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Reports

Stratigraphy, Sediment Dispersal and Facies Analysis of the Pennsylvanian Pictou Group in New Brunswick

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Introduction

Post Acadian deposition in the Carboniferous basin of the Maritime region commenced by middle Devonian time (River John Series, Hacquebard, 1971) and was first confined to a northeasterly trending basin or rift structure that extended from the Bay of Fundy area to White Bay, Newfoundland (Poole, 1967; Belt, 1968). Continued subsidence and gradual transgression from the initial basin onto the surrounding foreland areas characterized Mississippian events. By Pennsylvanian-Permian time the original site of deposition had gradually expanded to form a large successor basin that still underlies parts of Newfoundland, Nova Scotia, Prince Edward Island, New Brunswick and the Gulf of St. Lawrence. The succession is generally non-metamorphosed and only mildly deformed by the effects of salt tectonics and slight post-depositional tilting of basement blocks.

The present investigation is primarily concerned with the sedimentological and stratigraphic characteristics of the Pictou Group in New Brunswick. It forms part of a long-range project of Carboniferous studies and in the stratigraphic and palaeogeographic analysis of the basin,stresses the importance of considering the inter-relationships that exist between palaeoclimatic conditions, sedimentary tectonics and the three-dimensional geometry of the basin on the one hand, and the observed lithofacies characteristics and patterns of sedimentation on the other.

The Pictou Group

The Pictou Group is the most widespread stratigraphic unit in New Brunswick, and underlies an estimated 30 per cent of the Province. Pictou strata are mostly flat-lying except for locally tilted beds near faults and extend beyond the provincial boundaries into the Gulf of St. Lawrence, Prince Edward Island, Nova Scotia, Cape Breton and Newfoundland.

The name Pictou Group was first introduced by Bell (1944) and applies to the non-marine sequence of fluvial, lacustrine and palludal strata that comprise the youngest Carboniferous stratigraphic unit in the Canadian Atlantic region. The type section is situated along the west branch of the River John in central Nova Scotia where approximately 2250 metres of alternating red and grey sandstone are exposed.

Biostratigraphy

The biostratigraphy of the Pictou Group comprises three megafloral zones (Bell, 1938) and five, in part corresponding miospore zones (Barss and Hacquebard, 1967). The floral zones have been correlated with the Westphalian C and D of Europe but due to the paucity of plant fossils in the upper part of the Pictou Group, no age younger than the Westphalian D could be assigned. Subsequent work (Barss and Hacquebard, 1967), however, has established two additional miospore zones in previously undated strata from Prince Edward Island and this led to the expansion of the previous Pictou time limits from upper Pennsylvanian through Stephanian to lower Permian.

The biostratigraphy and range of each megafloral zone is as follows (after Barss and Hacquebard, 1967; Hacquebard, 1971):

TABLE 1

Megafloral and Miospore Zones of the Pictou Group

AGE	MEGAFLORAL ZONE	MIOSPORE ZONE	ZONE
Permian		Vittatina	e
Stephanian		Potonieisporites	d
Westphalian D	Ptychocarpus unitus	Thymospora	c
Westphalian C	Linopterus obliqua	Torispora	b
	Lonchopteris	Vestispora	a

In New Brunswick, the Pictou Group comprises spore zones a, b, c, and d (Westphalian C, D, and Stephanian). The oldest Pictou strata are primarily exposed along the southwestern and western margin of the basin, becoming younger in a southeastward direction. Pictou strata of Stephanian age, however, have recently also been identified in the Fredericton area (Hacquebard, 1971) from a down-faulted block in which a relatively thick section of Pennsylvanian-Stephanian strata have been preserved from erosion (van de Poll, 1970).

Lithostratigraphy

In southeastern New Brunswick the Pictou Group contains spore zones a, b, c, and d and has previously been subdivided into four lithostratigraphic units as follows (Gussow, 1953):

PICTOU GROUP	Tormentine Formation	- red sandstone, siltstone and minor conglomerate
	Richibucto Formation	- predominantly buff feldspathic sandstone
	Scoudouc Formation	- buff to red sandstone, siltstone and minor conglomerate

* Manuscript received May 4, 1974.

