

REVISION OF NOVA SCOTIA MIDDLE CARBONIFEROUS UNITS

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ABSTRACT. The Windsor, Canso, and Riversdale Groups of Nova Scotia, originally defined as time-stratigraphic units of late Viséan, Namurian A, and Westphalian A ages respectively, have been mapped by previous workers either as time-stratigraphic or as rock-stratigraphic units. A restudy of these units as previously mapped shows that they are valid lithologic units in certain districts of Nova Scotia and invalid in others.

Recent revision of fossil megaplant ranges in the Namurian standard section in Belgium and evidence from Nova Scotia fossil arthropods and microspores suggest that Namurian B and Namurian C are not missing between the Canso and Riversdale Groups as previously thought. Furthermore, no angular discordance is apparent between the two groups in any sections excepting those in western Minas structural basin.

The present revision is concerned with establishing natural middle Carboniferous lithologic units by extending the previous units where they were used as rock units into regions where they were used as time-stratigraphic units. The lithologic correlation was checked by fossil microspore zones constructed by M. S. Barss. Consequently, the Mabou Formation (previously considered synonymous with the Canso Group) is here raised to group status, and Canso and Riversdale Groups are no longer regarded as valid group terms. Windsor Group in the Cumberland structural basin is restricted to include only those nonmarine strata that contain interbedded marine limestone and evaporites.

The Mabou Group consists of nonmarine lutite and subordinate fine- to medium-grained sandstone; the group is subdivided into a dusky-red and greenish-gray fluvial facies and a dark- to medium-gray lacustrine facies. The Mabou Group conformably overlies marine limestone and evaporites of the restricted Windsor Group and interfingers laterally with and/or is conformably overlain locally by an "older coarse-grained" marginal facies (Boss Point or Port Hood Formations, or Cumberland Group), or it is unconformably overlain by a "younger" but similar coarse-grained blanket deposit (Pictou Group). Mabou strata include the West Bay, Parrsboro, Point Edward, Maringouin, Shepody, Middleborough, Lismore, and Cape Dauphin Formations of previous workers; all but the last two are retained here as formations within the new group. The Mabou Group is a valid group because it is subdivided into a number of mappable lithologic units (formations) and because it is lithogenetically distinguishable from the underlying Windsor Group and the overlying or laterally equivalent coarse fluvial facies.

INTRODUCTION

This paper proposes a group name and suggests revision of the previous subdivision of middle Carboniferous¹ strata in Nova Scotia. Revision is considered necessary because the previous units represent inadequately the lithologic facies and are wholly or in part based on the ranges of fossils contained in them. Detailed field work indicates that the unit here proposed, the Mabou Group, can be subdivided into formations and mapped over a large part of the province. Fossil microspore zones by M. S. Barss (ms) of the Geological Survey of Canada support the revised facies interpretation and reveal discrepancies in the previous subdivision of middle Carboniferous strata. In addition, studies in Europe (Stockmans and Willièrè, 1953) have revised the ranges of many Namurian and Westphalian megaplants common to Nova Scotia. This in turn

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¹ Middle Carboniferous is used here informally because the stratigraphic units and the facies under discussion span the Lower-Upper Carboniferous boundary and the Mississippian-Pennsylvanian boundary. Middle Carboniferous here includes the Riversdale Group, the upper Windsor Group, and the Canso Group of previous workers (Weller, 1948; Moore, 1944).

modifies the previous Nova Scotia correlation (Bell, 1944b) with European standard time units.

PREVIOUS SUBDIVISION

The area under consideration consists of the region of middle Carboniferous outcrop in the northern half of Nova Scotia. The localities shown on figure 1 indicate the general distribution of those outcrops. These localities are only the critical sections; many other sections studied are not shown.

Depositional setting

During Carboniferous time, about 25,000 feet of strata were deposited in an irregularly-shaped, rapidly subsiding basin designated the Fundy basin (Bell, 1958). Middle Carboniferous sediment in the basin was derived from source areas either outside the basin to the south and west (parts of the Meguma and New Brunswick Platforms, fig. 1) or from regions within or jutting into the basin (Caledonia and Cobequid Axes, fig. 1). The northern and eastern limits of the Fundy basin are poorly defined by the Nova Scotia Carboniferous facies; in fact the edge of the basin may have been north of Prince Edward Island somewhere in the Gulf of St. Lawrence. The entire Carboniferous section on the Meguma and New Brunswick Platforms thins to less than half that found in the Fundy basin. Carboniferous outcrops are widespread on the New Brunswick Platform but have been almost entirely removed from the Meguma Platform by post-Carboniferous erosion.

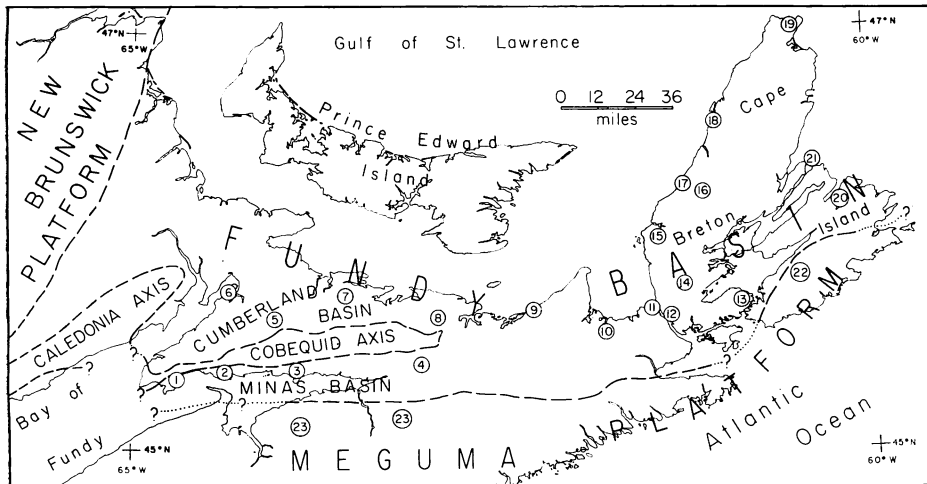


Fig. 1. Index map showing location of sections and tectonic framework for middle Carboniferous deposits. The following localities are identified according to number: 1, Spencers Island; 2, Parrshoro and West Bay; 3, Economy River and Economy Shore; 4, Salmon River and Black River near Truro; 5, Black River near Springhill; 6, Minudie shore to Downings Cove; 7, Wallace River; 8, Scotsburn anticline; 9, Merigomish basin; 10, Antigonish basin; 11, Bellefontaine-Creignish basin; 12, Richmond syncline; 13, River Tillard-Scott Brook syncline; 14, Maple Brook syncline; 15, Port Hood-Southwest Mabou River basin; 16, Mount Pleasant Brook; 17, Broad Cove; 18, Grand Etang shore to Friar Point; 19, Bay St. Lawrence shore; 20, Sydney basin; 21, Cape Dauphin; 22, Grand River and Big Barren fault blocks; 23, Stewiacke and Kennetcook synclines.

