Lithostratigraphy of the Prince Edward Island redbeds

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The redbeds of Prince Edward Island are of Stephanian-late Early Permian age and represent the youngest known on-land exposed strata of the post (Acadian) orogenic Maritimes Basin of eastern Canada. The Island redbeds have previously been informally subdivided into four fining-upwards megacyclic sequences I, II, III and IV, on the basis of variations in grain size and composition. It has also been past practice to informally assign the redbeds to the top of the Pictou Group of Nova Scotia and New Brunswick with which they merge uninterruptedly at depth below the Island.

Regional variations in conglomerate composition, maturity and sediment dispersal trends indicate that the redbeds comprise two separate lithofacies sequences representing: (1) the relative distal platformal Pictou Group lithofacies of New Brunswick to the southwest, and (2) the more proximal Cumberland Sub-basin Pictou Group lithofacies of Nova Scotia to the south.

It is suggested here that lithostratigraphic purpose may be best served by the following changes: The Northumberland Strait Supergroup be established to accommodate the Pictou Group below (grey and red terrestrial strata, locally coal measures) and the Prince Edward Island Group (redbeds) above. The Prince Edward Island Group is to be subdivided on the basis of their internal megacyclic order into five formal formations and two members. From oldest to youngest these are: Miminegash, Egmont Bay, Kildare Capes, Hillsborough River and Orby Head formations. The Hillsborough River Formation is further subdivided into the Malpeque and Wood Islands members.

The Stephanian-late Early Permian age of the Prince Edward Island redbeds is reasonably well established on the basis of paleontological evidence.

Les séries rouges de l'Ile du Prince-Edouard, d'âge compris entre le Stéphanien et la fin du Permien précoce, représentent les plus jeunes strates connues du Bassin post-orogénique (post-acadien) des Maritimes à affleurer sur la terre ferme. On a auparavant subdivisé ces séries de façon informelle, en raison de variations dans leur granulométrie et leur composition, en quatre mégaséquences granodécroissantes (I, II, III et IV). Il était aussi coutume d'attribuer de façon informelle ces séries rouges au sommet du Groupe de Pictou (Nouvelle-Ecosse et Nouveau-Brunswick), auquel elles s'incorporent continûment, et ce en profondeur sous l'île.

Les variations régionales dans la composition des poudingues, la maturité des sédiments ainsi que les tendances dans la dispersion des sédiments démontrent que les assises rouges s'articulent en deux séries distinctes de lithofaciès représentant (1) vers le sud-ouest (Nouveau-Brunswick), le lithofaciès de plate-forme plus externe du Groupe de Pictou et (2) vers le sud (Nouvelle-Ecosse), le lithofaciès plus proximal du Sous-Bassin de Cumberland dans le Groupe de Pictou.

On suggère que la lithostratigraphie serait favorisée par les changements suivants: que le Supergroupe de Northumberland Strait soit établi pour concilier en bas le Groupe de Pictou (strates terrestres grises et rouges, veines de charbon locales) et en haut le Groupe de Prince Edward Island (séries rouges). On subdivise de façon formelle le Groupe de Prince Edward Island en cinq formations et deux membres en s'appuyant sur leur disposition mégacyclique interne. De la plus vieille à la plus jeune, celles-ci englobent les formations de Miminegash, d'Egmont Bay, de Kildare Capes, de Hillsborough River et d'Orby Head. On subdivise aussi la Formation de Hillsborough River en deux membres: les membres de Malpeque et de Wood Islands.

L'âge stéphanien-éopermien tardif des assises rouges de l'Ile du Prince-Edouard est raisonnablement établi sur des bases paléontologiques.

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INTRODUCTION

Prince Edward Island lies in the southern part of the Gulf of St. Lawrence, eastern Canada (Fig. 1). The Island is nearly 230 km long and varies in width between 7 and 50 km. Its surface shows a gently rolling topography with a maximum elevation of nearly 150 m. Bays and estuaries deeply penetrate the Island showing the effects of the Holocene marine transgression.

Geological investigations of the Island under authority of the local Government date back to the middle of the last century (Dawson, 1842; Gesner, 1847; Dawson and Harrington, 1871; Dawson, 1874, 1878, 1891) and the Geological Survey of Canada (Ells, 1883, 1885). A total of nineteen on-land and five off-shore wells have been drilled on and around the Island since 1909. Drilling mainly for the exploration of coal, oil and natural gas also provided much valuable information on the subsurface

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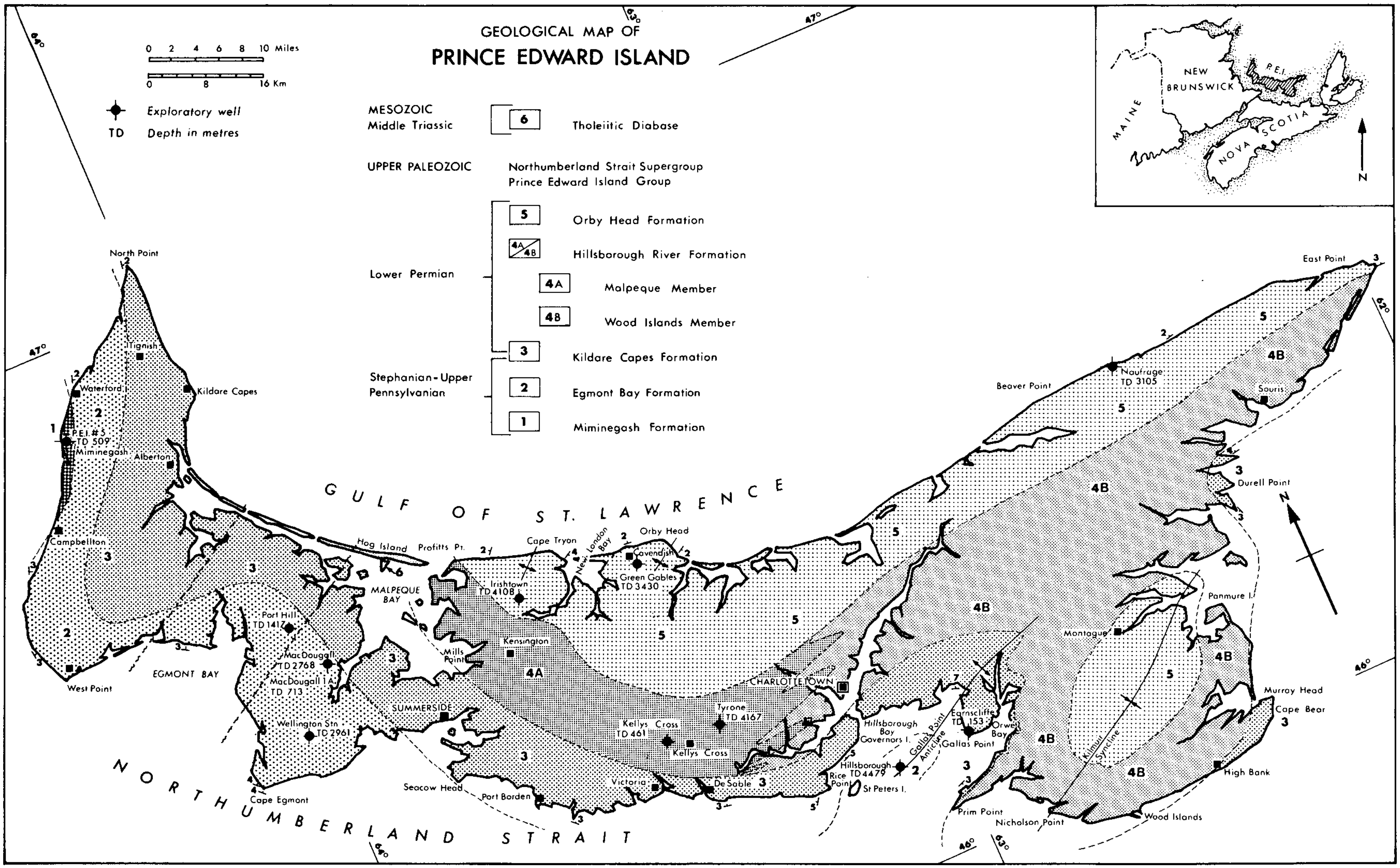