PICTOU GROUP	Salisbury Formation -	red siltstone, minor buff to red sandstone and conglomerate

Carr (1964) subsequently combined these four formations into two units, the Salisbury Formation at the base and comprising all red and essential lutaceous beds, and the Richibucto Formation at the top containing the buff to greenish-grey and red arenaceous strata.

Local stratigraphic names have also been applied to Pictou strata in the Grand Lake region of central New Brunswick. This succession comprises spore zones a and b (Hacquebard, 1971) and was subdivided by Müller (1952) as follows:

Sunbury Creek Formation -	greenish-grey conglomerate sandstone and minor grey siltstone
Hurley Creet Formation -	red and green or grey siltstone minor sandstone
Minto Formation (Upper) -	grey sandstone, siltstone and coal (Minto seam)
Minto Formation (Lower) -	grey conglomerate and sandstone

Subsequent work has shown, however, (van de Poll, 1970) that the Pictou Group is not readily divisable into standard rock stratigraphic units. The various lithologies are not laterally consistent but represent changing facies of recurring first- and second-order cycles that do not readily conform to standard stratigraphic procedure. Moreover, vertical distributions of facies and their lithological variations are poorly discernable in the generally flat-lying Pictou succession. Vertical sections, if present, are generally incomplete and tend to emphasize the more erosion resistant greenish-grey conglomerate and/or sandstone sequences with respect to the finer-grained and more easily eroded red sandstone and siltstone interbeds. As a result, interpretations concerning contact relationships invariably favour a coarsening-upward red siltstone to grey sandstone transition wherever the two lithologies are in vertical contact. This bias in exposure combined with the generally flat-lying nature of the strata and the observed southeastward younging of the succession has previously led to a simple depositional model of lateral infilling of the basin by deltaic sedimentation (eastward accretion, Kelley, 1967, p. 226).

It was subsequently recognized from detailed core-logging (van de Poll, 1970) that the Pictou Group did not represent such a simple two-step coarsening-upwards sequences, but is instead characterized by a repetitive succession of first-order fining-upward fluvial cycles. Furthermore, it became evident that the vertical distribution of these fluvial cycles is not random but that they themselves occur in ordered succession comprising several fining-upward megacycles of second order. Each second-order cycle is several hundreds of metres thick and consist of a relatively coarse grey facies sequence at the base and a finer-grained predominantly red facies sequence at the top.

Sedimentary Characteristics of the Pictou Group

First and Second-Order Cycles

First-order cycles representing fining-upwards fluvial sequences ranging from approximately 3 to 20 metres in thickness characterizes the Pictou Group in New Brunswick. Two major cycle types representing either channel or overbank environments of deposition can be recognized (van de Poll, 1970).

The channel-fill sequences are predominantly made up of thick-bedded, fining-upwards greenish-grey conglomerate and/or sandstone units. They form multi-story recurrences of top-truncated asymmetrical fluvial cycles and predominate in the lower grey facies sequences of each second-order cycle. The overbank strata are characterized by repeated basal-truncated symmetrical reversals of fine-grained red sandstone and siltstone, and characterize the upper part of each second-order cycle.

Quartz-pebble conglomerate commonly lies at the base of each second-order cycle and the most common lithology of the grey facies sequence is a medium-grained sandstone. The frequency distribution of the red facies sequence is moderately skewed towards the finer lithologies and the most common rock type is a very fine-grained red sandstone.

Of the primary sedimentary structures present, cross-bedding predominates in each of the grey facies sequences whereas ripple-drift and parallel laminations are relatively more common in the red strata. These features suggest that the two different facies represent not only changing energy distributions within each first-order fluvial cycle, but also indicate the presence of larger, superimposed oscillations in stream competence that have persisted over relatively long periods of time. These large-scale oscillations are reflected in the upward transition from the relatively high-energy grey, to the relatively low-energy red facies sequences of each second-order cycle.

