Some Middle Devonian to Lower Carboniferous Rocks of Cape George, Nova Scotia

by J. D. Keppie, P. S. Giles and R.C. Boehner

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J. D. KEPPIE, P. S. GILES, and R. C. BOEHNER

HALIFAX, NOVA SCOTIA

1978

HON. WILLIAM GILLIS, MINISTER

John C. Smith Deputy Minister	D. A. Murray, Director Mineral Resources

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SOME MIDDLE DEVONIAN TO LOWER CARBONIFEROUS ROCKS OF CAPE GEORGE, NOVA SCOTIA

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ABSTRACT

Two shore sections exposed on the shore of Cape George, Antigonish County, were re-examined. These sections are located (i) between Knoydart Point and McAras Brook, and (ii) between Ballantynes Cove and Wilkie Brook. Most workers have assigned the rocks cropping out in these sections to the mid-late Viséan Windsor Group while others have assigned some parts to the Horton Group. The results of this study have necessitated both revision and erection of terminology for these rocks.

The McAras Brook Formation (*sensu stricto*) is redefined to include only those conglomerates, sandstones and basalts between the unconformity with the Lower Devonian Knoydart Formation and a newly discovered unconformity which truncates the stratigraphically highest basalt flow in the type section. Correlation with a similar section at Ballantynes Cove indicates a Late-(?Middle) Devonian age for the McAras Brook Formation (*sensu stricto*). In more complete sections, the top of the McAras Brook Formation (*sensu stricto*) is defined as the top of the highest basalt flow.

The Martin Road Formation (new name) is defined in the Knoydart Point-McAras Brook shore section to include the sandstone, shale and conglomerate between the unconformity above the highest basalt flow and the base of the Ardness Limestone, the lowest unit of the Ardness Formation. Palynomorphs recovered from the Martin Road Formation indicate a Late Viséan age.

The Wilkie Brook Formation is formally defined here as the succession of conglomerate, sandstone, shale and limestone lying between the unconformity 380 m north of the mouth of Wilkie Brook and the base of the 21.3 m thick Marsh Cove Limestone (new name). Spore assemblages from the Wilkie Brook Formation are similar to assemblages reported from the Cheverie Formation of the Horton Group. Thus the Wilkie Brook Formation may be considered a facies equivalent of the Horton Group in its type area. The age of the Wilkie Brook Formation is Tournaisian.

We propose that the term Horton Group (*sensu stricto*) be restricted to its original definition of the type area, which includes the Lower Carboniferous Horton Bluff and Cheverie Formations. We thus exclude from the Horton Group those strata of Middle-Late Devonian age lying beneath the Wilkie Brook Formation in the Cape George area.

The base and top of the Windsor Group have been defined as the first and last appearance, respectively, of marine strata of Viséan age. We recommend that the definition of the Windsor Group be expanded to include those sections where the group is bounded by unconformities, either at the base or at the top. The absence of marine strata at the lower and upper extremities of the group, need not therefore, prohibit assignment of otherwise equivalent stratigraphic sections such as the Martin Road Formation, to the Windsor Group.

The absence of rocks equivalent to the Lower Windsor Group between the Martin Road and McAras Brook (*sensu stricto*) Formations, indicates the presence of the Northumberland Strait Landmass (new name) during part of the Early Carboniferous.

INTRODUCTION

Two coastal sections have been critically re-examined during this study. They occur near Knoydart Point, west of Arisaig and between Ballantynes Cove and Wilkie Brook (Fig. 1). The rocks in these two sections have been variously subdivided and correlated by different workers (Tables 1 and 2).

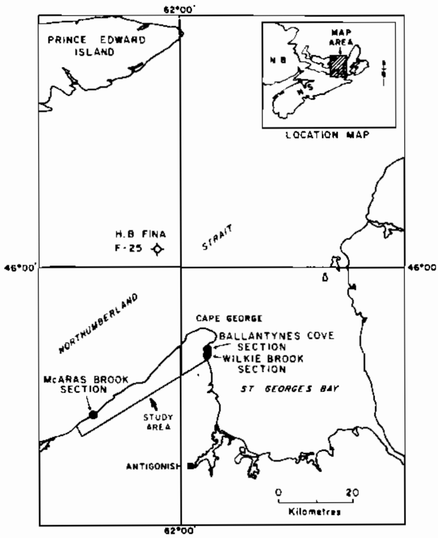


Figure 1 - Location map

In the vicinity of Knoydart Point (Fig. 2), a succession of chocolate-red conglomerates, sandstones and shales with four intercalated basaltic flows lying unconformable upon the Knoydart Formation and beneath the Ardness Limestone has been termed the McAras Brook Formation (Table 1). The McAras Brook Formation has been variously assigned to the Windsor or Horton Groups. During this study, an angular unconformity was discovered within the McAras Brook Formation so defined. This, together with palynological results from this section and from lithostratigraphically equivalent rocks at Ballantynes Cove, calls for re-definition of the McAras Brook Formation.

The section north of Wilkie Brook exposes Upper Devonian sandstones and siltstones unconformably overlain by a sequence of interbedded conglomerate, sandstone, siltstone, shale and minor limestone, capped by a 21.3 m thick limestone horizon and terminated by a complex fault zone in Marsh Cove. Part of the sequence above the unconformity was informally called the Wilkie Brook Formation by Murray (1960) and it has generally been correlated with the lower part of the Windsor Group

Table 1: Classification of Rocks Along McAras Brook Shore Section According to Different Authors

Diagrammatic section along McAras Brook shore	Williams, 1914		Bell 1926		Bell 1943	Kaminsky & Wheby, 1952		Wetzel, 1952	
Sandstone, shale	Ardness Formation	Windsor Group	Ardness Formation	Windsor Group	Upper Windsor Group		Windsor Group	Upper	Windsor Group
Limestone						E_1			
			DISCONFORMITY						
Sandstone, shale & conglomerate	McAras Brook Formation	Lower Carbon-iferous	McAras Brook Formation	Upper Horton Group				Lower	
Basalt, red sandstone & conglomerate									
ANGULAR UNCONFORMITY									
Knoydart Formation									

(continued below)

Diagrammatic section along McAras Brook shore	Mamet, 1970	Benson, 1974		Fralick, 1977			This study	
Sandstone, shale	Zone 16, ≡ C or D subzone Upper Windsor Group, latest Viséan	Windsor Group		Ardness Formation		Windsor Group	Ardness Formation	Late Viséan
Limestone		D_2					D_1	
		DISCONFORMITY						
Sandstone, shale & conglomerate		Rights River Formation	Horton Group	Upper Member	McAras Brook Fm.		Martin Road Fm.	
							UNCONFORMITY	
Basalt, red sandstone & conglomerate				Lower Member			McAras Brook Fm.	Late to Middle Devonian
ANGULAR UNCONFORMITY								
Knoydart Formation							Knoydart Fm. or Arisaig Gp.	Early Devonian or Silurian

Table 2: Classification of Rocks Between the Mouth of Wilkie Brook and Ballantynes Cove According to Different Authors