Fig. 1. Geological map of Prince Edward Island.

Carboniferous stratigraphy of the region (van de Poll, 1983). Following a comprehensive study and review of the mineral economic potential of the Island (Milligan, 1949) new studies on the surficial and bedrock geology were undertaken by the Geological Survey of Canada between 1953 and 1973 (Crowl, 1960a, 1960b, 1969; Crowl and Frankel, 1970; Frankel, 1960, 1966; Frankel and Crowl, 1970; Prest, 1962, 1964, 1972, 1973; Prest and Brady, 1964; Prest *et al.*, 1969). Minor occurrences of uranium were encountered in the redbeds mainly around Miminigash (Prest *et al.*, 1969) but a regional assessment of the uranium potential of the redbeds failed to identify economic concentrations of this energy resource (Dunsmore, 1977; van de Poll, 1983).

The most recent stratigraphic work (van de Poll, 1983; van de Poll and Forbes, 1984; van de Poll and Ryan, 1985) was undertaken with the objective of subdividing the Island redbeds into mappable lithostratigraphic units for the purpose of correlation, to better understand their structure and to form a basis for future economic assessment of the strata.

The present paper is a direct result of this latest work and the principal purpose for this presentation is to formally propose subdivision of the redbeds of Prince Edward Island and to incorporate them in the late Paleozoic stratigraphy of eastern Canada.

The age of the redbeds (reviewed by Langston, 1963) has been the subject of some controversy. Dawson (1842, 1855), Gesner (1847), Dawson and Harrington (1871), Bain (1881), Bain and Dawson (1885) all noted the similarity between the plant fossil imprints locally present in the Island redbeds and the coalified plant remains in the Carboniferous age strata of the neighbouring provinces. Nevertheless, for several decades during the late 19th century doubts concerning the true age of the redbeds were voiced by Dawson (1848) who notwithstanding the plant fossil evidence assumed the redbeds to be, at least in part, definitely post-Carboniferous and quite possibly of Triassic age. This erroneous interpretation was centered on the tentative interpretation of the vertebrate fossil *Bathygnathus borealis* (Fig. 2), discovered on the Island in a dug well near Cape Tryon. Leidy (1854) thought *Bathygnathus borealis* to be related to the bipeds which made the so-called bird tracks of the New Red Sandstone of the Connecticut valley necessitating a similar Triassic age for the redbeds of Prince Edward Island. This controversy was eventually resolved when Case (1905) and Huene (1905) identified *Bathygnathus borealis* as a Permian pelycosaur. Subsequent studies on plant fossil imprints from southern (Holden, 1913) and western Prince Edward Island (Darrah, 1936) as well as additional vertebrate fossil evidence contained in the redbeds (Langston, 1963) all support a Permo-Carboniferous age.

Additional confirmation concerning their age has subsequently been obtained from palynological studies of well cuttings from many of the wells of the Island. Westphalian (Pennsylvanian), Stephanian and Sakmarian (early Permian) ages have been interpreted from the youngest spores reportedly occurring at varying depth in the wells listed in Table 1 (after Prest, 1962; Barss *et al.*, 1963; Hacquebard, 1972; Howie, 1977; Barss *et al.*, 1979).

Summarizing the palynological data, it would appear that strata of known Stephanian (late Pennsylvanian) age underlie the western part of the Island at a relatively shallow depth (>600 m) whereas somewhat younger strata ranging in known age up to Sakmarian (early Permian) occur at shallow depth (100 m) at Gallas Point, on the eastern shore of Hillsborough Bay, and also in the northeastern part of the Island including strata on strike lying offshore (East Point Well E49) at a depth in excess of 650 m.

LITHOSTRATIGRAPHY

Prince Edward Island is underlain by a nearly flat lying to gently southeasterly, northeasterly, northerly and northwesterly dipping sequence of terrestrial redbeds comprising greyish-red quartz-quartzite pebble and cobble conglomerates, and intraformational mud-pellet conglomerates, very coarse- to very fine-grained red lithic and arkosic wackes, orange-red silt and claystone (mudstone) and minor pale-grey lacustrine limestone. The only known surface occurrence of igneous rock is a diabase sill or dike exposed on the eastern extremity of Hogg (George) Island in Malpeque Bay.

On Prince Edward Island the redbeds range in age from Stephanian to late-Early Permian and at depth below the Island are conformable with the Pennsylvanian-Stephanian strata of New Brunswick and Nova Scotia (Barss *et al.*, 1963). Drilling results from the Island and regional geological mapping in the Maritime Provinces have shown that the total Pennsylvanian - early Permian sequence comprises three major intervals: based on colour these are: (1) A basal grey conglomerate-sandstone interval with intercalations of red and grey mudstone, including coal measures: coalified plant remains are very common. The sequence is widely exposed in parts of New Brunswick, Nova Scotia and Cape Breton; (2) A transition zone comprising red and grey conglomerate and sandstone with intercalations of mainly red, fine- to very fine-grained sandstone and mudstone without coal measures: coalified plant remains are common only in the grey strata. The transition, widely present below the Island as seen in drillholes, is only exposed at Cape Tormentine, New Brunswick, and in the Tatamagouche Syncline area of Nova Scotia; (3) An upper red conglomerate-sandstone interval with intercalations of red, fine- to very fine-grained sandstone and mudstone. Coal measures and coalified plant remains are absent although hematitic fossil plant-remains and imprints of plant fossils are locally common in the lower part of the redbeds. The upper sequence of redbeds is exposed throughout Prince Edward Island and extends for an unknown distance beyond the coastal regions of the Island beneath the waters of the Gulf of St. Lawrence and parts of the Northumberland Strait.