A dark grey to black siltstone horizon of variable thickness, locally including a thin seam of coal and containing a characteristic miospore assemblage commonly occurs at or below the greenish-grey to red facies change. Each coal-bearing horizon corresponds with a spore zone and this feature has facilitated tentative subdivision of the Pictou Group on biostratigraphic and lithostratigraphic criteria into the aforementioned 5 spore zones and associated second-order cycles. Of these, 3.5 second-order cycles and 4 corresponding spore zones are present in New Brunswick (van de Poll, 1970, 1972). These are in descending order:

Second-Order Cycle IV -	lower grey facies sequence, exposed along the Northumberland Strait between Richibucto and Cocagne Harbour. The red facies sequence of second-order Cycle IV is interpreted to underlie the Northumberland Strait.

Second Order Cycle III - Beersville and Shediac coal seams (spore zones c and d combined) at the transition from the lower grey facies sequence to the upper red facies sequence.

Second Order Cycle II - Mowatt Brook and Dunsinance coal seams (spore zone b) within the lower grey facies sequence.

Second Order Cycle I - Minto and Clones coal seams (spore zone a) just below the transition from the lower grey facies sequence to the upper red facies sequence.

The presence of first-order fluvial cycles in the Pictou succession can be readily explained in terms of lateral migration of braided and meandering streams across a wide flood plain. However, an explanation for the presence of second-order cycles is less obvious.

The repeated vertical alternation of grey and red facies sequences may be the result of lateral migration of multi-storey and multi-lateral channel belts. Such lateral migration could have taken place as a result of avulsion in response to sedimentary tectonics and gradual changes in the physiography of the basin as sedimentation proceeded in time. Alternatively, the differing lithologies and sedimentological characteristics of the grey and red-facies sequences can also be interpreted to reflect basin-wide changes in stream competence. Such widespread changes, however, are more readily attributed to large-scale influences on the patterns of sedimentation rather than local fluctuations in the hydrodynamic segregation of fluvial facies, and may reflect changes in base level or slight palaeoclimatic variations during Pictou time.

In the latter event, a relatively more arid palaeoclimate would have led to the deposition of the red facies, whereas a somewhat more pluvial climate would account for the greater stream competence in evidence during the depositional interval of the grey-facies sequences.

The recognition of the characteristic vertical facies changes has greatly facilitated lithological mapping within the Pictou succession. The mapped distribution of the second-order cycles is shown in Figure 1 and indicates a gentle southeasterly dip of the strata of a few degrees or less, except in the southern part of the basin where the facies distributions show a gentle north-northwesterly dip of the sequence. The previously observed southeastward younging of the succession, rather than reflecting eastward accretion by deltaic sedimentation, is now interpreted to be the result of slight post-depositional tilting of the strata. As a result, the interpretation that the extent of the basin reflects its palaeogeography is no longer tenable. The present southwestern and western limits do not represent the palaeomargin of the basin but constitute either a faulted contact or a basal unconformity. The Carboniferous succession of New Brunswick, therefore represents an erosional remnant of a once much larger basin of deposition that probably extended beyond its present limits into western New Brunswick and the northeastern New England