Diagrammatic section between Ballantynes Cove & Wilkie Brook	Kramer & Phinney, 1953; Kaminsky, 1953	Erlanger & Howard, 1959	Murray, 1960	Schenk 1969, 1975	Benson, 1970	Boucot *et al.*, 1974	This study	
LIVINGSTONE-BALLANTYNES COVE FAULT	FAULT	FAULT	FAULT	FAULT		FAULT	FAULT	
Basalt and conglomerate	McAras Brook Fm. (WINDSOR GROUP)	Silty Congl. Unit (Horton Formation)	McAras Brook Fm. (WINDSOR GROUP)	(WINDSOR GROUP)	(Unit 9 HORTON GP.)	McAras Brook Fm. (part of Horton Fm. stratigraphically below Horton Fm. sandstone)	McAras Brook Fm. (Pre-Horton Group *(sensu stricto)*)	Late to Middle Devonian
Covered interval (440 ft.-134.1 m)	FAULT (+minor syncline)	SYNCLINAL AXIS	?FAULT		SYNCLINAL AXIS	?FAULT or ?SYNCLINE	SYNCLINAL AXIS	
MARSH COVE: Shale & limestone Sandstone conglomerate 5 basalt flows Conglomerate	McAras Brook Formation	Silty Conglomerate Unit	McAras Brook Formation			McAras Brook Formation	Unnamed Unit McAras Brook Fm.	
FAULT ZONE with sheared basalt & conglomerate, & schistose gypsum Covered interval (260 ft.-79.2 m)	MINOR FAULT (Succession generally concordant)	?FAULT ZONE	MINOR FAULT ZONE (Succession generally concordant)	MINOR FAULT ZONE (Succession generally concordant)	MAJOR FAULT ZONE	MAJOR FAULT ZONE	MAJOR FAULT ZONE A1 Lst. Windsor Group	Middle Viséan
21.3 m limestone	?A_2		?A_2			A_2	Marsh Cove Lst. Group	
							DISCONFORMITY	
Sandstone conglomerate shale & limestone Algal limestone Sandstone, shale & limestone Conglomerate sandstone shale & limestone	Lower part of Windsor Group	Windsor Formation	Wilkie Brook Formation A_1 (Position of boundary uncertain) ? Rights R. Fm. (?HORTON GP.)		WINDSOR GROUP	Windsor Formation	Wilkie Brook Formation (Horton Group *(sensu stricto)*)	Early Tournaisian
ANGULAR UNCONFORMITY								
Sandstone conglomerate & shale Mouth of Wilkie Brook	Horton Group	Horton Formation	South Lake Creek Fm.		Unit 7 HORTON GROUP	Horton Formation Sandstone	Pre-Horton Group *(sensu stricto)*	Late Devonian

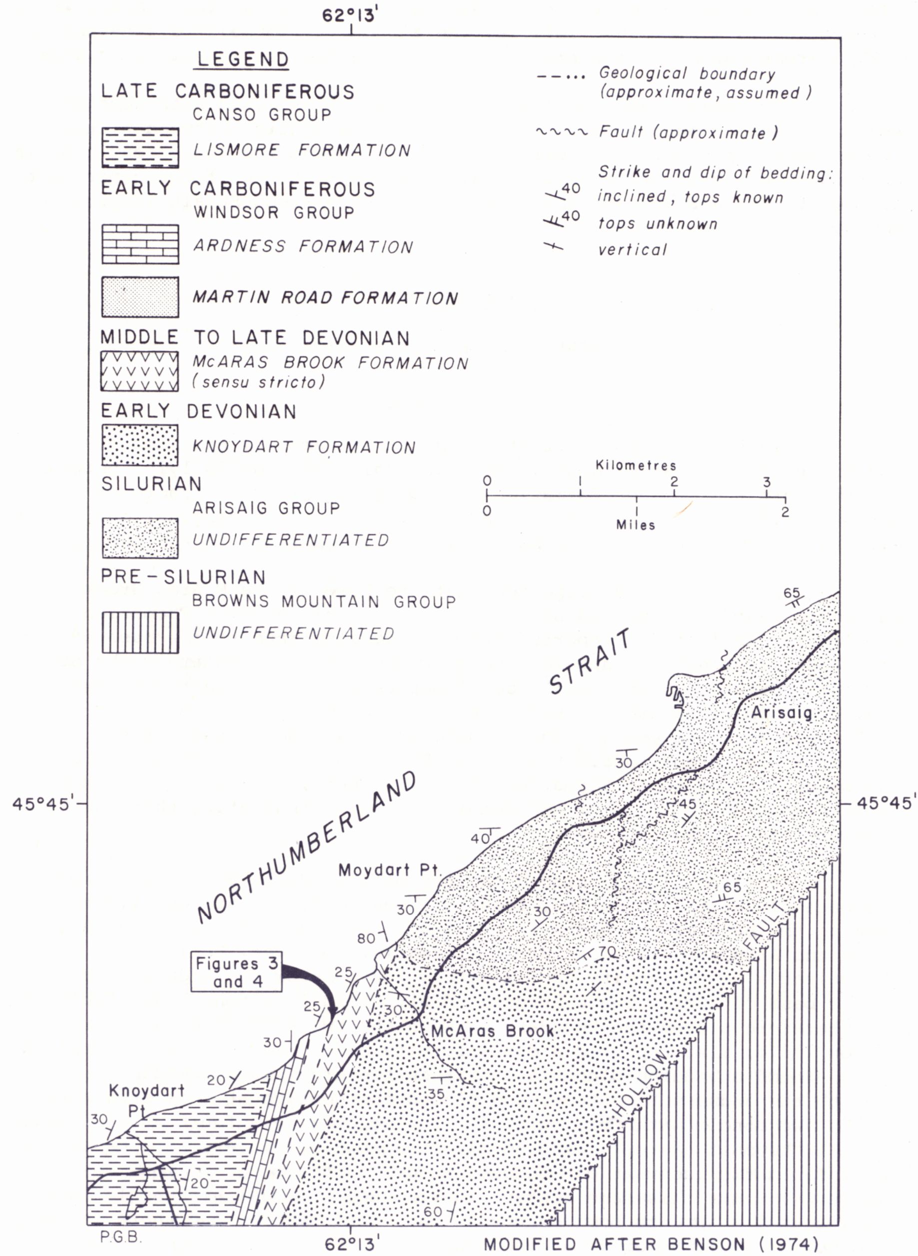


Figure 2 - Geological map of the McAras Brook-Knoydart Point shore section.

(Table 2). Palynomorphs recovered during this study indicate that this correlation is incorrect. This led the authors to formally define the Wilkie Brook Formation and propose alternative correlations in this paper.

The senior authors (P.S.G. and J.D.K.) examined both sections while the junior author (R.C.B.) remeasured the section between Wilkie Brook and Marsh Cove. The borehole log, SB-1, from the Shubenacadie Basin was added by one of us (P.S.G.) to allow interpretation of the upper part of the H.B. Fina F-25 well log from the Northumberland Strait (Fig. 1) to be made.

STRATIGRAPHY

MCARAS BROOK TYPE SECTION

Stratigraphy

The McAras Brook Formation was first named by Williams (1914), and included the coarse conglomerates and calcareous grits lying between the Knoydart and Ardness Formations cropping out along the shore of Northumberland Strait near McAras Brook (Fig. 2). The original definition will be followed until the formation is redefined later in the paper.