Carboniferous sedimentary rocks reflect either a nonmarine fluvial or lacustrine environment, or a marine environment of deposition (Gussow, 1953; Bell, 1958; Neale and Kelley, 1960; Greiner, 1962; Belt, 1963a; Laming and Lawson, 1963). Evaporites and limestone containing neritic or littoral fauna account for about 5 percent of the total Carboniferous strata; the remainder consists of nonmarine, fluvial, and lacustrine strata.

Lower Carboniferous strata

Thin marine beds alternating with thicker fluvial and fluvio-lacustrine beds are restricted to a small stratigraphic segment in the lower part of the Carboniferous section. These strata, easily recognized by early workers (Lyell, 1843; Logan, 1845), have been designated the Windsor Group (Dawson, 1873; revised by Bell, 1929). Strata below the Windsor Group and above the pronounced pre-Carboniferous unconformity form an entirely nonmarine fluvial and lacustrine unit designated the Horton Group (Dawson, 1873; revised by Bell, 1929).

Windsor Group.—The Windsor Group forms a natural lithologic unit only where it has been subdivided by previous workers (Bell, 1929; Stacy, 1953; Sage, 1954) into six subzones (A through F) based on marine invertebrates. The subzones indicate a late Early Carboniferous (middle or late Viséan) age (Bell, 1944b; Hacquebard, 1960). Many of these subzones have been reported from outside Nova Scotia, namely, from New Brunswick, Prince Edward Island, Magdalen Islands, and western Newfoundland (Bell, 1948, 1958; Gussow, 1953; R. D. Howie, personal communication). The nonmarine facies are similar to fine-grained fluvial facies above and below Windsor strata, and as the Windsor facies contain poorly preserved megaplant fossils, rock type or megafossils are of little use for correlation. Nonmarine Windsor microfossils (microspores) are being studied by the Geological Survey of Canada in order to correlate the nonmarine facies (Barss, personal communication). Nonmarine units previously assigned to the upper Windsor strata (Bell, 1944b) in the Cumberland structural basin (fig. 1) are here excluded from the Windsor Group and included with the overlying nonmarine unit (formerly Canso Group, here Mabou Group), as previously suggested by Gussow (1953, p. 1750), because they overlie the highest stratigraphic occurrence of marine beds in that region.

Post-Windsor subdivision

The unity of both the Horton and the Windsor Groups as previously used throughout most of the province is based on lithology and not the ranges of fossils because Horton megaplants are not found in the Windsor or succeeding strata and Windsor marine fossils are not found in the Horton or other Carboniferous units. Hence facies fossils whose distribution is controlled by environmental changes prevent a time-stratigraphic subdivision of the lower Carboniferous strata. Subdivision of the Horton Group is based on lithologic rather than paleontologic criteria because its megaplants are sparse and long-ranging. Subdivision of the Windsor Group is based on the vertical distribution of marine fossils (criteria that are both lithologic and time-stratigraphic); the validity of the subzones is beyond the scope of this discussion. In contrast,

two of the post-Windsor units (Canso and Riversdale) are based on the ranges of fossils only (Bell, 1944b), and it will be shown here that these units do not correspond to valid lithic facies.

A great thickness of nonmarine strata overlies the widespread upper Windsor marine limestone and evaporites. Inasmuch as these rocks contain commercial coal, subdivision was attempted early in the history of their study (Lyell, 1843; Logan, 1845; Dawson, 1845, 1855, 1873). The subdivision was based on the British scheme and was formalized by Dawson. Between 1870 and 1900 inch-to-the-mile mapping by the Geological Survey of Canada emphasized the inadequacy of Dawson's subdivisions, so that they were revised in the early part of this century (Bell, 1912; 1926; 1938, especially p. 1-19, maps 359A, 360A, 361A with marginal notes; 1944b). The nomenclature developed by Bell (1944b) is currently used by most workers in the province. His subdivisions with the relative age according to Hacquebard (1960) are:

Pictou Group (late Westphalian B, Westphalian C and D)

Cumberland Group (early Westphalian B)

Riversdale Group (early Westphalian A)

Canso Group (Namurian A).

Bell (1944b, fig. 10, p. 2-4; 1958, p. 31, 33, 34) defined each unit by (a) the ranges of fossil megaplants and/or nonmarine invertebrates, and (b) convenient stratigraphic horizons interpreted as unconformities or disconformities. In some cases Bell's groups defined a valid lithologic unit, but as this is not the case in the type sections of the Canso and Riversdale Groups, they will be considered here in some detail.

Canso Group.—The Canso Group of previous workers is a nonmarine unit consisting principally of lutite interbedded with fine-grained sandstone, and in parts of Cape Breton Island (fig. 1, locs. 15, 17, 18, 20, 21) is a valid lithic unit which occurs above marine Windsor strata and below coarse fluvial facies previously assigned to the Riversdale or Pictou Groups. In the Cumberland structural basin (fig. 1, locs. 6-7), Canso strata do not form a lithic unit because they overlie similar fine-grained nonmarine fluvial facies assigned by previous workers to the upper Windsor Group, although they underlie a marked lithologic change of coarse fluvial facies assigned to the Riversdale Group (Bell, 1944b, 1958). Elsewhere (fig. 1, locs. 1, 2, 9, 13, 14), Canso rock types are very similar to the entire Riversdale section at those localities. In other areas (fig. 1, locs. 10, 12), Canso rock types are similar to the lower Riversdale section at the same locality. In the localities where Canso rocks are lithologically similar to the upper Windsor or Riversdale sections, the upper and lower boundary of the Canso time-stratigraphic "group" occurs within a lithogenetic unit of fine-grained fluvial or lacustrine facies. A marked lithologic change (either the occurrence of marine horizons in the Windsor or the occurrence of coarse fluvial strata in the Riversdale) is found several hundred to several thousand feet stratigraphically above or below the Canso beds of previous workers. In western Minas structural basin (fig. 1, locs. 1, 2), however, an angular unconformity marks the boundary and occurs within a fine-grained (though locally conglomeratic) fluvial and lacustrine facies, and thus here the previous Canso-Riversdale boundary is well defined on structural grounds.