The degree and extent of reddening of the strata in the "transition zone" which essentially separates the (lower) predominantly grey beds of New Brunswick and Nova Scotia from the (upper) redbeds of Prince Edward Island appears to reflect the original organic content in the redbeds and is time-transgressive between Stephanian and early Permian. Strata in which coalified plant remains are relatively common or abundant are invariably grey, whereas strata in which coalified plant remains are not so common or absent tend to be red in colour. This feature is

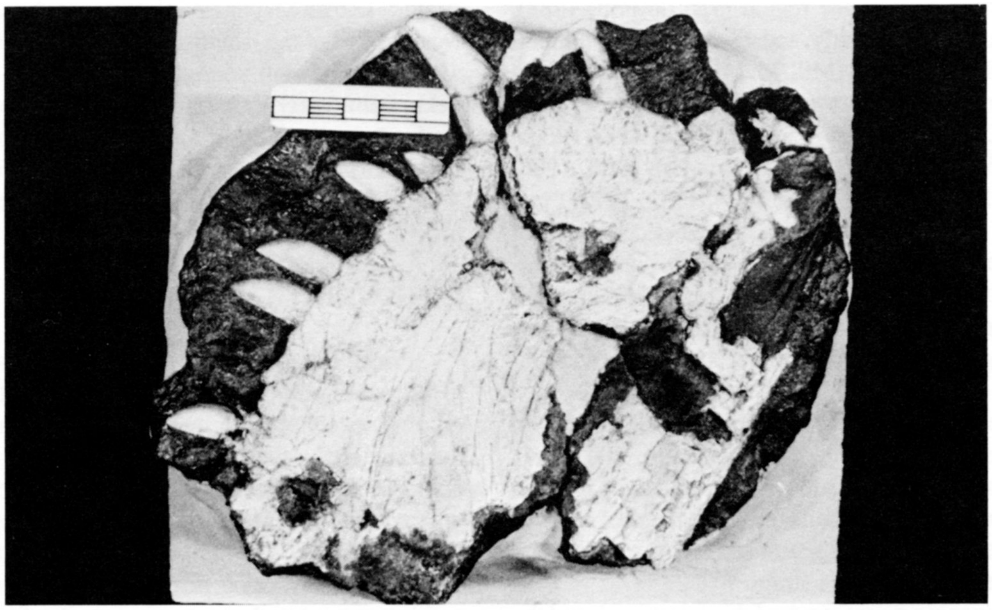

Fig. 2. Cast of the jaw-bone with teeth, *Bathygnathus Borealis* Leidy. The cast was kindly donated to the author in 1985 by Dr. V.K. Prest formerly with the Geological Survey of Canada (centimeter bar scale for size).

Table 1. Summary of interpreted age distribution based on palynology, along borehole intersection of Prince Edward Island wells.

From West to East:-

Well Name	Approximate depth below sea level	Age
Port Hill	481-1197 metres	Stephanian - Westphalian
MacDougall	20-1072 metres	Stephanian - Westphalian C
MacDougall #1A	543 metres	Stephanian
Wellington Station	487-1137 metres	Stephanian - Westphalian C
Irishtown	780-786 metres	Sakmarian
Green Gables	791-1814 metres	Stephanian - Westphalian C?
Tyrone	1190-3014 metres	late Westphalian B to Stephanian
Hillsborough	400-2133 metres	Stephanian - Westphalian C
Earnscliffe	96-102 metres	Sakmarian
Naufrage	648-3072 metres	Sakmarian/Stephanian to Westphalian?
East Point E49	1052-2856 metres	Sakmarian/Stephanian to Westphalian D?

particularly noticeable in the Tatamagouche Syncline area of Nova Scotia and led to the suggestion by Ryan (personal communication, 1986) that colouration of the strata is not a primary feature, but that downward reddening took place during Late Permian - Triassic diagenesis (i.e., below the Triassic unconformity).

The basal grey beds, as well as the strata of the grey and red transition zone, have previously been assigned to the Pictou Group (cf. Bell, 1944; Barss and Hacquebard, 1967; Hacquebard, 1972), but the redbeds of Prince Edward Island have not yet formally been given a stratigraphic designation, although Barss and Hacquebard (1967), Hacquebard (1972), and van de Poll (1983) informally extended the Pictou Group upward to include the redbeds.

This approach can be justified by the absence of a clearly recognizeable structural or stratigraphic break between the predominantly red strata of Prince Edward Island and the mainly grey (Pictou) beds of New Brunswick and Nova Scotia and by their similarity in terrestrial origin, facies and lithologies, and fluvial style. On the other hand combining such a large group of rocks in terms of areal extent and thickness into one unit (up to several thousand metres) is bound to create problems of its own. For example, in the current usage the Pictou Group includes strata that cross tectosome boundaries, thus combining stable platform with subsiding basin lithofacies, have different source areas and consequently display differences in composition and maturity. Also the lithostratigraphic relationships between the expanded Pictou Group and the Morien Group of Cape Breton, both occupying approximately the same stratigraphic position, might have to be reviewed because the Prince Edward Island redbed portion of the Pictou Group also overlies the Morien Group in the off-shore region between Cape Breton and Newfoundland (cf. Hacquebard, 1984, Fig. 2). Nevertheless, despite these objections, combining the redbeds of Prince Edward Island in one form or another with the Pictou Group below would to many geologists probably be preferable over the erection of a completely separate lithostratigraphic unit for the redbeds, mainly because of the problem of establishing a lower limit of the redbeds on lithogenetic or structural criteria.

The situation is also complicated by the fact that at least two major lithofacies sequences (van de Poll and Ryan, 1985) make up the expanded Pictou Group of New Brunswick, Nova Scotia and Prince Edward Island, representing either stable platform depositional or subsiding sub-basin depositional conditions. The two lithofacies sequences can be identified on the basis of differences in composition and maturity, clast morphometrics, cyclicity and paleocurrent directions into (1) the New Brunswick Platform, and (2) the Cumberland Sub-basin lithofacies sequences. The New Brunswick Platform lithofacies are generally more mature in composition, better rounded and have better developed megacyclic repetition (cf. van de Poll, 1970, 1973, 1983; LeGallais, 1983) than the Cumberland Sub-basin lithofacies of the Pictou Group where megacyclic sequences on the scale identified in the New Brunswick Platform sequence are absent (Ryan, personal communication, 1987).

Stratigraphic subdivision of the Pictou Group (including the Prince Edward Island redbeds) of the Platform lithofacies sequence is not possible except on the basis of its repetitive nature of fining-upward megacyclic sequences, each several hundreds of metres thick.

The foregoing clearly demonstrates that the Pictou Group (with or without the Prince Edward Island redbeds included) shows the type of internal diversity that defies ready subdivision on accepted stratigraphic principles (cf. Hedberg, 1972). Undoubtedly because of its internal diversity and difficulty of further subdivision the Pictou Group has in practice become over the years a collector-unit for all Pennsylvanian-Permian fluvioclastic strata, including grey and redbeds, lacustrine facies and/or coal measures, displaying either mature, submature or immature lithologies. The unit, in its current usage is bounded at the base in most areas by the Westphalian B disconformity and at the top by the Permian-Triassic (angular) unconformity representing the late Palaeozoic orogeny (Alleghanian equivalent?) of eastern Canada. Its time-span in terms of European stratigraphy, covers the upper part of the Westphalian, the Stephanian, Asselian, Sakmarian and Artinskian Stages (Haq and van Eysinga, 1987). In terms of North American stratigraphy the expanded Pictou Group includes the Atokan/Derryan, the Desmoinesian Missourian, Virgilian, Wolfcompian and Leonardian Stages covering a total time-span of approximately 40 million years. One could argue with considerable validity that the Pictou Group is misidentified and should be referred to as the "Pictou Series", i.e., a formal unit not in the conventional lithostratigraphic sense but in the chronostratigraphic hierarchy, ranking above a Stage and below a System (Hedberg, 1972). However, the likelihood that the Pictou can be subdivided into readily identifiable Stages defined by boundary strato-types has not yet been demonstrated. Clearly, the stratigraphy of the Pictou, either as a group or a series is at an impasse and a workable subdivision on either lithostratigraphic or chronostratigraphic criteria within the guidelines suggested by the International Guide to Stratigraphic Classification appears as elusive as ever. On the other hand it would certainly be desirable to subdivide such a voluminous sequence of rocks into workable lithogenetic units by whatever means if for no other reason than to gain a better understanding of the internal structure and hierarchy in its depositional evolution in both time and space.