Williams (1914) reported that the base of the McAras Brook Formation rests with marked unconformity upon the Knoydart Formation (Table 1). Bell (1926) reported 4.8 m of conglomerate at the base of the formation, resting with angular unconformity upon sedimentary rocks of the Knoydart Formation. This basal conglomerate and the contact with the Knoydart Formation, are exposed in the west bank of McAras Brook about 100 m upstream from its mouth. The unconformity is also exposed on the shore east of McAras Brook, where the McAras Brook Formation rests upon rocks of the Silurian Stonehouse Formation (Fig. 2). Here, the base of the McAras Brook Formation consists of amygdaloidal basalt, indicating that the basal conglomerate is discontinuous.

Williams (1914) placed the top of the McAras Brook Formation at the base of the 6.1 m, marine, fossiliferous, oolitic, Ardness limestone marking the base of the Ardness Formation. He reported that the McAras Brook and Ardness Formations are conformable. However, Bell (1926) recognized a disconformity approximately 1.2 m below the Ardness limestone at the base of a grey shale associated with thin limestone beds (Table 1) and therefore placed the boundary between the two formations at this level. Benson (1974) also reported a disconformity here. More recently, Fralick (1977) found a bedding plane fault within the grey shale immediately beneath the Ardness Limestone, and placed the contact at this structnral break. We concur with Fralick (1977) in recognizing a fault at this level, beneath the most easterly exposed limestone bed. However, no apparent major fault displacement can be discerned. Furthermore, in more westerly exposures, where this same contact is repeated by local high angle faults, the succession appears both concordant and conformable, and there is no evidence of faulting or of a disconformity.

Bell (1926) measured and described the type section of the McAras Brook Formation and reports 264 m of chocolate red conglomerate, sandstone and shale with four intercalated basaltic flows in the lower part. Fralick (1977) divided the McAras Brook Formation into two members at the top of the highest basalt (Table 1). The lower member, 157.9 m in thickness, is dominated by red conglomerates and amygdaloidal basalt lava flows, with some arkosic sandstones and shales. Concretionary limestone nodules are characteristically scattered throughout the shaly beds. The upper member, 122.0 m in thickness, is predominantly sandstone with maroon and minor grey shales. Concretionary barite with associated copper mineralization occurs near the middle of this upper member. Ripple marks, parting lineation, and trough cross-bedding are characteristic, as are shale-pebble conglomerates. Carbonaceous plant debris is locally abundant in grey arkosic sandstone beds. Pebbles in the conglomerates of both members are predominantly red sandstone and siltstone derived from the underlying Knoydart Formation (Fralick, 1977), and are characteristically coated with a hematitic staining in the lower member. Fralick (1977) reported highly contrasting paleocurrent orientations from these two members, towards the west in the lower member, and towards the southeast in the upper member.

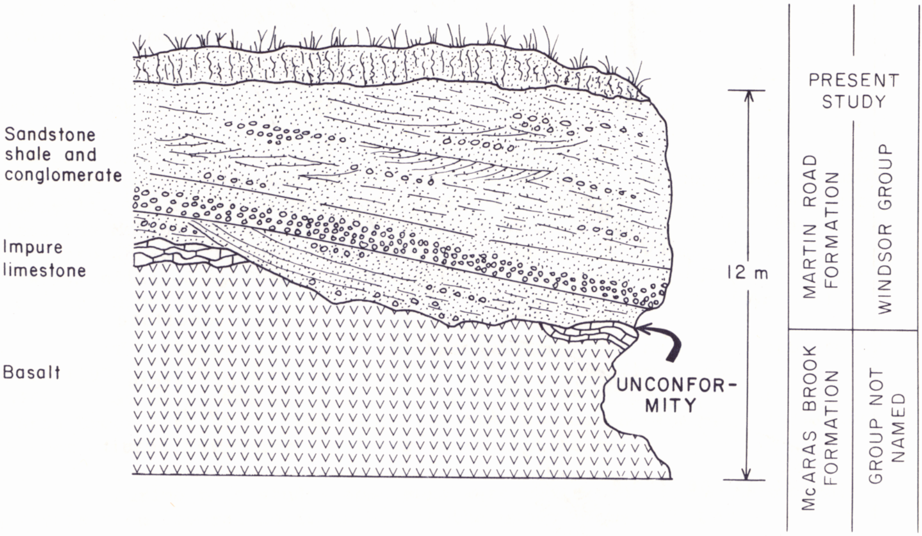


Figure 3 - Sketch of the unconformity at the top of the McAras Brook Formation (*sensu stricto*).

The presence of two contrasting members, with contrasting paleocurrent orientations (Fralick, 1977) possibly indicative of differing source areas, led us to re-examine the contact relationships between them. The contact between the members of Fralick (1977) is exposed at the top of the most westerly basalt flow (Figs. 3 and 4). On the headland, 100 m east of the contact, two basalt flows (nos. 3 and 4 in Fig. 5) are interbedded with red conglomerate and sandstone. In contrast, at the contact between the members, the uppermost basalt (no. 4) and its surrounding sedimentary rocks are missing. Here, the upper member comes to rest directly upon basalt no. 3. The base of the upper member consists of coarse sandstone with conglomerate lenses. In places, it rests upon an impure limestone, locally truncated where the sandstone rests directly upon basalt no. 3 (Fig. 3). The contact between the basalt and the overlying sandstone is