The Canso Group type section (fig. 2) originally designated by Bell (1944b) occurs in the Richmond syncline on the Strait of Canso (fig. 1, loc. 12). Bell (1958, p. 140), Kelley (personal communication), and Hacquebard (personal communication) note that the Canso-Riversdale contact in the Canso type section was arbitrarily placed at a predetermined number of several thousand feet below (by Ferguson, 1946) a specific "marker" sandstone (fig. 2) prominently exposed on the shore but unfortunately similar to other sand-

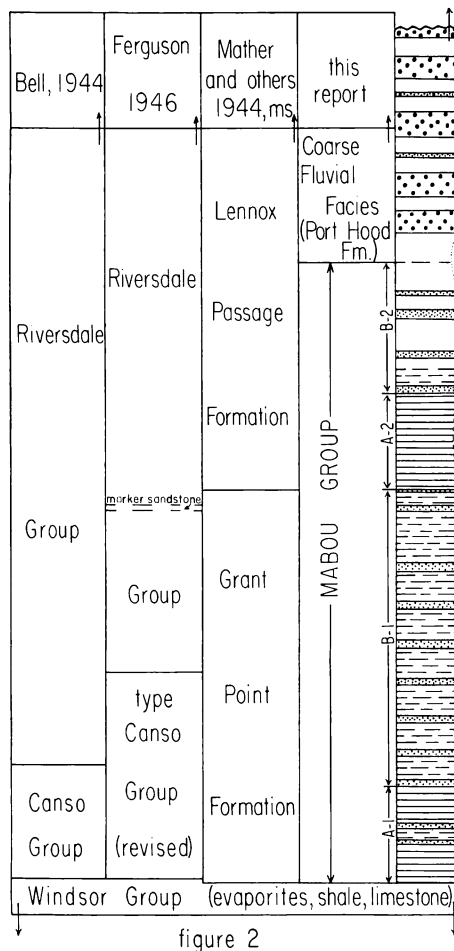


figure 2

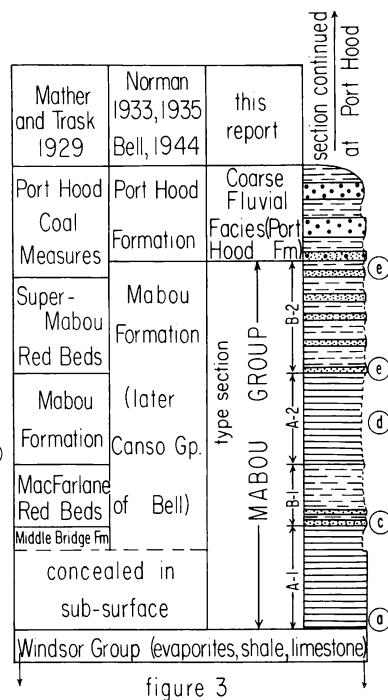


figure 3

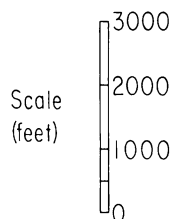


Fig. 2. Reference section of the Mabou Group on the strait of Canso and Emery Brook, Richmond syncline, compared with previous subdivision.

Fig. 3. Type section of the Mabou Group on the southwest Mabou River and Campbell Brook compared with previous subdivision.

In both figures, horizontally ruled lines represent dark- to medium-gray shale; dashed lines represent dusky-red and greenish-gray lutite; fine dots represent fine-grained sandstone; coarse dots represent coarse-grained sandstone. Encircled lower-case letters to the right of the lithologic column represent fossil microspore zones. Mabou Group is subdivided into two facies, A and B, and each show a lower (1) and an upper (2) member.

stone units in the Richmond syncline and elsewhere. The type section of the Canso unit was originally defined to include 1844 feet of strata (Bell, 1944b, p. 6), but was later redefined to include 3342 feet of strata (Ferguson, 1946; Ferguson and Weeks, 1950). Bell (1958, p. 140, and personal communication) approved the revision because the Canso Group was better defined by Windsor and Riversdale fossils in the Southwest Mabou area (fig. 1, loc. 15) where it had a thickness of about 4000 feet (therefore to Bell 3342 feet was preferable to 1844 feet). Although the Canso Group in the Southwest Mabou area (termed the Mabou Formation by previous workers) formed a natural lithic unit, neither the original nor the revised boundaries of the Canso Group in the Richmond syncline were placed at changes in lithology (fig. 2). Hence the currently accepted type section is misleading as a lithologic basis for recognizing the Canso elsewhere. Furthermore, the need for lithologic subdivision of the strata in the Richmond syncline (fig. 2) was demonstrated by Mather, Tullis, and Beck (ms, p. 26) because of the lack, in their estimation, of fossil material for time-stratigraphic subdivision. Unfortunately, their subdivisions were not used by subsequent Canadian workers.

Canso strata are considered by most previous workers to be Namurian A in age throughout the province. The majority of fossils correlated with European standard sections are megaplants (Bell, 1944b, p. 23-25; 1958) and crustacea (Copeland, 1957), and these occur mainly in the Parrsboro district or in the Sydney district (fig. 1, locs. 2, 20, respectively) and not in many other sections, notably the Canso type section. Most other Canso sections contain a few scattered megafossils, namely branchiopods (Leaïid and Estheriïd types), megaplants (*Calamites*, *Sphenopteris*, *Lepidodendron*), and pelecypods (*Carbonicola*, *Myalina*). These megafossils because of their endemic or scattered occurrence are of little use for intercontinental correlation of specific horizons, and thus only a small number of the Canso sections can be correlated to standard sections with any confidence.

From the above reasoning it becomes evident that rocks of the Canso Group cannot be distinguished from some Windsor and some Riversdale rock types. This is particularly true of the Canso Group type section. Furthermore, Bell (1944b), following the time-stratigraphic method of rock subdivision, considers the Canso and all other Carboniferous "groups" in Nova Scotia to be a "local or provincial unit which may represent only part of an epoch" (p. 5, footnote). On that basis, the Canso Group of Bell (1944b) is a time-stratigraphic unit to the degree that it is considered Namurian A throughout its extent.

Riversdale Group.—The Riversdale Group of previous workers consists of two distinct facies; (1) yellowish-gray medium- to coarse sandstone with minor beds of dusky-red and greenish gray or medium-gray lutite and fine-grained sandstone; conglomerate is abundant; (2) dark to medium-gray and dusky-red lutite with beds of fine-grained sandstone. The coarse facies, believed to be fluvial in origin (Bell, 1958; Laming and Lawson, 1963), comprises the entire Riversdale section in the Cumberland structural basin (fig. 1, locs. 5, 6, 7, 8), on western Cape Breton Island (fig. 1, locs. 15, 17, 18), and on the Meguma Platform (fig. 1, locs. 22, 23). The fine-grained facies, believed to be fluvial and lacustrine in origin (Bell, 1958), comprises the entire group in the

Minas structural basin (fig. 1, locs. 1, 2, 3, 4), north of St. Peters on Cape Breton Island (fig. 1, loc. 13), and in the Merigomish basin (fig. 1, loc. 9). In other areas, the fine-grained facies comprises the lower portion and the coarse facies comprises the upper portion of the Riversdale section (fig. 1, locs. 10, 12). The remaining sections in figure 1 are too incomplete for similar analysis. The fine-grained Riversdale facies are very similar to those in the Canso Group, and all these fine-grained facies, whether in the Canso or the Riversdale Group, are markedly different from the coarse Riversdale facies.