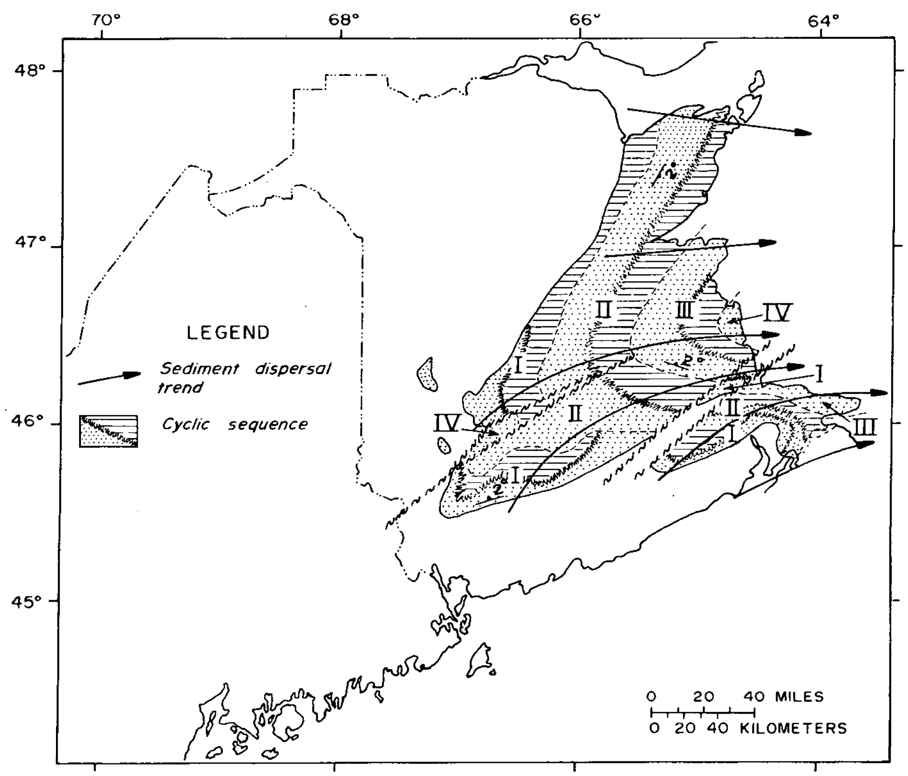

Fig. 1. - Distribution of sedimentary cycles and dispersal trends.

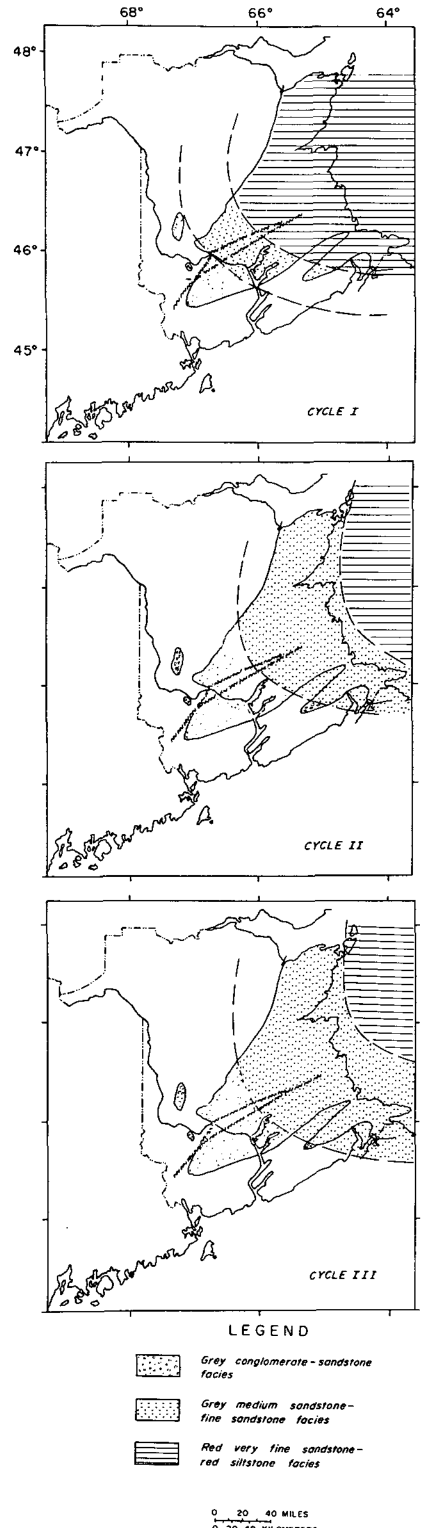

Fig. 2. - Facies distribution.

States. The presence of Stephanian-age strata (spore zone d, Hacquebard, 1971) preserved in a down-faulted block along the western margin of the basin near Fredericton, supports this interpretation Approximately 600 metres of Pictou strata are present in this structural graben, and as much as an additional 450 metres of upper Pennsylvanian-Stephanian strata once covered the southwestern part of the basin during Late Palaeozoic times.

