity in New York and eastern Pennsylvania (Fig. 3).
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 Alleghanian 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; Street & 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; Street & 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 Street & Traverse (1978) and McGregor (1979) on the distribution of the lepidophytyus 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 (Street & Traverse, 1978; Clendenin, 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 diachronous 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 diachronic 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 PALEOCCLIMATE

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

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 Herringburgh 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, 1958; 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 Tournaissian 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 cladoxylean anatomy, and herbaceous lycopsids 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 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 anepiphytes and herbaceous lycopsids 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 lycopsids.

Similarly, floral zone VII, characterized throughout by *Rhacophyton* (or its near equivalent *Cephalopteris*) and *Archaeopteris*, shows the introduction of new tree lycopsids (especially *Cyclagnosta*) 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 *Cyclagnosta*, 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 & Piefferkorn (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 Late 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, Alloconiopteris, 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 *Archeopteris* 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 *Lepidoden- dopsis*. 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 Horsehoe 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* (= *Archeopteris*) 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; England & Henry, 1984) with an equivalent European zone. At present this boundary, based on megafossil 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 L.s. of Western Maryland and South-Central Pennsylvania). The Maccrady and basal unit of the Greenbrier (Hillsdale) are absent here, presumably by post depositional erosion (Yielding 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 (Rhaeophyton 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 Rhaeophyton (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 corroborations 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 Lepidozamites 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