The type section of the Riversdale Group, in eastern Colchester County on the Salmon and Black Rivers near Truro (fig. 1, loc. 4), consists of dark- to medium-gray lutite with beds of medium-gray sandstone and dusky-red lutite—i.e. the fine-grained facies described above. The section is fairly well exposed, but unfortunately it is located in a fault block within which extensively folded and faulted strata are not in contact with older or younger Carboniferous units outside the fault block. In addition, fossils are not abundant, and because the structural complexities within the fault block have not yet been unraveled, few fossils can be located stratigraphically within the estimated 7000 feet of section. In spite of these difficulties, fossils from the Riversdale type section are frequently the basis for Riversdale correlation throughout Nova Scotia; Riversdale strata are considered Westphalian A by most workers (Norman, 1935, p. 47; Bell, 1944a, p. 111; 1944b, fig. 11; Weeks, 1954, p. 80-81; Copeland, 1957, p. 9; Hacquebard, 1960, table 3). As in the case of the Canso Group, the majority of Riversdale fossils used for correlation with Europe and the United States are megaplants and nonmarine crustacea. In contrast with the Canso Group, diagnostic fossils are fairly abundant in many although scarce or extremely rare in certain (fig. 1, locs. 3, 9, 10, 12, 13, 14) Riversdale sections. In those sections (locs. 13, 14, and many other incomplete sections not shown on fig. 1) where the pelecypod *Naidites* sp.² is found alone or associated with fossils that are of little value for correlation, the strata containing the pelecypod were assigned to the Riversdale Group. Unfortunately, *Naiadites* sp. was used by Bell (1944b, p. 25) for defining the Riversdale Group faunally and was thus considered by most previous workers to be confined to that "group". It was found by the writer (Belt, ms, p. 201-202, figs. 109-112) associated on the same bedding plane with *Carbonicola* (?) *angulata* (Dawson),³ a pelecypod used by Bell (1944b, p. 23) for defining the Canso Group faunally. Only one such locality was found, however (fig. 1, loc. 3). Thus, if the identification is correct (tentative by W. A. Bell, verbal communication; M. J. Rogers, written communication), those two pelecypods, endemic to Nova Scotia, are misleading for correlation within the province, although widely used for such.

DISCUSSION

If the Canso and Riversdale Group of previous workers are separated by a disconformity (paraconformity in the sense of Dunbar and Rodgers, 1957)

² Formerly cited as *Naiadites* of the *N. modiolaris* group by Bell (1944b); Rogers (in press; personal communication) showed it was a species of *Naidites* not previously described and whose range was unknown.

³ Formerly cited as *Anthracomya angulata* by Bell (1944b); the change in nomenclature was proposed by Rogers (1963).

that represents a large amount of missing section spanning the late Namurian and if the hiatus can be proved to exist throughout Nova Scotia (not just in western Minas basin where fossil evidence is good and an angular unconformity is seen), then Mabou Group as defined below has no lithogenetic justification. On the other hand, if it can be shown that the hiatus between the Canso and Riversdale Groups is localized near an active source area (namely the Cobequid Axis) and that elsewhere in Nova Scotia continuous deposition with only minor hiatuses prevails, then Mabou Group is valid.

The problem might be attacked by considering (a) the structural evidence at the point of contact between the Canso and Riversdale Groups of previous workers, and (b) the paleontologic evidence across the previous Canso-Riversdale boundary. Of these, the paleontologic evidence is more critical, but as this is most frequently lacking at the contact previous workers have had to rely rather heavily on the structural evidence alone.

Canso-Riversdale unconformity

The contact between the Canso and Riversdale Groups of previous workers is exposed, or present but concealed, in many sections in Nova Scotia (fig. 1, locs. 1, 2, 6, 7, 9, 10, 12, 14, 15, 17, 18), but angular discordance can be seen only in western Minas structural basin (fig. 1, locs. 1, 2). The possible existence of angular discordance in western Cape Breton Island (fig. 1, locs. 17, 18) has caused considerable controversy between those in favor of no discordance (Eastern Gulf Oil Company, Mather and Trask, 1929; Norman, 1935; Cameron, 1948; Copeland, 1957; Kelley, 1958; Belt, ms) and Dr. Bell (1944a, b; 1958) who is in favor of slight angular discordance. Thus most previous workers note the lack of angular discordance between the Canso and Riversdale Groups in all but sections 1 and 2, and they consider the contact disconformable because of the fossil evidence.

Apparently, therefore, only paleontologic evidence can be relied on to establish the presence of a large hiatus between the Canso and Riversdale Groups except in the Minas structural basin. The problem then becomes that of deciding whether the contact is one of disconformity or of continuous deposition.

Riversdale correlation

The paleontologic evidence used by previous workers for a disconformity between the Canso and Riversdale Groups appears to be insufficient. In all sections where the contact is exposed and undeformed (fig. 1, locs. 6, 7, 9, 10, 12, 15, 17, 18), no megafossils of any use for correlation are found within several hundred and in some cases several thousand feet stratigraphically above or below the contact. Thus the fossil evidence (Dunbar and Rodgers, 1957, p. 127; Weller, 1960, p. 398-400) that would determine whether or not a disconformity exists between the two groups is lacking at or near the contact.

Most paleontologists concerned with correlating Canso and Riversdale strata with the standard North American and European time-stratigraphic units consider Canso Group to be Namurian A and Riversdale Group to be Westphalian A (Bell, 1944b) or early Westphalian A (Hacquebard, 1960). The Southwest Mabou River section (fig. 1, loc. 15), however, is considered on

fossil arthropod evidence by Copeland (1957, p. 8) to represent continuous deposition between the base of the Namurian and the base of the Westphalian; likewise Bell (1958, p. 111) implied no hiatus in that section when he indicated that the Canso Group there extended into "Late (?) Namurian".

Bell's data on the ranges of megaplants in the Riversdale, however, need to be reexamined as a result of a recent study on the Namurian flora in the type section in Belgium (Stockmans and Willièrè, 1953). Namurian type megaplant fossils were compared with floral lists for most of Europe, Great Britain, U.S.S.R., and the United States. All the important megaplant species of the Riversdale Group, described by Bell (1944b, p. 25-26, fig. 10) and listed in table 1, are found in many other localities, significantly in the type Namurian, to range into the Namurian B and C and are not confined to the Westphalian A.

TABLE 1

Megaplant fossils of the Riversdale Group, considered by Bell (1944b) no older than Westphalian A, are found to range to the base of the Namurian B (data from Stockmans and Willièrè, 1953) in the following countries. Stratigraphic units containing the flora are as follows: United States, (West Virginia, Virginia), Pocahontas seams 1 to 3; Great Britain (South Wales coalfield), Floral Zone B; France, couches d'Annocullin; Belgium, assise d'Andenne; Netherlands, Epen group; Germany (1), (Westphalia) Flözleeres; Germany (2), Lower Sattelflozgruppe; Poland (Upper Silesia), couches anticlinales; U. S. S. R. (Donez), zone C₁⁴ and lower zone C₁⁵.