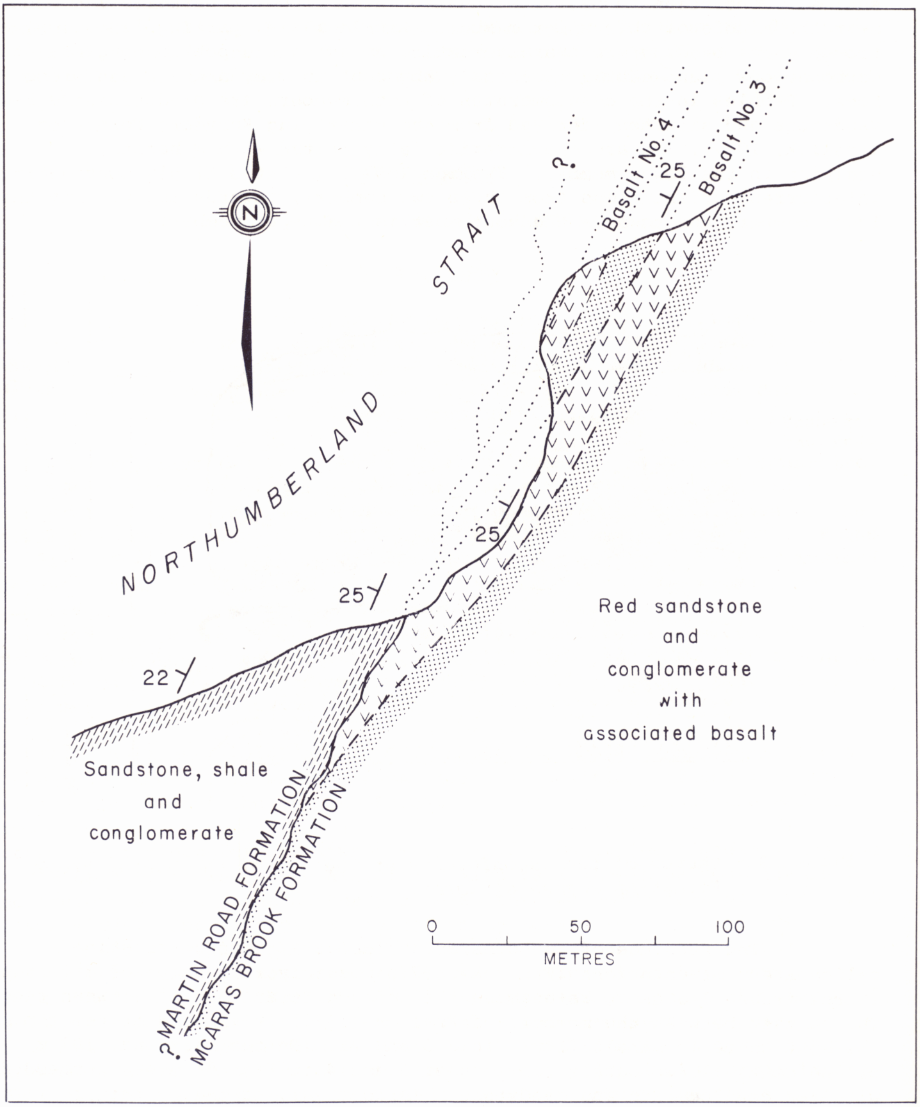


Figure 4 - Sketch map of the contact between the McAras Brook (*sensu stricto*) and Martin Road Formations.

sharp, in contrast to similar relationships lower in the succession, where flow tops are typified by admixtures of basalt cobbles and blocks in a terrigenous matrix. We interpret the contact between the two members as a regionally angular unconformity which truncates the uppermost basalt (no. 4) and surrounding sedimentary rocks. Bell (1926) and Fralick (1977) invoked lateral pinch-out of the highest flow to explain its termination. The viscosity of basalt flows is such that they generally occupy a wide area. This, combined with the observations presented above, led us to prefer truncation by erosion at the unconformity (Fig. 4) as a more appropriate explanation.

Age

Although Bell (1926) reported several genera of fossil plants in his description of the type section of the McAras Brook Formation, and used these to assign the formation to the Horton Group, he appeared to doubt their definitive value when he later (Bell, 1943) placed the formation within the Windsor Group.

Until now, no additional fossils have been recovered from the McAras Brook Formation (of Bell, 1926). Thus, its age has been inferred from its relationship with the Ardness Formation. Generally, those who interpret the contact between the Ardness and McAras Brook Formation to be a disconformity assign the McAras Brook Formation to the upper Horton Group (Table 1). On the other hand, those who believe the contact is conformable place the McAras Brook Formation in the Windsor Group. The uncertainty in assigning an age to the McAras Brook Formation (of Williams, 1914) is clearly indicated by Bell's (1926) initial assignment of it to the Horton Group and subsequently (Bell, 1943) to the Windsor Group (see Table 1).

The identification of the Ardness limestone as C or D subzone by Mamet (1970), as D_2 by Benson (1974), as E_1 by Sage (in Boucot *et al.*, 1974), or as D_1 by one of us (P.S.G.) provides an upper limit for the McAras Brook Formation. The Early Devonian age of the Knoydart Formation (Boucot *et al.*, 1974) gives a lower limit for its age.

During this study, specimens were collected for palynological analysis from several horizons within the upper member (Fig. 5).

SAMPLE E09-6003 yielded the following forms (Barss, 1977):

Calamospora spp.
Convolutispora sp.
Crassispora sp.
Granulatisporites sp.
Perotrilites perinatus Hughes & Playford
Perotrilites sp.
Punctatisporites spp.
Retusotrilites incohatus Sullivan
Rugospora cf. *R. corporata* Neves & Owens
Rugospora spp.
Schopfites claviger Sullivan
cf. *Schopfipollenites* sp.

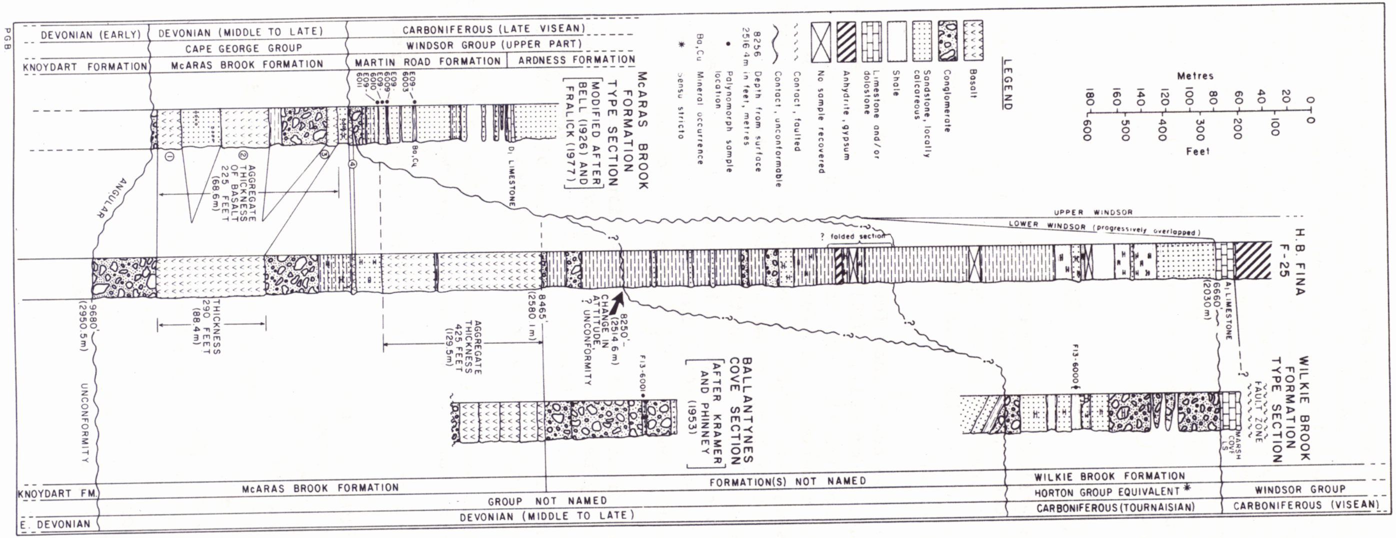


Figure 5 - Correlation of Devonian and Carboniferous strata in the Cape George area.