The potential confusion created by the application of lithostratigraphic and chronostratigraphic criteria in the Permo-Carboniferous stratigraphy of eastern Canada has been recognized as early as over two decades ago (Kelley, 1967). However, the fact that little has been accomplished since that time to resolve the problem may be taken as an indication that in so far as the Pictou strata are concerned the current system, though not ideal, actually works quite well provided that unit boundaries can be established on the basis of disconformities and unconformities as initially envisaged by Bell (1944, 1958). Keeping the foregoing in mind, the following proposals are made here to formalize the Pennsylvanian-Permian lithostratigraphy and to provide an appropriate stratigraphic niche for the redbeds of Prince Edward Island.

Because the Pictou Group appears at the present to be more readily divisible on the basis of lithostratigraphic units (megacyclic sequences, van de Poll, 1973) than on chronostratigraphic criteria it is proposed here that the name Pictou Group be retained in recognition of its historical lithostratigraphic connotation despite its valid chronostratigraphic aspects.

It is further proposed that in recognition of the considerable time span and the lateral and vertical extent represented by the total rock sequence, the Pictou Group and the Prince Edward Island redbeds be formally combined into one supergroup referred to as the Northumberland Strait Supergroup.

Northumberland Strait Supergroup (new)

The name is derived from the Northumberland Strait separating Prince Edward Island from mainland New Brunswick and Nova Scotia and along which shores both the Pictou and Prince Edward Island strata are so very well exposed. As defined in the Code for Stratigraphic Nomenclature, the term supergroup may be used for several associated Groups or Formations and Groups with significant lithologic features in common (Hedberg, 1972). By this designation the Northumberland Strait Supergroup will consist of two groups, which are in ascending order the Pictou Group (mainly grey beds) below and the Prince Edward Island

Group (redbeds) above. The contact between the two Groups is transitional and time transgressive. It is also recognized here that the Northumberland Strait Supergroup consist of two major, approximately time equivalent, lithofacies sequences, which are informally referred to here as the New Brunswick Platform lithofacies and the Cumberland Sub-basin lithofacies. The transition from platform to sub-basin lithofacies takes place approximately across the (mainly buried) east-northeasterly trending Westmoreland Uplift, a basement ridge that extends from southeastern New Brunswick into southern Prince Edward Island. The Prince Edward Island redbeds contain in part the characteristics of the Platform lithofacies (northern, central and western Prince Edward Island) and in part those of the Sub-basin lithofacies (southeastern Prince Edward Island) except for the youngest redbeds which form a blanket deposit overlying the Cumberland Sub-basin lithofacies in eastern Prince Edward Island.

No formal lithostratigraphic significance is given as yet to the two lithofacies sequences except in Prince Edward Island where separate member status is assigned to each lithofacies sequence being laterally equivalent within the confines of a single formation (Hillsborough River Formation).

Lithostratigraphy of the Prince Edward Island Group (newly proposed, see Fig. 1)

The redbeds of Prince Edward Island Group range from Stephanian to late Early Permian in age. The name is derived from Prince Edward Island where the unit is exposed to the virtual exclusion of all other rocks (Geological map, Fig. 1). The total sequence is represented by fluvioclastic strata in which floodplain, channel and levee-splay facies associations can be readily recognized (van de Poll, 1983; Foley, 1984). Little attempt had been made prior to 1983 to subdivide the redbeds into mappable lithostratigraphic units, except in southeastern Prince Edward Island (Frankel, 1966), mainly because the flat lying nature of the strata, rapid facies changes and the presumed absence of recognizable marker horizons would make subdivision impractical (Frankel, 1966).

Recent work has indicated however (van de Poll, 1983) that the Prince Edward Island redbeds can be subdivided on an island-wide basis into at least five lithostratigraphic units by combining a spectrum of lithologies into major fining-upward (locally first coarsening then fining-upward) megacyclic sequences. Each megacyclic sequence is at least 250 m thick and comprises greyish-red pebble and cobble conglomerate and/or coarse-grained red wacke at the base, fining upwards through reddish-brown, medium- to fine-grained wacke in the middle to orange-red very fine wacke and mudstone at the top. Each megacyclic sequence is in turn made up of smaller scale fluvial cycles comprising channel, levee-splay and floodplain facies associations. Subcyclic sequences resembling megacyclic sequences but on a smaller scale (i.e., lesser thickness) are also present.

Although formal designation of multi-lithology, cyclic stratigraphic units is admittedly unconventional the assignment of formational status to megacyclic sequences nevertheless can be interpreted to fall within the stated purpose of lithostratigraphic subdivision, which is:

> "to systematically organize rock strata of the Earth into named units which will represent the principal manifestations and variations of these rocks in lithologic character. The recognition of such units is useful in general lithologic studies, in determining local and regional structure in working out stratigraphy and geologic history and in investigating and developing mineral resources" (Hedberg, 1972, p. 19).

As a formation is the fundamental formal unit of lithostratigraphic classification and is the rank immediately below a group, it can be argued that each megacyclic sequence may be given the status of formation by virtue of (1) its unified combination of lithologic types (cyclic nature), (2) its character as a unit through its full extent, both vertically and laterally (fining-upward nature), and (3) by its sharp upper and lower (mudstone-conglomerate/sandstone) boundaries. Any further subdivision of whole megacyclic sequences into smaller units with greater lithologic uniformity is not practical because it ignores the lithogenetic affinity of the relatively coarse (multi-channel) and more fine-grained (floodplain) strata within each megacyclic sequence. It was found that under current conditions where the various lithologies are not laterally consistent but represent rapidly changing and interdigitating facies of recurring Multi-story fluvial channel and floodplain cycles, the smallest practical and mappable lithostratigraphic unit of the Prince Edward Island redbeds, on an island-wide basis, is the megacyclic unit (van de Poll, 1983).

Although age plays no role in lithostratigraphy the subdivision of the Prince Edward Island redbeds into five formations (megacyclic sequences) not only improves our knowledge concerning the structure of the redbeds, it also lends credence to Langston's (1963) interpretation that: (1) the age of the redbeds differ from place to place; (2) the oldest strata occur in the southern and western parts of the Island; (3) younger beds appear in the north central part; (4) there is no evidence for the presence of Triassic rocks (except for the diabase sill at Hogg Island). To this may be added that on the Island the uppermost redbeds and perhaps also the youngest occur between Cape Tryon and East Point and also as an outlier in the core of the Kilmuir Syncline of southeastern Prince Edward Island.