	United States	Great Britain	France	Belgium	Netherlands	Germany (1)	Germany (2)	Poland	U.S.S.R.
<i>Sphenopteris obtusiloba</i>	cf.			X	X				
<i>Sphenopteris schätzlarensis</i>						X			X
<i>Mariopteris acuta</i>		X		X	X	X	X		upp.
<i>Neuropteris smithsüi</i>	X								
<i>Neuropteris schlehani</i>	X	X	cf.	X	X	X	X	X	X
<i>Alethopteris lonchitica</i>		X		X		X			
<i>Alethopteris decurrens</i>		X		X		X			
<i>Calamites suckowi</i>				X	X		X		X
<i>Calamites undulatus</i>	X	X		X			X		X
<i>Asterophyllites grandis</i>				X	X		cf.		upp.
<i>Sphenophyllum cuneifolium</i>				X	X	X			X
<i>Lepidophloios larinicus</i>	X			X		X	X		X
<i>Cordaïtes principalis</i>		X			X	X			
<i>Samaropsis parvefluitans*</i>				X					
<i>Asterophyllites charaeformis</i>									X
<i>Lepidophyllum lanceolatum</i>	X	X		X	X		X		X

* indicates *Samaropsis parvefluitans* is *S. cornuta* of Bell (1944b) as redefined by Stockmans and Willièrè (1953); "cf." here means species in that country are similar and perhaps the same as the name given in the table; "upp." means that in those countries the species is found in strata no older than upper Namurian B.

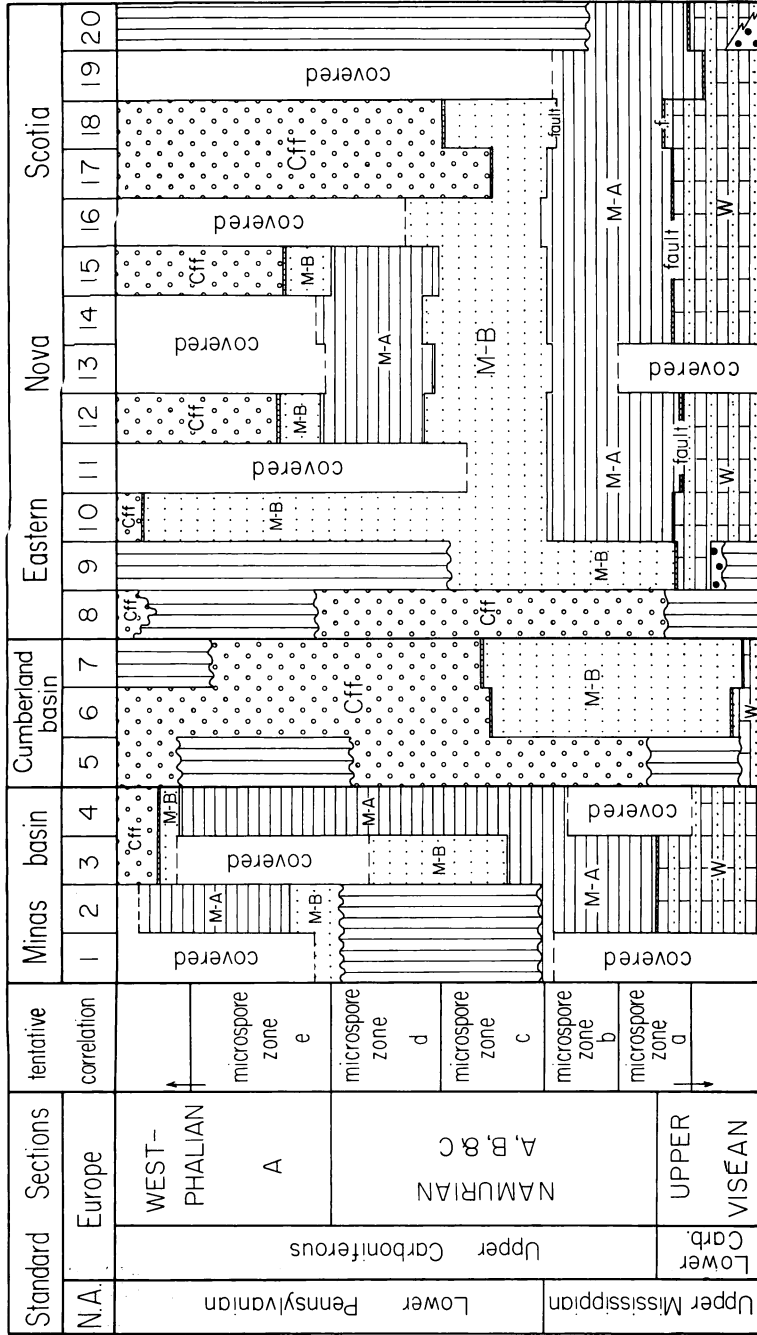


Fig. 4. Revision of middle Carboniferous strata based on lithologic correlation by E. S. Belt and fossil microspore zones by M. S. Barrs. Mabou Group is represented by two facies: (1) M-A, dark- to medium-gray laminated shale with dusky-red lutite interbeds, indicated by horizontal lines; (2) M-B, dusky-red and greenish-gray lutite and sandstone, indicated by open circles and the symbol, Cff. Windsor Group is represented by the brick pattern alternating with a dot pattern and the symbol, W. Coarse conglomerate in the Windsor Group is indicated by filled circles. Correlation of microspore zones with standard sections is tentative.

In addition, Nova Scotia microspores indicate the presence of zones that appear tentatively to be older than Westphalian A, but yet younger than Namurian A (Barss, personal communication), although no correlation can be based on those zones until the many new genera and species have been described. Thus the available evidence suggests the absence of a disconformity between the Canso and Riversdale Groups throughout most of Nova Scotia, and the problem becomes one of determining whether or not these "groups", which are considered to be successive time-stratigraphic units without a "zone" of overlap or a time-gap, have been correctly extended from their type sections.

When strata previously assigned to Canso and Riversdale Groups are compared with the microspore control (fig. 4), a number of cases are found where some Canso strata contain the same microspore zone as some Riversdale strata. For example, by comparing figure 4 with figures 2 and 3, upper Canso strata in the Southwest Mabou section can be seen to occur within the same microspore zone (d) as lower Riversdale strata in the Richmond syncline. Likewise, strata in the River Tillard-Scott Brook syncline (fig. 4, column 13), previously defined by Weeks (1954, p. 80) to be entirely Riversdale Group, occur within the same microspore zone (d) as upper Canso in the Southwest Mabou section. Finally, the Riversdale type section (fig. 4, column 4) contains microspore zone (c), though tentatively assigned by Barss (ms). Microspore zone (c) occurs specifically in the lower Canso Group of previous workers in the Maple Brook Section (column 14), Southwest Mabou section (column 15), the Antigonish basin section (column 10), and in other sections (fig. 4). Thus as time-stratigraphic units, Canso and Riversdale Groups need to be revised.

GROUP PROPOSED

The Canso and Riversdale Groups of previous workers are not considered here to be separated by a disconformity throughout most of Nova Scotia, and thus the strata included in those units are reconsidered in terms of continuous deposition. The reorganization shows that the lithofacies cut across the previous Canso-Riversdale contacts in all sections excepting those in western Cape Breton Island and the Cumberland structural basin where the previous boundary was placed at a lithologic change. The previous Canso-Windsor contact is taken here as the base of the Mabou Group in all sections where the previous contact was placed above the uppermost marine limestone or evaporite horizon, namely, in all sections but those in the Cumberland structural basin.