Three other specimens (Fig. 5, E09-6009, E09-6010, and E09-6011) were collected from a 10 m interval about 25 m above the highest basalt flow. The following spore assemblage was identified in these three specimens:

Apiculatisporites sp.
Auroraspora macra Sullivan
A. Sp.
Calamospora microrugosa (Ibrahim) Schopf, Wilson & Bentall
C. pallida (Loose) Schopf, Wilson & Bentall
Cirratriradites sp.
Crassispora trychera Neves and Ioannides
C. spp.
Convolutispora sp.
Cyclogranisporites sp.
Deltoidospora sp.
Densosporites sp.
Dictyotriletes submarginatus Playford
Discernisporites irregularis Neves
D. micromanifestus (Hacquebard) Neves and Owens
D. sp. *A.* Neves and Belt
D. sp.
Endosporites sp.
Granulatisporites cf. *G. tuberculatus* Hoffmeister, Staplin & Malloy
Grandispora sp. *A.* Utting
Knoxisporites sp.
Lycospora pusilla (Ibrahim) Somers
Perotrilites perinatus Hughes and Playford
P. sp.
Punctatisporites planus Hacquebard
P. validus Felix and Burbridge
P. spp.
Raistrickia ponderosa Playford
Reticulatisporites sp.
Retusotriletes incohatus Sullivan
Rugospora cf. *R. corporata* Neves and Owens
Rugospora minuta Neves and Ioannides
R. polyptycha Neves and Ioannides
R. sp.
Schopfipollenites ellipsoides (Ibrahim) Potonie & Kremp
Schopfites claviger Sullivan
S. spp.
Secarisporites sp. *A.* Utting
Spelaeotriletes arenaceous Neves and Owens
S. spp.
Verrucosisporites morulatus (Knox) Smith & Butterworth
V. sp.

Barss (1977) concluded that the above assemblages appeared characteristic for rocks of the Upper Windsor Group of probable Late Viséan age. Thus, a Late Viséan age is assigned to the upper member of the McAras Brook Formation. Furthermore, it supports the interpretation that the contact between the Ardness and McAras Brook Formations is conformable.

Although specimens of basalt from the lower member of the McAras

Brook Formation were collected for K/Ar age dating, alteration was too severe for them to yield meaningful dates. The age of the lower member is based upon correlations with sections described below.

MCARAS BROOK FORMATION AT BALLANTYNES COVE, CAPE GEORGE AREA

Stratigraphy

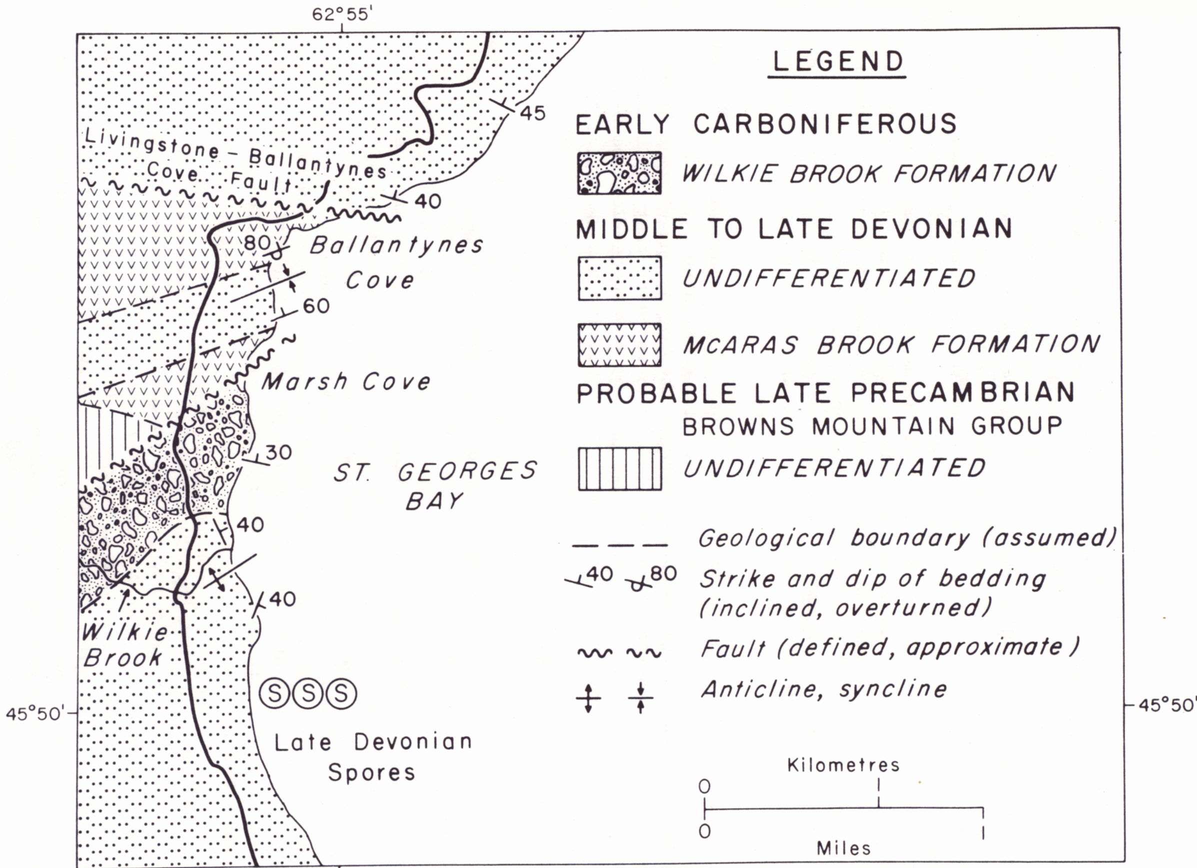
A detailed stratigraphic section of the McAras Brook Formation at Ballantynes Cove (Fig. 6, Table 2) appears in Kaminsky (1953) and Kramer and Phinney (1953, p. 27) and is reproduced by Boucot *et al.* (1974). Here, the section of the McAras Brook Formation is cut off both to the north and south by faults. To the south a complex fault zone containing large blocks of basalt, conglomerate and, locally, schistose gypsum separates rocks of the McAras Brook Formation from an A subzone Windsor limestone (Table 2, Fig. 5). On the north side of Ballantynes Cove, the Livingstone-Ballantynes Cove Fault terminates the section. Thus, the stratigraphic position of the McAras Brook Formation is uncertain here. Boucot *et al.* (1974) discuss three possibilities but prefer that shown in Table 2. Moreover, the section at Ballantynes Cove is covered in the middle of the cove. Kramer and Phinney (1953) believe that a fault in this covered interval repeats the section. On the other hand, Erlanger and Howard (1959, p. 12) place a synclinal axis in the covered interval. Re-examination during this study revealed younging directions which would support the synclinal hypothesis. The southern limb of the syncline provides the most complete section and is summarized in Figure 5 after Kramer and Phinney (1953), and Kaminsky (1953).

This section (Fig. 5) consists of conglomerate at the base, succeeded by approximately 68.6 m of basalt in which up to five flows were recognized by Kramer and Phinney (1953). Conglomerates dominate the section above the basalts for an additional thickness of 106.8 m, although calcareous sandstones and shales appear in moderate amounts near the top of the succession. The pebbles in the conglomerate have a dark red-brown, shiny, hematite coating, and consist predominantly of quartzitic siltstone, red siltstone, red sandstone with minor amounts of granite (Erlanger and Howard, 1959).

Age

A grey shale sample collected from near the top of the section at Ballantynes Cove (Fig. 5) yielded palynomorphs which Barss (1977) assigned to the Devonian and probably the Late Devonian. This sample (F13-6001) yielded the following forms (Barss, 1977):

Apiculiretusispora sp.
Emphanisporites rotatus McGregor
Grandispora cf. *G. spinosa* Hoffmeister, Staplin and Malloy
Hystricosporites spp.
Raistrickia sp.
Spinozonstriletes sp.