Lateral Facies Distributions

The cyclically upward-fining facies characteristics of the Pictou Group are laterally modified by basal truncations of the coarser members. As a result, there is within each second-order cycle a lateral facies change from grey conglomerate-sandstone near the present southwestern margin of the basin, to predominantly fine-grained red sandstone-siltstone in the Northumberland Strait area and beyond (Fig. 2). These facies changes probably reflect proximal-distal relationships of the strata with respect to distance of transport. In these relationships the finer-grained red-facies sequences are interpreted to predominate in the axial region whereas the coarser-grained strata reflect an environment of deposition that was relatively nearer to the palaeomargin of the basin.

Sediment Dispersal

Palaeocurrent analysis, based primarily on vector orientation of cross-bedding and to a lessor extent parting lineation, ripple drift, fluvial channels and plant fragments (van de Poll, 1966, 1970) indicates that a northeasterly to easterly direction of sediment transport prevailed during the Pictou depositional interval. The dispersal pattern shows a gradual easterly deflection from northeasterly in the southwestern apex area, to easterly and east-southeasterly in the eastern and northern part of the basin respectively (Fig. 1).

This pattern conforms closely to a longitudinal sediment dispersal model whereby the grand transport mean lies parallel to, and in the symmetry plane of the basin. Contrary to previous interpretations of a northeasterly trending basin (Poole, 1967; Belt, 1968) the observed dispersal pattern suggests that an open-ended easterly trending basin structure persisted during the Pictou depositional interval with a symmetry axis that was approximately centered on the present site of Miramichi Bay (Fig. 3).

Synthesis of the Basin and Summary of Conclusions

The Pictou Group in New Brunswick consists of alternating grey and red strata which occur in the succession as second-order cycles. Each second-order cycle is made up of a lower grey-facies sequence of first-order fluvial channel cycles, and an upper redbed sequence that is characterized by multi-storey first-order fluvial overbank cycles.

Previously established spore zones correspond and, in part, overlap the mega cycles of second order and this combination of lithostratigraphic and biostratigraphic characteristics has aided the subdivision of the Pictou Group in New Brunswick into mappable lithostratigraphic units.

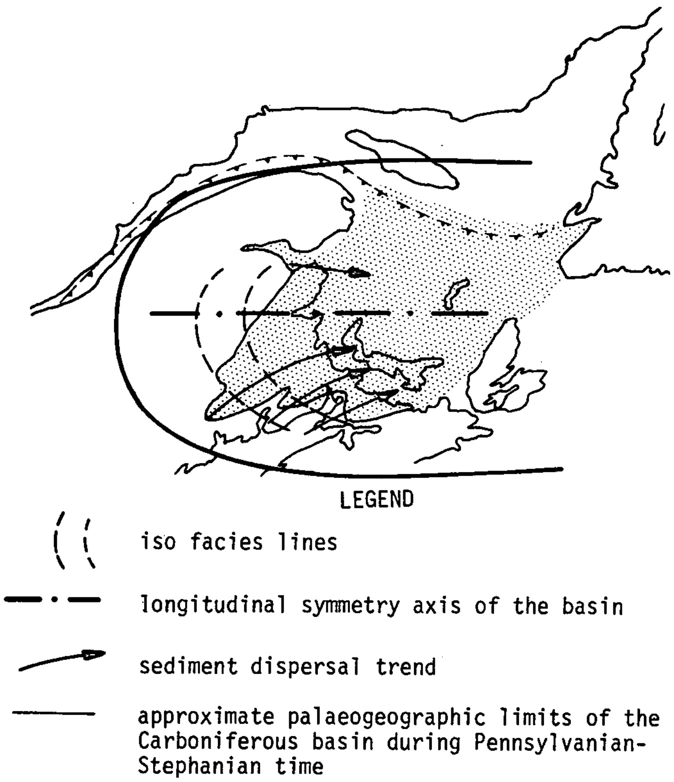

Fig. 3. - Paleocurrents of the Pictou Group in the Carboniferous Basin.