Mabou Group

Mather and Trask (Eastern Gulf Oil Company, 1929) proposed the term Mabou Formation for a dark- to medium-gray lutite unit in the Port Hood and Southwest Mabou River district (fig. 1, loc. 15). Mabou Formation was one of four subdivisions (fig. 3) recognized in the section. All four subdivisions consist predominantly of lutite and fine-grained sandstone and occur below coarse sandstone, conglomerate, and productive coal (Port Hood Coal Measures), and above Windsor evaporites and limestone. These subdivisions (labelled A-1, B-1, A-2, and B-2 in figs. 2, 3) have been recognized and mapped throughout much of eastern Nova Scotia (Belt, ms) and will be formally discussed in a later report.

G. W. H. Norman (1933, 1935) extended the term Mabou to include all of Mather and Trask's units above the Windsor and below the Port Hood Coal Measures (fig. 3, column 2). Norman's Mabou Formation was adopted by most early workers in western Cape Breton Island although it was later considered synonymous with Canso Group (Bell, 1944b, p. 6, fig. 11). Unfortunately, Norman (1935) considered Mather and Trask's (Eastern Gulf Oil Company, 1929) Super-Mabou Red Beds (fig. 3) to be repeated MacFarlane Red Beds and hence his measurements are 1750 feet shorter than theirs or those of Belt (ms), although his mapped contact (Norman, 1933) with the Port Hood Formation is the same stratigraphic position chosen independently by both Mather and Trask and by Belt.

The term Mabou as defined and mapped by Norman (1933, 1935) is appropriate for a unit of group status because Mabou has lithogenetic entity and contains subdivisions (A-1, B-1, A-2, B-2) that are lithologic units of formation rank. It is here proposed that the name Mabou Group be defined to include all middle Carboniferous formations in Nova Scotia above the top of the Windsor Group marine beds and below the base of the medium- to coarse-grained yellowish-gray sandstone with minor beds of dusky-red and gray lutite, conglomerate and commercial coal that are considered a fluvial facies and informally designated here the Coarse Fluvial Facies (figs. 2, 3, 4). The Coarse Fluvial Facies includes the Boss Point and Port Hood Formations of the Riversdale Group of previous workers and the post-Riversdale Carboniferous units (Cumberland and Pictou Groups).

The Mabou Group includes the West Bay, Parrsboro, Point Edward, Maringouin, Shepody, and Middleborough Formations of previous workers and three new formations in eastern Nova Scotia to be defined in a later report. Other formations that were considered by Bell (1944b) to be included in the Canso or Riversdale Groups are dropped as formal units (for example, Lismore, Cape Dauphin, Alma, and Union Formations).

Lithologic definition.—The Mabou Group is a nonmarine lithogenetic unit consisting of lutite and as much as 50 percent fine- to medium-grained sandstone. A dusky-red and greenish-gray lutite and sandstone facies interfingers complexly with a dark- to medium-gray laminated shale facies. Mabou strata consist entirely of the dusky-red and greenish-gray lutite and sandstone facies in the Cumberland and Merigomish structural basins, entirely of the dark- to medium-gray laminated shale facies in eastern Minas structural basin, and of varying proportions of the two facies elsewhere. A fluvial origin of the "red" facies is inferred from the presence of amphibian footprints and bones (Romer, 1958; Baird, 1962b, and unpublished notes), fossil lungfish, channel sandstones, and interchannel units. Lacustrine origin of the "gray" facies is inferred from the presence of fossil algae, fish (Baird, 1962a), freshwater pelecypods (Lucas, ms, 1955; Bell, 1944b, 1958), conchostracans (Copeland, 1957; Tasch, personal communication), and laminated shale. Hopper-shaped casts, dusky-red lutite beds, and varying water depths indicated by organisms in the gray facies suggest a marked cyclical fluctuation of the lake margin similar to that found in the Triassic Lockatong Formation of Pennsylvania and New Jersey (Van Houten, 1962). The widespread occurrence of hematite in all

dusky-red units of the Mabou Group suggests an oxidizing environment in a seasonally wet climate, although the need for postulating such a climate may decrease to the extent that future investigations show whether hydrohematite and goethite convert to hematite diagenetically (Van Houten, 1961, p. 120). Mabou facies contain abundant intraformational conglomerate of carbonate and/or lutite pebbles but less than 1 percent conglomerate derived from pre-Mabou rock. In contrast, all Coarse Fluvial Facies and some Windsor facies (Grantmire, McAra Brook, St. Ann, and other formations) contain conglomerate units with abundant pre-Carboniferous pebbles. The Mabou Group contains thin, impure coal seams at two localities (Antigonish structural basin, loc. 10; Maple Brook syncline, loc. 14); in contrast, Windsor contains no coal and Coarse Fluvial Facies contain abundant productive coal seams, averaging about 5,600,000 short tons per year since 1900 (Girroit, 1961, table 10).

Table 2 summarizes the lithologic comparison between Windsor, Mabou, and Coarse Fluvial Facies. The comparison of sandstone composition and sorting characteristics need further explanation, however.

Fine- and medium-grained sandstones from the Mabou Group and Coarse Fluvial Facies were analyzed and point counted with reference to the end-members indicated in the three-component diagram shown in figure 5. Sandstone composition was analyzed in terms of the composition of sand-sized particles, neglecting the matrix, according to the method of Folk (1954). The majority of Mabou Group sandstones have a compositional range considerably more mature than the Coarse Fluvial Facies. To some degree the compositional difference is a function of the finer sand size in the Mabou Group than in the Coarse Fluvial Facies. On the other hand, certain Mabou sandstones (the crosses in fig. 5) show a compositional range intermediate between or overlapping the compositional range of the Coarse Fluvial Facies. These fine-grained sandstones are samples from the Mabou facies that are gradational either laterally or vertically into the Coarse Fluvial Facies. The Mabou sandstone labelled "B" in figure 5 was sampled from a thick conglomerate and coarse sandstone tongue within the lower lacustrine unit (A-1) of the Mabou Group and reflects a nearby source area of brief occurrence in northern Cape Breton Island (fig. 1, loc. 19; source area not indicated).