Modified after Boucot et al., 1974

Figure 6 - Geologic map of the shore section between Wilkie Brook and Ballantynes Cove.

Thus, the McAras Brook Formation here is Devonian, probably Late and possibly partly Middle Devonian in age.

WILKIE BROOK FORMATION TYPE SECTION

Stratigraphy

The section between the mouth of Wilkie Brook and Marsh Cove (Fig. 6) was first measured and described in detail by Kramer and Phinney (1953) and Kaminsky (1953) (Table 2). An angular unconformity was recorded 380 m north of the mouth of Wilkie Brook. The interbedded red and green sandstone, shale and conglomerate below the unconformity they referred to the Horton Group. The sequence of polymictic conglomerates, sandstones, shales and limestones occurring above the unconformity they correlated with the lower part of the Windsor Group. Part of this succession was informally referred to as the Wilkie Brook Formation (Table 2) by Murray (1960). The limited distribution of this report (Murray, 1960) and the loose definition of the Wilkie Brook Formation do not qualify the use of the name according to the American Code of Stratigraphic Nomenclature (1970). The Wilkie Brook Formation will be formally defined and described in this paper. The type section was remeasured and is described in an appendix to this report, and summarized in Figure 7.

The angular unconformity just north of the mouth of Wilkie Brook provides a natural break in the stratigraphic section which, with one exception, was used as the boundary between the Horton and Windsor Groups (Table 2). The exception is Murray (1960) who suggests that the boundary is somewhere (not defined) in the lower part of the succession above the unconformity. We concur with most authors in placing a boundary at the angular unconformity, and define it as the base of the Wilkie Brook Formation (Table 2, Fig. 7).

The 21.3 m thick limestone horizon cropping out on the south side of Marsh Cove, here named the Marsh Cove Limestone, provides a distinctive marker horizon. The base of the Marsh Cove Limestone is here defined as the top of the Wilkie Brook Formation. Murray (1960) did not clearly define the top of his Wilkie Brook Formation, but probably included the 21.3 m thick limestone within it (Table 2). The Marsh Cove Limestone is typically yellow, vuggy and recrystallized and parts of it are finely laminated, folded and brecciated (see Appendix). It appears to have been originally a finely laminated limestone which has undergone severe leaching, dissolution and boring by beach pebbles. Transitions can be seen both laterally and vertically between highly altered limestone and laminated limestone.

The Wilkie Brook Formation has a total thickness of 206 m. The lower part is predominantly red polymictic conglomerate and sandstone, which rapidly grades upwards into an interbedded sequence of conglomerate, sandstone, siltstone, shale and limestone. The upper part of the formation consists mainly of conglomerate (Fig. 7). Clasts in the conglomerate are generally of igneous and metamorphic origin. Locally a calcareous cement is common in the conglomerates and sandstones. Two grey-green shale horizons in the section are characterized by calcareous concretions and ostracods. The limestone beds are typically thin and discontinuous, and are locally oolitic and algal. Unit 44 (see Appendix) has been described as an algal reef by Kaminsky (1953) but no confirmed algal structures were observed. Sedimentary structures include graded bedding, both tabular and trough cross-bedding, groove casts, ripple marks and mud cracks. Plant debris is sporadically distributed throughout the section.

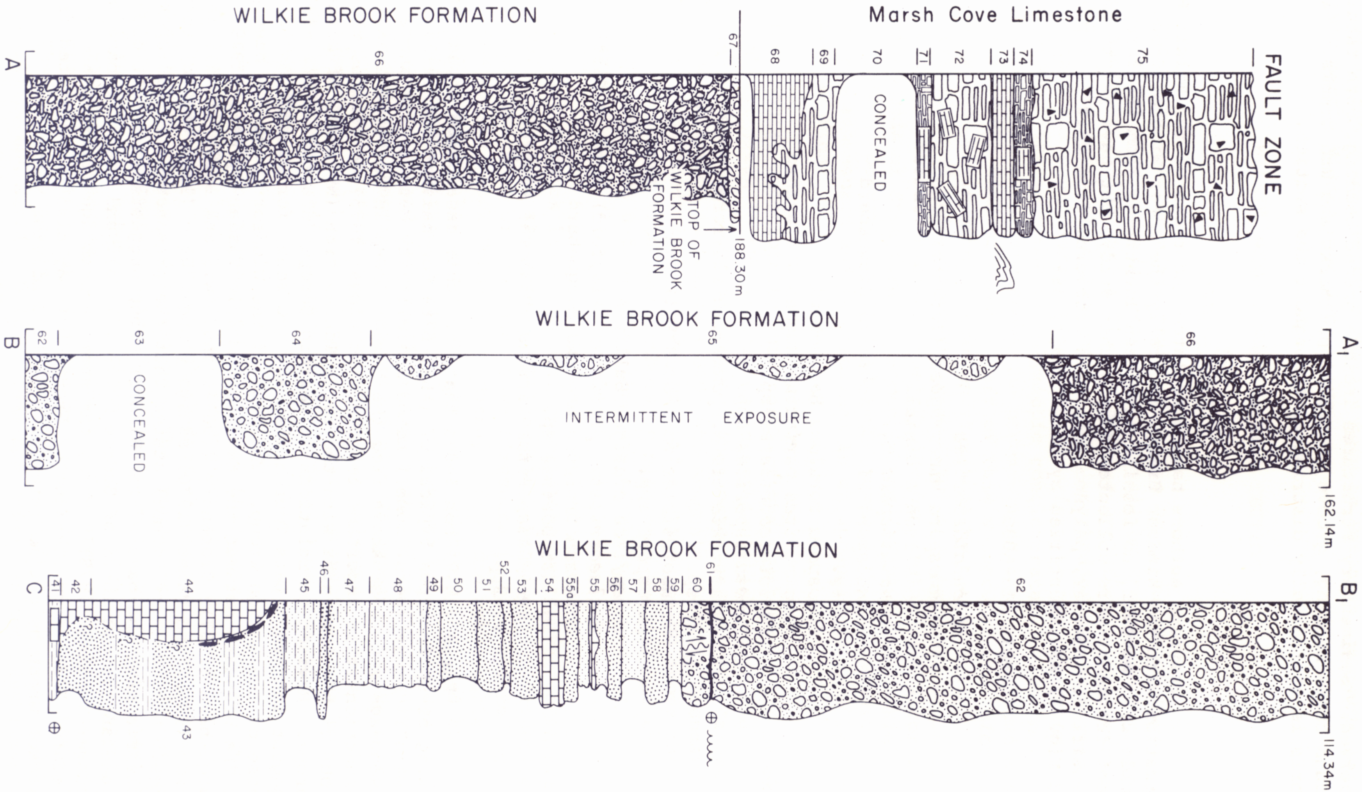
Age

Previous authors have correlated the rocks of the Wilkie Brook Formation with the Windsor Group, generally the Lower Windsor Group (Table 2). However, no fossils have been identified from the formation. Plant fragments were collected during this study, but have yet to be identified. However, palynomorphs were recovered from Unit 40 (Appendix and Fig. 7) and identified by Barss (1977) as:

Sample F13-6000

Apiculatasporites
Calamospora microrugosa (Ibrahim) Schopf, Wilson & Bentall
Convolutispora sp.
Grandispora cf. *G. echinata* Hacquebard
G. sp.
Lycospora torulosa Hacquebard
Perotrilites perinatus Hughes & Playford
Phylothecotriletes sp.
Punctatisporites spp.
Raistrickia cf. *R. ponderosa* Playford
R. sp.
Retusotriletes incohatus Sullivan
Rugospora spp.
Schopfites claviger Sullivan
Spelaeotriletes pretiosus (Playford) Neves & Belt
Spinozonotriletes uncatus Hacquebard
Vallatisporites sp.
Verrucosisporites nitidus (Naumova) Playford
V. spp.