Although the degree of chronostratigraphic unity of the formations of Prince Edward Island has not yet been fully assessed, integration of previous and present work suggests that the Pennsylvanian-Permian boundary is centered approximately on the Kildare Capes Formation. The apparently conformable nature of the strata as obtained from borehole intersections and uniformity of composition and fluvial style between the redbeds and the mainly grey strata of the underlying Pictou Group below would suggest that sediment accumulation in the area continued across the system boundary without obvious interruption.

The lithological and morphometric characteristics of the basal pebble and cobble conglomerates contribute greatly to the lithostratigraphic subdivision of the redbeds. Pebble counts of all known conglomerate exposures have confirmed that the conglomerates can be assigned to either one of three major assemblages depending on clast composition, maturity, shape and roundness. Assemblage A conglomerates are characterized by a relatively high quartz + quartzite content and roundness. Assemblage B by a high rhyolite content and Assemblage C by relatively low maturity and low roundness of the clasts (van de Poll, 1983, Fig. 2).

The total redbed succession is slightly tilted (<3°) towards the east-southeast in the western part of the Island and up to 7° to the northwest, north, northeast and southeast in most of the remaining parts of the Island. Dips of 12° to the southeast were observed in the coastal cliff section immediately east of Cape Tryon. In general, dips exceeding 3-4° (i.e., Cape Tryon, Hillsborough Bay, Cape Bear) reflect the effects of salt doming at considerable depth by evaporites of the Mississippian Windsor Group.

In ascending order, the Prince Edward Island Group is subdivided into the Miminegash, Egmont Bay, Kildare Capes, Hillsborough River and Orby Head formations.

(1) ***Miminegash Formation (new, see Fig. 1)***

Only a small segment of the top of the Miminegash Formation is exposed along the western coast of Prince Edward Island. The exposed part of the Miminegash Formation extends along the coast from just south of the town of Waterford to just north of Campbellton. Its exposed thickness is approximately 40 m. Exposures are intermittent and coastal exposures from just north of Miminegash to just north of Campbellton is designated here as the type section. The formation is named after Miminegash, a small fishing and Irish-moss gathering and processing town, situated near the exposed centre of the formation. The formation consists essentially of orange-red mudstone with interbeds of fine- to very fine-grained wacke. The exposed part of the Miminegash Formation makes up the top beds of the unit, the remainder of which underlies the Northumberland Strait, and has also been intersected by P.E.I. Well #5, drilled in 1910 just north of Miminegash in search of coal. The top and upper contact of the unit is exposed in the coastal cliffs just south of Waterford and just north of Campbellton where it is conformably overlain by the relatively medium- to coarse-grained sandstone, intra-formational mud-pellet conglomerate and extrabasinal small-pebble conglomerate of the Egmont Bay Formation. Although coal was not intersected in P.E.I. Well #5, both the red and grey transition sequence as well as the greybeds of the Pictou Group were encountered at shallow depth at 223.9 m and 324.0 m respectively indicating that the Miminegash Formation is the lowermost redbed unit of the Prince Edward Island Group.

Plant fossil imprints including those of fossil ferns similar to the ones found in the Pennsylvanian coal measures of Nova Scotia have previously been recorded from strata along the west coast of the Island now included in the Miminegash Formation (Dawson and Harrington, 1871; Bain, 1881; Bain and Dawson, 1885; Prest, 1973; van de Poll, 1983; van de Poll and Forbes, 1984). Based on the fossil plant evidence, both a Stephanian age (Darrah, 1936) and a Permian age (Holden, 1913) has been suggested for the strata. Copeland (1957) arrived at a Stephanian age based on the bivalve *Carbonita inflata* which was obtained from a lacustrine limestone bed near Miminegash, and which he recognized as a Carboniferous species occurring in Pictou rocks of Nova Scotia and New Brunswick.

A Stephanian age, based on palynological evidence (Barss *et al.*, 1963; Barss and Hacquebard, 1967) has also been previously assigned to the Pictou strata in the Shediac region of New Brunswick. When projected along strike and down dip beneath the Minimegash area at an average inclination of 1-2° these beds would intersect P.E.I. Well #5 at a similar shallow depth (around 600 m) as that found in the core (324 m). Based on the combined evidence from plant, spore and bivalve dates, a Stephanian age is favoured here for the exposed top of Miminegash Formation on Prince Edward Island.

(2) ***Egmont Bay Formation (new, see Fig. 1)***

The Egmont Bay Formation underlies mainly the western part of the Island and is interpreted here to also form the exposed interior of the Gallas Point Anticline (salt cored) with exposures at St. Peters and Governors Island in Hillsborough Bay of southeastern Prince Edward Island.

Its name is derived from the exposures around the coast of Egmont Bay and Cape Egmont, although good exposures of this formation also occur along the western coast of the Island between Miminegash and North Point and between Campbellton and West Point.

The lower limit of the Egmont Bay Formation is well exposed in coastal cliffs, just north of Campbellton where it is set at the scoured and sharp contact between the overlying coarse pebbly sandstone of the Egmont Bay and the mainly red mudstone of the Miminegash Formation below. The upper contact is exposed in the coastal cliffs, some 2 km south of North Point, and is set at the conformable transition from mudstone and fine- to medium-grained wacke of the Egmont Bay below to thick units of quartz pebble conglomerate with interbedded coarse to medium wacke of the Kildare Capes Formation above.

The Egmont Bay Formation comprises a complete fining-upwards megacyclic sequence that can be recognized by its relatively coarse, locally pebbly, wacke at the base changing to mudstone with interbeds of fine wacke at the top. The designated type section lies along the northwestern shore of Prince Edward Island just south of Waterford to approximately 2 km south of North Point. The total sequence represented in the section is approximately 250 m thick.

The age of the Egmont Bay Formation appears reasonably well established from plant fossil and palynological evidence. Like the Miminegash Formation below, the redbeds of the Egmont Bay Formation, in particular the finer grained facies, contain many plant fossil imprints, but no coaly remains. Locally, the plant imprints are extensively hematized with local concentrations of deep purple and ochre colours in the redbeds being a guide to their presence. The plant fossil assemblage is poorly preserved, however, and relatively meagre with *Pecopteris, Alethopteris, Neuropteris, Cordaites, Calamites, Arborescens* and *Walchia* appearing to be ones most commonly present (cf. Dawson and Harrington, 1871; Forbes, personal communication, 1980). They are identical to the ones also occurring in the youngest Pennsylvanian coal measures of Nova Scotia and New Brunswick (Dawson and Harrington, 1871).

Surface and subsurface redbeds of the Egmont Bay Formation are also intersected in at least five wells of which Wellington Station, Port Hill, MacDougall and MacDougall #1A are sited in the western part of the formation and the Hillsborough well is sited in Hillsborough Bay, in the southeastern part. Palynological data indicates that the youngest strata in each well from which spores have been obtained are Stephanian in age, occurring at varying depths between 30-550 m (van de Poll, 1983). On the basis of the total fossil evidence an assignment of a Stephanian age to strata of the Egmont Bay Formation is justified.