Because sorting is difficult to measure in thin section, only relative sorting was determined by noting the largest visible sand diameter and the percentage of silt and clay matrix. The assumption was made that if the percentage of matrix was appreciable (commonly the case) and not secondarily introduced, all sand sizes smaller than the largest sand diameter were present in the sample, but, of course, in unknown quantities. As shown in table 2, most sandstones in the Windsor, Mabou, and Coarse Fluvial Facies have a high percentage of quartz silt, clay, or calcilutite matrix. Disrupted sandstone frameworks (30 to 50 percent matrix) are common as are sandy lutites (greater than 50 percent silt and clay). The Coarse Fluvial Facies, however, contain numerous sandstones with 20 to 30 percent matrix. These are considered to be filled fluvial channels, and they alternate with thinner units considered to be the inter-channel deposits that contain thin sandstone beds with more than 30 percent matrix and thicker lutite beds. The channel sandstones of Mabou fluvial facies

TABLE 2

Comparison of Windsor, Mabou, and Coarse Fluvial Facies

Feature compared	Windsor Group	Mabou Group	Coarse Fluvial Facies
Marine limestone and evaporites	abundant	absent	absent
Color of nonmarine beds	dusky-red and greenish-gray	One facies is dusky-red and greenish-gray; the other facies is dark- to medium gray	Sandstones are yellowish gray or dusky-red and greenish-gray; lutite is same as Mabou Group
Bedding thickness and character	Sandstone and limestone beds thin and flaggy; lutite locally in thick units; conglomerate beds lenticular and of varying thickness	Channel sandstone units flaggy and lenticular; interchannel sandstone beds very thin and tabular; lutite predominant interchannel rock	Channel sandstone units thicker than in Mabou, massive-bedded generally, and well-jointed. Interchannel units thinner but similar in rock type to Mabou Group
Coal (productive or non-productive)	absent	very rare; non-productive seams	abundant productive seams
Percentage of lutite	more than 50%	more than 50%	less than 50% except locally
Percentage and type of matrix in sandstones	about 30% or more estimated from field observations	rarely less than 30% quartz silt, clay, calcilutite, hematite	rarely less than 20% quartz silt, clay, calcilutite, hematite
Size-range in sandstones	very fine to medium, locally coarse; average is fine-grained	very fine to medium, rarely coarse; average is fine-grained	very fine to coarse; average is medium-grained
Calcareous concretions over $\frac{1}{2}$ ft in diameter	absent	very rare	abundant
Air-heave structures	absent	very rare	abundant
Tree trunks buried upright	absent	rare	abundant at certain horizons
Hopper-shaped casts	abundant at certain horizons	abundant at certain horizons	rare or absent
Pebbles derived from pre-Carboniferous rocks	locally abundant	very rare: less than 1%	abundant in most sections
Sandstone composition	not analyzed	mature composition (see fig. 5)	moderately immature composition (see fig. 5)

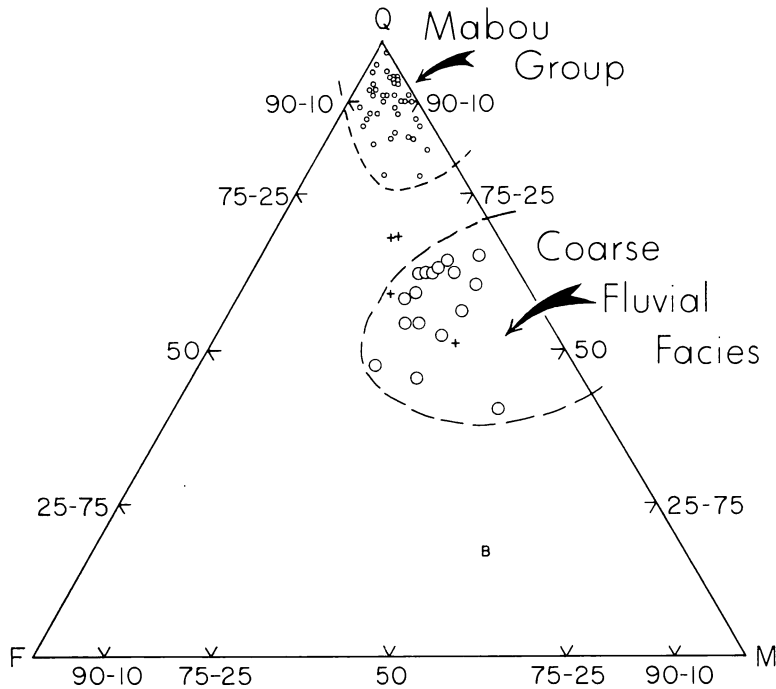


Fig. 5. Comparison of sandstone composition from the Mabou Group and the Coarse Fluvial Facies. End-members after Folk (1954) where Q is quartz, chert, and sedimentary rock fragments; F is feldspar and igneous rock fragments; and M is mica, metaquartzite, and other metamorphic fragments. Smaller circles represent typical Mabou Group, the cross symbol represents Mabou Group transitional into the Coarse Fluvial Facies, and the symbol, B, represents a sandstone and conglomerate tongue within the lower Mabou Group at locality 19.

are in many respects similar to the Coarse Fluvial Facies because they contain about 30 percent matrix. The Mabou channel sandstones, however, are much thinner than those in the Coarse Fluvial Facies, and most are hematite-stained or greenish-gray in contrast to the yellowish-gray color of the Coarse Fluvial channel sandstones. Although some of the matrix in these sandstones may have resulted from the diagenetic breakdown of feldspar, the high percentage of quartz silt and calcilutite with clay minerals would seem to confirm the hypothesis that almost all the matrix is original. Table 2 also shows that commonly the Coarse Fluvial Facies and locally the Windsor Group contain medium- and coarse-grained sand sizes, in contrast with the Mabou Group which rarely contains those sizes.

Thickness.—The thickness of the Mabou Group varies between 300 feet (Cape Dauphin, loc. 21) and approximately 20,000 feet (Antigonish structural basin, loc. 10). The Cape Dauphin section has been subjected to post-Mabou pre-Pictou erosion, whereas the Antigonish sections show continuous deposition from the Mabou Group into the Coarse Fluvial Facies (fig. 4). In general, the thickness of Mabou strata averages about 7000 feet where not eroded or faulted.

Stratigraphic relationship.—The Mabou Group throughout Nova Scotia overlies the restricted Windsor Group and underlies the Coarse Fluvial Facies except on the Meguma Platform where the latter overlaps the Mabou strata and rests directly on the Windsor strata (fig. 1, locs. 22, 23). This zone of overlap probably indicates a region of marginal coarse facies laterally equivalent to the fine Mabou facies of the center of the Fundy basin and not post-Windsor pre-Coarse Fluvial Facies erosion, although microspore data from those sections are not presently available. Elsewhere, the fossil microspores are found to occur in stratigraphic sequence from zone (a), the oldest, to zone (e), the youngest, regardless of the rock type in which the fossils are found (fig. 4). They thus prove the lateral interfingering relationship of the Mabou Group with the Coarse Fluvial Facies; the Mabou Group interfingers laterally with and/or is conformably overlain by the Coarse Fluvial Facies.

The Mabou Group is in part conformably overlain and in part unconformably overlain by the Coarse Fluvial Facies. The unconformable cover is a younger blanket component of the Coarse Fluvial Facies, currently termed the Pictou Group (columns 9, 20; Pictou not shown on fig. 4). Pictou Group also unconformably overlaps the Mabou Group at Cape Dauphin (fig. 1, loc. 21). Unconformities within the Coarse Fluvial Facies (fig. 4, columns 5, 8) occur near the Cobequid Axis (fig. 1) where the Cumberland Group overlaps coarse facies previously included in the Riversdale Group.