The mapped distribution of the second-order cycles indicates a gentle southeasterly dip of the strata, except in the southwestern part of the basin where the succession dips gently to the north-northwest at a few degress or less. Restoration of the slightly tilted sequences shows that an additional 450 metres of Pennsylvanian-Stephanian strata covered the western and southwestern margin of the basin during upper Palaeozoic time.

Recurrences of first-order fluvial cycles are common in the continental Pictou strata of New Brunswick, and reflect lateral migration of braided and meandering fluvial channels across the flood plain. Fluvial cycles therefore, if mapped as lithostratigraphic units, tend to be diachronous features, but there is as yet insufficient evidence to decide whether the second-order cycles are also diachronous or constitute time-equivalent units. Avulsion of braided multi-storey and multi-lateral channel belts could result in lateral migration of the grey and red strata and account for the vertical and lateral distribution of the grey and red-facies sequences as sedimentation proceeded in time. Major lateral shifts in facies distribution would lead to the deposition of diachronous lithostratigraphic units and may take place in response to base-level changes or to gradual changes in the three-dimensional geometry of the basin. Alternatively, fluctuations in precipitation rates in the palaeoclimatic record could lead to long-term changes in stream competence and bedload transport. Lithostratigraphic units reflecting such palaeoclimatic variations, therefore, can be expected to be time-equivalent over relatively large areas. In the latter case the grey-facies sequences would reflect a relatively pluvial palaeoclimate whereas the alternating recurrences of redbeds would record more arid palaeoclimatic intervals. In this respect it is of importance to note the apparent restriction of diagnostic miospores to specific stratigraphic intervals. This restriction might be explained by partial, perhaps local, extinctions of plant populations as a result of long-term oscillations in precipitation rates or other palaeoclimatic factors during Pennsylvanian-Permian time.

Proximal-distal relationships of the strata are reflected in the lateral facies changes within each second-order cycle. The proximal lithofacies are the grey conglomerates and sandstones in the southwestern part of the basin, whereas the fine-grained red sandstone-siltstone is primarily confined to the axial region. These changes indicate that reco_nition of second-order c_cles is a _roximity-to-source characteristic and that subdivisions of the Pictou Group in the axial region of the basin on these lithological criteria is not likely to be possible.

The sediment dispersal pattern of the Pictou Group in New Brunswick is asymptotic to an easterly trending transport mean. Assuming that the position of the longitudinal transport mean was subparallel to, and in the symmetry plane of the basin, the observed dispersal pattern is suggestive of an easterly trending basin structure with a symmetry axis that was approximately centered on the present site of Miramichi Bay (Fig. 3). This interpretation is also supported by the observed facies pattern and indicates that during the Pictou depositional interval the basin axis transected the Appalachian structural trend at an acute angle of approximately 30 degrees. Sedimentary basins that parallel the regional structural trend are usually deep and steep-sided (Potter and Pettijohn, 1963), whereas by inference those that transect the regional trend tend to be relatively shallow and may show widespread overstep of strata onto basement rocks.

The latter interpretation is favoured here and the regional extent and interpreted palaeogeographic limits of the basin during Pictou time are indicated in Figure 3.

Basement massifs such as the Caledonia Mountains and the Kingston Uplands within the southwestern part of the basin apparently had little effect on the sediment dispersal pattern during Pennsylvanian-Stephanian time. The observed easterly orientation of the longitudinal transport-mean indicates that the prevailing northeasterly structural trend in its physiographic configuration primarily reflects a subsequent destructional phase rather than the depositional phase, in the evolution of the basin.