(3) *Kildare Capes Formation (new, see Fig. 1)*

The Kildare Capes Formation extends from North Point in the northwestern part of the Island, via the southern coastal region to just south of Souris in eastern Prince Edward Island. The name of the formation is derived from Kildare Capes on the eastern coast between the towns of Alberton and Tignish in northern Prince Edward Island where the formation is particularly well exposed. The designated type-area extends along the coast from North Point to the southern limit of Kildare Capes. Other coastal sections where the formation is well exposed include the one from Port Borden to Rice Point along the southern coast, the coastal area around Hillsborough Bay (Fig. 3), coastal cliffs at Cape Bear and at Durell Point in eastern Prince Edward Island. The base of the formation is marked by the lowermost exposure of Assemblage B (high rhyolite) conglomerates of the Kildare Capes Formation, which on North Point can be seen to overlie the distinctly finer grained beds of the Egmont Bay Formation below. The fine-grained top of the Kildare Capes Formation, because of its low resistance to weathering and erosion, is mainly obscured by surficial deposits in low lying coastal and inland regions except along the eastern shore of Orwell Bay and along Prim Point (Hillsborough Bay). Here the relatively coarse-grained base of the next megacyclic sequence (Wood Islands Member of the Hillsborough River Formation) can be seen to overlie red mudstone and interbedded fine-grained sandstone of the Kildare Capes Formation. The total thickness of the formation is estimated to be approximately 350 m.

The age of the Kildare Capes Formation is not as well documented as that of the older formations. Plant fossil imprints have so far only been reported from Rice Point (van de Poll, 1983), Gallas Point (Dawson and Harrington, 1871), and Murray Head (van de Poll, 1983; Place, personal communication, 1987).

Plant stems replaced mainly by silica, barite and/or hematite, largely too poorly preserved for identification, have been observed from the coastal sections near De Sable (van de Poll, 1983; Dawson and Harrington, 1871) and Gallas Point (Dawson and Harrington, 1871; van de Poll, 1983). Fossil plant remains from the latter locality have been interpreted to indicate a late Pennsylvanian or early Permian age for the strata at Gallas Point (Dawson and Harrington, 1871).

Spore data obtained from purplish grey strata near the surface in Earnscliffe Well # 1 at Gallas Point similarly indicate an early Permian (Sakmarian) age (Barss *et al.*, 1963; Hacquebard, 1972) for the strata assigned here to the Kildare Capes Formation. This early Permian age is further supported by the presence of vertebrate fossils obtained from a number of localities around Hillsborough Bay (Langston, 1963) and by a recent find at Prim Point of tetrapod trackways in upper Kildare Capes strata interpreted to represent *Amplisauropus latus Gilmoreichnus kablikae* and possibly *Ichniotherium willsi* indicating a similar early Permian age (Mossman and Place, 1989). On tenuous evidence Langston (1963, p. 29) suggested that vertebrate fossiliferous beds exposed further west at Seacow Head are

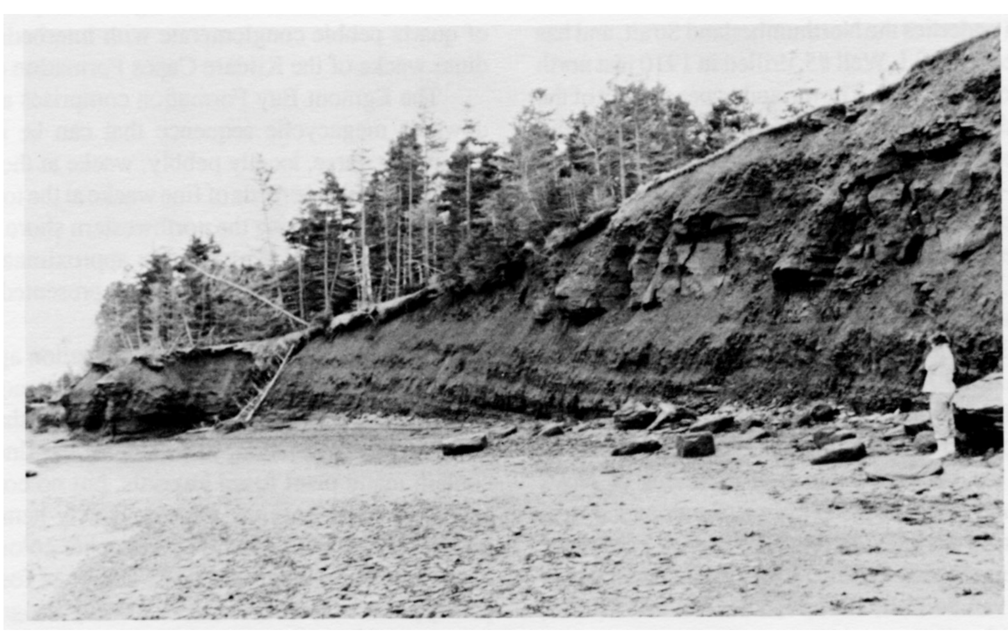

Fig. 3. Slightly tilted fining-upward channel-overbank sequences of the Kildare Capes Formation, at Fort Amherst, Hillsborough Bay near Charlottetown, Prince Edward Island (standing person for scale).

the same age as those around Hillsborough Bay. The present lithostratigraphic interpretation supports this suggestion as the beds at Seacow Head and the Hillsborough coastal region are all included in the Kildare Capes Formation.

On the basis of the available evidence it is suggested here that the Kildare Capes Formation is the earliest Permian unit of the Prince Edward Island redbeds and that the transition from Upper Carboniferous (Pennsylvanian) to Lower Permian is centered on or near the base of this formation.

(4) ***Hillsborough River Formation (new, see Fig. 1)***

The Hillsborough River Formation extends from Malpeque Bay in the west to just south of East Point and also underlies extensively the southeastern part of the Island except for the core of the Kilmuir Syncline and for exposures at Cape Bear which belong to the Orby Head and Kildare Cape formations respectively.

The name is derived from Hillsborough River near Charlottetown and the geographic center of the formation, which is also near the lateral transition boundary between the two members that make up this formation. The upper and lower boundaries of the unit will be discussed below under the sub-headings of the Malpeque and Wood Islands Members.

The Hillsborough River Formation is subdivided into two members in recognition of two distinctly different lithogenetic sub-units within the otherwise similar terrestrial redbed sequence. The lithogenetic dissimilarities reflect the earlier mentioned differences between the New Brunswick Platform and Cumberland Sub-basin lithofacies sequences in terms of morphometrics, and compositional maturity of the basal conglomerates, their overall coarseness and direction of sediment dispersal. Based on these distinguishing features the Malpeque Member forms the western part of the formation and demonstrates lithogenetic affinity with the generally finer grained, more mature and more distal Platformal lithofacies sequence of New Brunswick. The Wood Islands Member forming the eastern part of the formation, belongs more readily to the coarser grained and more proximal, less mature Cumberland Sub-basin lithofacies sequence of Nova Scotia. The Malpeque Member appears to have been derived from an Appalachian source terrane lying to the southwest in the New England states whereas the Wood Islands Member has had a source terrane to the south or southeast, in central Nova Scotia or beyond.

Malpeque Member (new, see Fig. 1)

The Malpeque Member of the Hillsborough River Formation extends from Malpeque Bay to the Elliot River where it grades laterally into the Wood Islands Member underlying southeastern Prince Edward Island. The name of the unit is derived from Malpeque Bay in central western Prince Edward Island.