MABOU TYPE AND REFERENCE SECTIONS

The Mabou Group type locality, in the Southwest Mabou River and its tributaries, Inverness County, Cape Breton Island (fig. 1, loc. 15), is where Mather and Trask (Eastern Gulf Oil Company, 1929) and Norman (1933; 1935) first applied the term Mabou. The type section occurs north of Middle Bridge (an abandoned settlement on the Southwest Mabou River) and east of the point where Campbell Brook (an eastward-flowing tributary of the Southwest Mabou, north of Middle Bridge) is crossed by a dirt road connecting route 19 to the settlement of Glengarry. The thickness, approximately 5750 feet, and description of the type section (Belt, ms, p. 284-295), are based on surface measurements and well logs (Imperial Oil Company Ltd.). The section is faulted at the bottom (an estimated 1600 feet of lower Mabou removed), and a number of faults and folds found near the middle of the section are the result of a large piercement structure of Windsor evaporites. The upper contact is poorly exposed in the headwaters of Campbell Brook, for typical Coarse Fluvial Facies are not well defined there. Within the Southwest Mabou River area, however, 80 percent of the Mabou Group is exposed.

Due to the structural deformation of the Mabou type section, a reference section is designated in the Richmond syncline (fig. 1, loc. 12; total thickness approximately 9660 feet, Belt, ms, p. 264-274). Although the exposures in the reference section are much less extensive than in the type section on the Southwest Mabou River, there is little structural complexity except at the Mabou-Windsor contact. Unfortunately, the Mabou Group contact with the overlying Coarse Fluvial Facies (Port Hood Formation, fig. 2) lies somewhere within a 1000-foot covered interval.

In the type (fig. 3) and reference (fig. 2) sections, the Mabou Group consists of dark- to medium-gray laminated shale units that alternate with dusky-red and greenish-gray lutite and sandstone units (indicated on the figures as A-1, B-1, A-2, and B-2). A dusky-red and greenish-gray lutite and sandstone unit of varying thickness (B-1) is found to overlie the gray shale unit (A-1) in other sections in eastern Nova Scotia (fig. 4, columns 10, 11, 12, 13, 14, 15, 16, 17, 18), and this in turn is overlain by another gray shale unit (A-2) of more limited extent (fig. 4, columns 12, 13, 14, 15). In those sections where the upper gray shale unit is found, it is overlain by a second dusky-red and greenish-gray lutite and sandstone unit (B-2) that forms the top of the Mabou Group directly beneath the Coarse Fluvial Facies (fig. 4, columns 12, 15). In those sections where no upper gray shale unit (A-2) is developed, upper Mabou Group consists entirely of dusky-red and greenish-gray lutite and sandstone (fig. 4, columns 10, 16, 17, 18); where no lower (A-1) or upper (A-2) gray shale units are developed, Mabou Group is entirely dusky-red and greenish-gray lutite and sandstone (fig. 4, columns 6, 7, 9). In the Minas structural basin, Mabou Group is predominantly dark- to medium-gray shale with minor dusky-red lutite and fine-grained sandstone interbeds (facies M-A) although some thick units of dusky-red and greenish-gray lutite and sandstone (facies M-B) are found (fig. 4, columns 1, 2, 3, 4).

The Mabou Group contains an angular unconformity in western Minas basin (fig. 4, columns 1, 2). About 30 feet of dusky-red and greenish-gray pebbly sandstone and conglomerate (facies M-B) overlie vertical strata of dark- to medium-gray laminated shale with dusky-red and greenish-gray lutite interbeds (facies M-A). Several thousand feet of normal dusky-red and greenish-gray lutite and sandstone (facies M-B) occur above the 30-foot basal conglomerate overlying the unconformity. "Red" (M-B) facies is replaced by "gray" (M-A) facies higher in the section (fig. 4, column 2), and farther east the unconformity is represented by "red" (M-B) facies (fig. 4, column 3), and still farther east by "gray" (M-A) facies (fig. 4, column 4).

An angular unconformity occurring within the Mabou Group in western Minas basin is here considered consistent with the depositional framework and hence the lithologic entity of the group. The Mabou section at Spencers Island and Parrsboro (fig. 1, locs. 1, 2) is predominantly lutite with minor sandstone and the basal conglomerate referred to above. Mabou there is thus markedly different from Windsor Group or Coarse Fluvial Facies. Furthermore when these two sections are considered in terms of their proximity to an active middle Carboniferous source area (fig. 1, Cobequid Axis), the unconformity disappears towards the central and eastern part of the Minas basin.

CONCLUSIONS

The Windsor, Canso, and Riversdale Groups were defined and are presently used by many previous workers as time-stratigraphic units of Viséan, Namurian A, and Westphalian A ages respectively. Fossil microspores indicate that the Canso and Riversdale Groups are not time-equivalent throughout their extent although defined and extended by means of the megaplant fossils contained in them.

Recent data on the ranges of megaplant fossils from the Namurian type section in Belgium (table 1) indicate that plants of the "Riversdale flora" occur in strata as old as Namurian B. Furthermore the pelecypods, *Carbonicola* (?) [*Anthracomya*] *angulata* (Dawson) and *Naiadites* sp. (*Naiadites* cf. *modiolaris*), both endemic to Nova Scotia, can no longer be used to distinguish the Canso strata from the Riversdale strata.

The Windsor, Canso, and Riversdale Groups are not valid lithologic groups in many parts of Nova Scotia. Specifically, the Canso Group in the type section is very similar to the lower Riversdale Group in the same area, the boundary being placed within a lithogenetic unit (fig. 2, unit B-1). Furthermore, the Riversdale Group type section is very similar to the "gray" facies included in the Canso Group (figs. 2, 3, unit A-1), and very dissimilar to the Riversdale Group in the Cumberland structural basin (fig. 1, locs. 5, 6, 7, 8) and in western Cape Breton Island (fig. 1, locs. 15, 17, 18). The Windsor Group is not a lithogenetic unit in the Cumberland structural basin because several thousand feet of strata previously considered upper Windsor, occur above the highest stratigraphic occurrence of marine limestone or evaporites.

For the reasons outlined above, reorganization of the middle Carboniferous units in Nova Scotia was considered necessary. The Mabou Group is proposed to consist predominantly of lutite with minor fine-grained sandstone. It is distinguished from the underlying unit, the restricted Windsor Group, by the absence of marine limestone and evaporites and from the overlying unit, informally termed the Coarse Fluvial Facies, by the absence of productive coal and thick coarse sandstone and conglomerate units. The Mabou Group has been subdivided into nine mappable lithic units or formations, three of which will be proposed in a later report, six of which have names currently in the literature.

The Mabou Group is a conformable sequence throughout Nova Scotia except in western Minas basin where an angular unconformity occurs within the unit (fig. 4). The Mabou Group is a central-basin lateral equivalent of the marginal-basin Coarse Fluvial Facies. In addition Coarse Fluvial Facies conformably as well as unconformably overlie the Mabou Group.

The fossil microspore zones (Barss, ms) were constructed after the lithic facies and hence strengthened the lithologic "correlation". The writer advocates application of the stratigraphic procedures suggested in the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961), because previous workers approached subdivision of Nova Scotia middle Carboniferous strata by developing the time-stratigraphic units before developing the rock-stratigraphic units. The result was that the facies were poorly understood, and the time-stratigraphic units were improperly correlated due to the poor control by fossil megaplants.

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