Barss (1977) concludes that "... this assemblage appears to be a mixing of spore types typical of [the] Late Tournaisian and/or Early Viséan". Barss (pers. comm.) noted a similarity between the above assemblage and those known from the Horton Group in the type area. In this connection it is important to note that Higgs (1975) correlates the Horton Group of the type area with the Early Tournaisian (NV zone) of western Europe. Revised correlations in western Europe (Clayton *et al.*, 1977) suggest instead a Late Tournaisian age (PC zone) for assemblages similar to those of the Horton Group. The base of the Windsor Group has been placed at the boundary between the Early and Middle Viséan by Bell (1929, 1958), Hacquebard (1957), Globensky (1967), and Howie and Barss (1975), whereas Lewis (1935) and Mamet (1970) assign younger ages (late Viséan) to the base. Utting (pers. comm.) states that the presence of *Vallatisporites ciliaris* near the base of the Windsor Group suggests it is not older than Arundian (Viséan 1b-2a of George *et al.*, 1976), and that its base may be younger (Utting, 1978). Thus, the spore assemblage reported above not only predates those from the Windsor Group, but may also be separated from the Windsor Group by a time interval of 7 to 8 million years.



WILKIE BROOK FORMATION
Marsh Cove Limestone
A
66
67
68
69
70
71
72
73
74
75
CONCEALED
FAULT ZONE
TOP OF WILKIE BROOK FORMATION
188.30m
WILKIE BROOK FORMATION
B
62
63
64
65
66
A1
CONCEALED
INTERMITTENT EXPOSURE
162.14m
WILKIE BROOK FORMATION
C
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55a
55
56
57
58
59
60
61
62
B1
114.34m

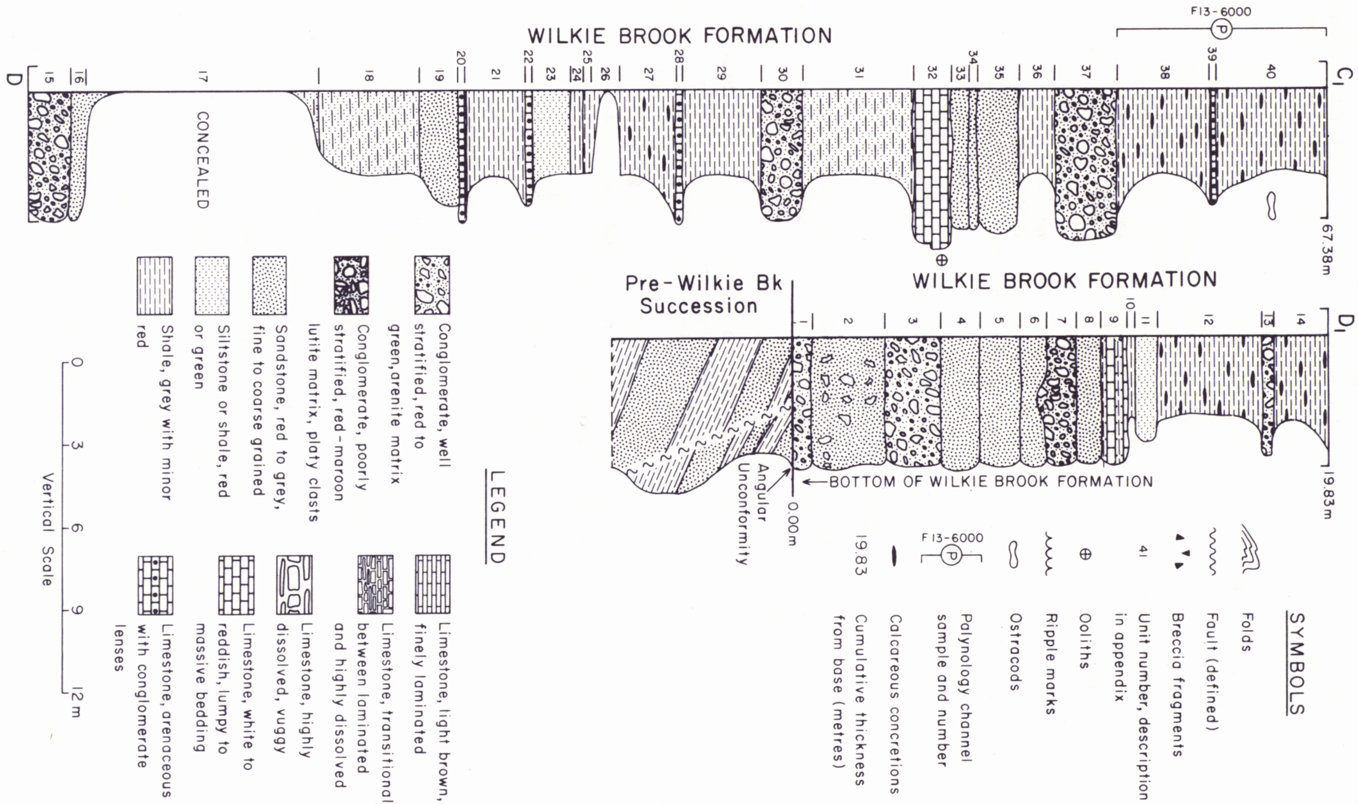


Figure 7 - Type section of the Wilkie Brook Formation.

Benson (1970) reports Late Devonian spores from the rocks lying beneath the angular unconformity at the base of the Wilkie Brook Formation. This provides a lower limit on the age of the Wilkie Brook Formation. The upper limit is not well defined and depends upon lithostratigraphic correlation of the Marsh Cove Limestone with limestones of the Windsor Group. Kaminsky (1953), Kramer and Phinney (1953), Murray (1960), and Boucot *et al.* (1974) all correlated the Marsh Cove Limestone with the A2 limestone of Sage (1954). Such a correlation necessitates the inference of a facies change for the rocks below the A2 limestone between areas with typical Windsor Group lithologies and the Wilkie Brook area. However, based upon both the age of the spore assemblage recovered from the Wilkie Brook Formation, and the laminated character of the Marsh Cove Limestone, two of us (P.S.G. and R.C.B.) correlate the Marsh Cove Limestone with the basal A1 Windsor Limestone. Thus we conclude that the Wilkie Brook Formation is Tournaisian to Early Viséan and probably Late Tournaisian in age and is equivalent to the Horton Group in the type area (Bell, 1960).

H.B. FINA F-25 WELL, NORTHUMBERLAND STRAIT

Stratigraphy

The section in H.B. Fina F-25 well (Hudsons Bay Oil & Gas Co., 1970) is the most complete section available in the vicinity of Cape George and is summarized in Figures 5 and 8.