The Malpeque Member is poorly exposed along the main part of its strike length except where the coarse basal wackes and conglomerates are exposed in gravel pits near Kellys Cross just north of Victoria. Upper and lower contacts with the Orby Head Formation above and Kildare Capes Formation below are not known to be exposed. Judging from the generally gentle northerly and northeasterly dips it is believed here that the Malpeque Member is conformable with both the overlying and underlying strata. The eastern shore of Malpeque Bay from Mills Point where the basal conglomerate is exposed to Profitts Point is designated here as the formal type area for the Malpeque Member, although admittedly the exposure is rather poor. The conglomerates belong to the characteristically high rhyolite Assemblage B. The unit is estimated to be 400 m thick. The age of the Malpeque Member is poorly documented as neither plant nor vertebrate fossils have been identified from this formation. The Tyrone Well located some 18 km to the southwest of Charlottetown intersected Stephanian age spores at a depth of 1308 m. Considering the depth at which Stephanian strata occur in the Tyrone Well taken together with the apparently conformable relationships across the Kildare Capes - Malpeque contact a tentative age that is no older than Early Permian (Asselian-Sakmarian) would seem quite justified.

Wood Islands Member (new, see Fig. 1)

The Wood Islands Member of the Hillsborough River Formation is approximately laterally time-equivalent to the Malpeque Member but its different composition, unique within the Prince Edward Island redbed sequence, warrants its separate member status.

The Wood Islands Member extends from the Elliott River area on its western margin, via Prim Point, Wood Islands, Panmure Island and Souris to just south of East Point. The Member is interpreted here to extensively underlie the central eastern part of the Island, an area of virtually no exposure.

The name of the member is derived from Wood Islands in southeastern Prince Edward Island where the characteristic basal conglomerates are particularly well exposed. The western limit of the Wood Islands Member merges with the Malpeque Member in the Charlottetown (Elliot River) area where the conglomerates of the transition zone typically display a bimodal nature reflecting in part the characteristics of Assemblage B (high rhyolite content) of the Malpeque Member and in part those of Assemblage C (relatively immature, low roundness, low rhyolite content) of the Wood Islands Member. Thin, small-pebble conglomerate lenses of the Wood Islands member have been traced along strike to as far northeast as the Souris area, indicating lateral reductions in clast size and presumably also in unit thickness away from Wood Islands in both directions (to the west and the northeast).

The designated type section for the Wood Islands Member lies along the southeastern limb of the Kilmuir Syncline, and extends along the southeastern coast from Nicholson Point to High Bank.

The lower contact of the member is exposed along the Prim Point peninsula, where upper red mudstone and interbedded fine wackes of the Kildare Capes Formation is conformably overlain by the medium to coarse, locally pebbly, wackes of the Wood Islands Member. This is one of the best and most accessible sections where the upper part of a megacyclic sequence is exposed. Interestingly the conglomerates of the Wood Islands

Member do not reach to the base of the unit but commence at some distance above the base. This led Foley (1984) to suggest that the megacyclic sequences are not entirely fining up as previously stated by van de Poll (1983) and van de Poll and Forbes (1984), but display in part coarsening-up tendencies. Depending on where one wishes to place the contact each megacyclic sequence may either (1) in part be fining and then coarsening up, if the base of each megacyclic sequence is taken at the first conglomeratic interval, or (2) coarsening up changing to fining up, if taken at the most significant lithologic change, i.e., the first appearance of medium- to coarse-grained wacke or conglomerate. Given that in a sequence of conformable strata of similar lithologies and facies, stratigraphic boundaries are at best somewhat artificial, it is suggested here that, (1) because of time-lag in the fluvial system, conglomerates may not everywhere appear at the same time at the base of each megacyclic sequence (formation), and (2) lithostratigraphic practice is best served by establishing unit boundaries at the most significant lithologic change. In the redbeds at hand, this most significant lithologic change is from mudstone below to coarse wacke (conglomerate if present) above. Provided that the contact is laterally continuous over a considerable mappable distance the sharp mudstone-wacke (conglomerate) transition would be the preferred one to use. Adherence to this suggestion means that formations and members can in part be coarsening up at first and then fining-upwards as well as entirely fining-upwards. Results of a detailed lithofacies and sediment dispersal analysis of the redbeds between Prim Point and Murray Head has indicated that the Wood Islands Member (Megacyclic Sequences III and IIIA) is not fining upwards but is for the main part coarsening upward, culminating in the coarse conglomerates at Wood Islands (Place and van de Poll, 1988). It should be remembered, however, that the coastal section from Nicholson Point to Murray Head is on the average 15° to the strike of the beds.

The section therefore can be expected to display both vertical and lateral lithofacies changes. It is known that the conglomerates diminish in clast size away from the coarsest conglomerates at Wood Islands. It is quite possible therefore that the coarsening-upward nature of the Wood Islands Member is more apparent than real and that it may reflect at least in part lateral (east west) lithofacies changes across a northward prograding braidplain or alluvial fan.

The top of the Wood Islands Member is not exposed but is projected to lie just below the basal conglomerates of the Orby Head Formation. Previous mapping (van de Poll, 1983) has shown the Wood Islands Member in the type area to consist not of one but at least two fining upward sequences both conglomeratic at the base with a mudstone interval at the top. Both conglomerates typically belong to Assemblage C, however, and in the current regional stratigraphic subdivision it is probably best to combine both sequences into one member. Its exposed combined thickness in the type section is approximately 910 m (Place, personal communication, 1988), not including approximately 100 m of concealed strata at the top of the unit which are not exposed in the type section.

The Wood Islands Member is of special interest here because its conglomerates are unique in composition and maturity, with respect to the other conglomerates (Assemblages A and B) of the Prince Edward Island redbeds. The Wood Islands conglomerates are compositionally less mature and less rounded than any of the other conglomerates in the Prince Edward Island Group. The common presence of disc and roller shaped pebbles (Zingg classification, Blatt *et al.*, 1980) suggests an origin mainly from a relatively nearby meta-sedimentary (greywacke) terrane. This observation coupled with a generally northerly direction of sediment transport (based on cross-bedding) in the Wood Islands Member (van de Poll, 1983) suggests that these redbeds represent a northward prograding alluvial wedge of the Cumberland Sub-basin lithofacies across the northeasterly prograding New Brunswick Platform lithofacies (see also Frankel, 1966; Foley, 1984; van de Poll and Ryan, 1985). The lithogenetic influence of this northward prograding wedge may have been of relatively short duration as it does not extend upwards into the more mature conglomerates of the overlying Orby Head Formation. It is not known, however, whether or not the Cumberland Sub-basin lithofacies extend downwards into the underlying Kildare Capes Formation.

The Wood Islands Member is mildly folded by the effects of salt tectonics at depth beneath Hillsborough Bay (Gallas Point Anticline), and by uplift of an unnamed structure (salt cored anticline?, basement uplift?) lying offshore to the east of Cape Bear. The age of the Wood Islands Member has not yet been documented for lack of recognizable fossils. It overlies the Early Permian Kildare Capes Formation conformably however, and like its laterally equivalent Malpeque Member, its suggested age is Early Permian (Asselian-Sakmarian).