Results from the present investigation indicate that the Carboniferous in New Brunswick represents an erosional remnant of a much larger basin of deposition that during upper Palaeozoic time, extended beyond its present limits to cover parts of southern Nova Scotia, western New Brunswick, northern Maine and the Gaspé. It is not likely, however, that the Carboniferous basin of Atlantic Canada extended sufficiently far southwestward to form part of the

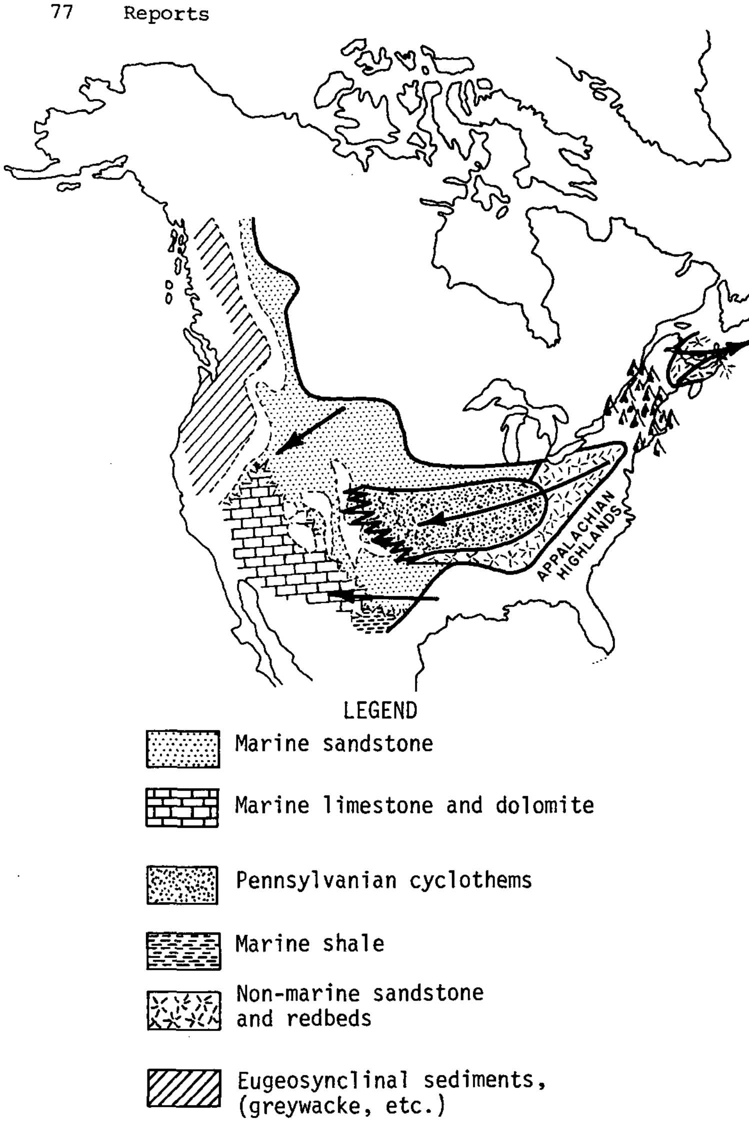

Fig. 4. - Facies distribution and dispersal trends of Appalachian basins.

Anthracite and Northern Appalachian basins of Pennsylvania, Ohio, Maryland, southern New York and northern West Virginia. Wanless (1967) included the Carboniferous of eastern Canada in his comprehensive facies analysis of upper Carboniferous marine and non-marine strata of North America. Although he did not arrive at any specific conclusions concerning intrabasinal relationships, his facies and sediment dispersal maps (Wanless, 1967, Figs. 8, 9, and 15) appear to favour the interpretation that the Carboniferous of eastern Canada represents the proximal piedmont and fluvial equivalent strata of the deltaic facies of the Northern Appalachian Basin. Results from this investigation, however, tend to rule out this possibility. Palaeocurrent analysis shows that the Carboniferous of eastern Canada displays an easterly direction of sediment transport which is in direct contrast to the generally westerly dispersal trends and facies distributions of the Appalachian Basins (Fig. 4). This divergent pattern of sedimentation indicates that a structural divide across the New England States separated the two basins of deposition during upper Palaeozoic time and that they must be regarded therefore, as two separate entities in North American palaeographic interprètations involving Pennsylvanian-Stephanian strata.

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