(5) ***Orby Head Formation (new, see Fig. 1)***

The Orby Head Formation underlies the central northern and northeastern part of the Island extending from Profitts Point in the west to East Point in the east. An outlier of the Orby Head Formation comprising mainly conglomerate and coarse to medium wacke underlies the core of the Kilmuir Syncline in southeastern Prince Edward Island.

The formation is named after Orby Head, a prominent headland near Cavendish on the north shore of the Island where it is particularly well exposed. Good exposures also occur along the north shore between Profitts Point and New London Bay, from Beaver Point to East Point, and in several conglomerate (gravel) pits in the core of the Kilmuir Syncline. The basal contact is not exposed and is arbitrarily set at just below the occurrence of basal conglomerates (Assemblage A, low rhyolite, well rounded pebble and cobbles) of the Orby Head Formation. The top of the formation lies to the north in the Gulf of St. Lawrence. Much of the mapped exposures of the Orby Head Formation are strike sections and a well exposed type section representative of all of the sequence is not available. The best section for this purpose would be coastal exposures west of Cape Tryon but unfortunately the characteristic Assemblage A conglomerate is not exposed at the base here.

The lack of inland exposures is further complicated by two northeasterly trending and plunging(?) salt-pillow or broad anticlinal structures centered on Cape Tryon and Orby Head separated by a synclinal or basinal structure centered on New London Bay in between.

The age of the Orby Head Formation is poorly documented. Identifiable plant fossils have not been encountered or reported from the Orby Head redbeds except for a few doubtful specimens completely replaced by hematite from the St. Peter's Bay area. Rhizocretion-like carbonate-filled tubal structures up to 3 cm in diameter and up to 75 cm in length are locally present at Orby Head and East Point and some of them could conceivably represent fossil roots.

The Irishtown, Green Gables and Naufrage wells spudded in surface exposures of the Orby Head Formation all have Early Permian or Stephanian to Early Permian spores reported from strata ranging in depths between 671 and 853 m.

A few vertebrate fossils were previously reported from strata in northern Queens County, now assigned to the Orby Head Formation. Most notable among them is the type specimen of *Bathygnathus borealis* Leidy (Fig. 4), discovered in 1845 during the digging of a well about 2.8 km south of Cape Tryon lighthouse in the French River district (Langston, 1963). The age of the vertebrate fossils is believed to be approximately early Artinskian, younger than the Early Permian strata of the Hillsborough Bay area (Langston, 1963, p. 28). On the basis of this information, and considering the apparently conformable relationship with older Permian strata below, it would seem reasonable to conclude that an Artinskian age is probably correct and that the youngest sedimentary rocks of the Island are probably no younger than late Early Permian in age.

SUMMARY

(1) It is proposed here to modify the Permo-Carboniferous stratigraphy of eastern Canada with the establishment of a new supergroup named the Northumberland Strait Supergroup.

(2) The Northumberland Strait Supergroup is bounded at the base by a disconformity of Westphalian B age except in the Cumberland Sub-basin of Nova Scotia where the Cumberland Group apparently grades upward into the Northumberland Strait Supergroup without interruption. The top of the supergroup is tentatively set at the late Paleozoic unconformity separating in eastern Canada, Permo-Carboniferous from Triassic strata.

(3) The approximate age of the supergroup ranges from early Westphalian C to early Artinskian (European stages) or Desmoinesian to Leonardian (North American stages) covering a timespan of some 40 million years.

(4) It is further proposed here to subdivide the Northumberland Strait Supergroup into two Groups: the Pictou Group below and the Prince Edward Island Group above. The Pictou Group continues to incorporate all Westphalian C, D and Stephanian aged grey and redbeds, and coal measures of New Brunswick and Nova Scotia which have historically been assigned to it. The Prince Edward Island Group is a newly proposed lithostratigraphic unit to include all of the redbeds of Prince Edward Island. The contact between the Pictou and Prince Edward Island groups being essentially based on colour, is gradational and time transgressive across the Stephanian Stage. The age of the group is from Stephanian to late Early Permian.

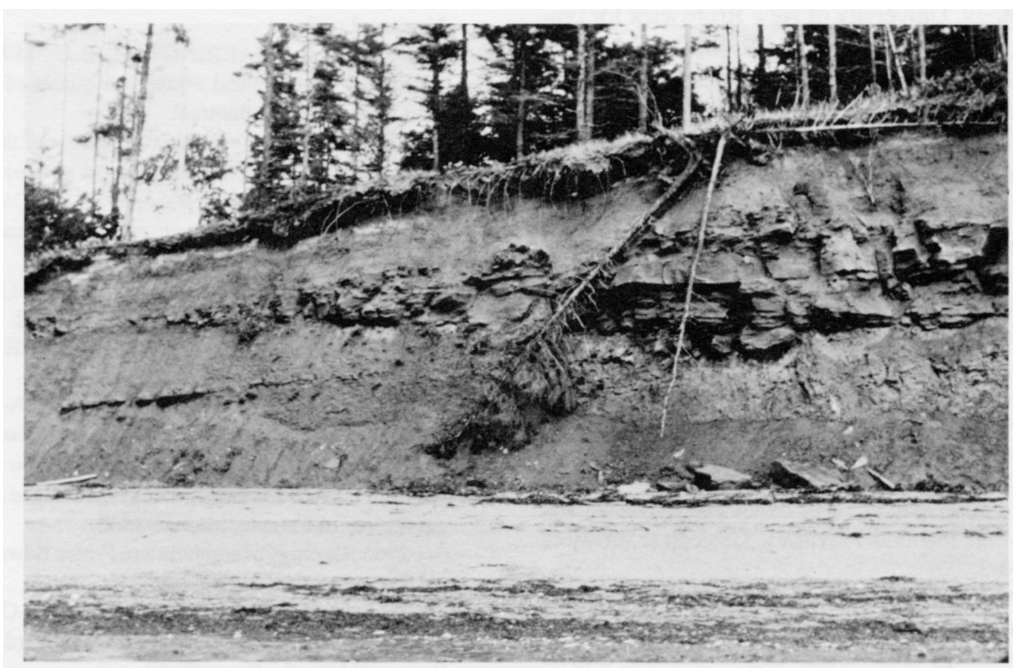

Fig. 4. Small channel and levee-splay sequence in floodplain strata of the Kildare Capes Formation at Tea Hill, Hillsborough Bay near Charlottetown, Prince Edward Island (trees for scale).

(5) The Pictou Group has not yet been formally subdivided into formations, but a proposal is made here to subdivide the Prince Edward Island Group into five formations and two members.

From oldest to youngest the proposed five formations of the Prince Edward Island Group are: the Miminegash, Egmont Bay, Kildare Capes, Hillsborough River and Orby Head formations. Of these, the Hillsborough River Formation is subdivided into two laterally equivalent members, the Malpeque and Wood Islands members which have separate lithogenetic affinities with the New Brunswick Platform lithofacies and Cumberland Subbasin lithofacies respectively.

Redbeds of the Prince Edward Island Group are slightly folded on northeasterly trending and plunging axes attributed here in part to slight post-depositional tilting of basement and overlying strata and in part to salt migration (Windsor evaporites of Mississippian age) into salt pillows and/or domes at depth.

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