Rocks below 2950.5 m are comparable to the Knoydart Formation, although they could conceivably be older. Between 2580.1 m and 2950.5 m, interbedded basalts and sedimentary rocks were intersected. Between depths of 2030.0 and 2580.1 m, the rocks are reported to be red sandstone, minor conglomerate, and red and grey shale, with some anhydrite nodules. Dipmeter surveys indicate a significant change in attitude at 2514.6 m and a possibility of folding between depths of 2292.0 and 2347.0 m. Above 2030.0 m, a limestone was encountered overlain by evaporites followed upwards by interbedded sandstone, siltstone, evaporite and minor limestone. No ages are available for rocks in this well.

CORRELATION

Since the H.B. Fina F-25 well has the most complete section in the vicinity of Cape George all other sections discussed in this paper are related to it. Unfortunately, no fossils were identified from this well so correlations must be entirely lithostratigraphic. In order to provide some control on the upper part of the H.B. Fina F-25 well, correlation is made with a reference section of the Windsor Group in the Shubenacadie basin (Fig. 8) where Bell's (1926) subzones of the Windsor Group are well understood. Examination of Figure 8 reveals good lithostratigraphic correlation for the Lower Windsor Group and indicates that the limestone horizon, the base of which occurs at a depth of 2030.0 m in the Fina well, is the A_1 limestone at the base of the Windsor Group.

In the Knoydart Point area, the fossils recovered from the Ardness Limestone and spores from the upper member (of Fralick, 1977) of the McAras Brook Formation indicate equivalence with the upper part of the Windsor Group. On the other hand, the basalts in the lower member (of Fralick, 1977) of the McAras Brook Formation may be correlated with those

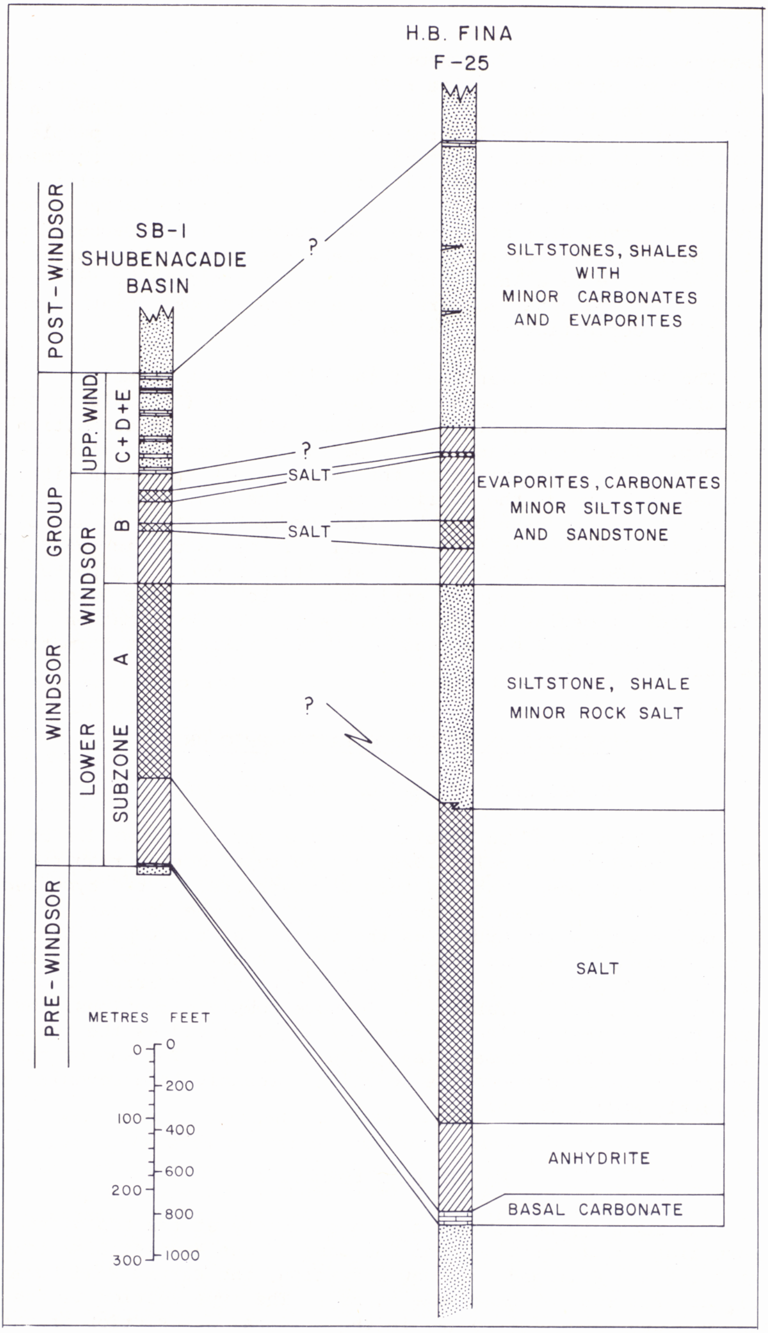


Figure 8 - Correlation of Windsor Group Strata in Hole HB Fina F-25, with the Windsor Group of the Shubenacadie Basin.

at Ballantynes Cove (Table 2, Boucot *et al.*, 1974) and in the lower part (2580.1-2950.5 m) of the H.B. Fina F-25 well (Fig. 5). Such a correlation is supported by the presence of red conglomerates and sandstones interbedded with the basalts in all three sections. Furthermore, pebble lithologies and the hematitic coating of the pebbles in the conglomerates are the same at McAras Brook and Ballantynes Cove. This correlation requires that the lower member (of Fralick, 1977) of the McAras Brook Formation in the type area be of Late and possibly Middle Devonian age, the age of the McAras Brook Formation at Ballantynes Cove. This conclusion indicates that there is a large time interval represented by the unconformity between the lower and upper members of the McAras Brook Formation and requires its re-definition (see below).

The Late Tournaisian age of the Wilkie Brook Formation indicates that it must have been deposited after the (?)Middle to Upper Devonian part of the McAras Brook Formation, and prior to deposition of the Windsor Group. The correlation of the Marsh Cove Limestone with the A1 limestone suggests a correlation of the Wilkie Brook Formation with the section immediately below the A1 limestone in the H.B. Fina well (Fig. 5). The unconformity at the base of the Wilkie Brook Formation cannot be identified with certainty in the Fina well. It may occur in the (?)folded section between 2292.0 and 2347.0 m or at 2514.6 m where a dipmeter survey indicated a significant change in attitude. Also, the Late Devonian sedimentary rocks immediately beneath the Wilkie Brook Formation could occur above the uppermost basalt and below the Wilkie Brook Formation in the Fina well (Fig. 5).

DEFINITIONS OF LITHOSTRATIGRAPHIC UNITS

MCARAS BROOK FORMATION *(sensu stricto)*

The discovery of an angular unconformity in the middle of the McAras Brook Formation (of Bell, 1926) at the type section requires that it be redefined. We propose that the term be restricted in the type section to those rocks lying between the unconformity with the Knoydart Formation and the unconformity which truncates the basalts at the top (Fig. 5). It will be designated the McAras Brook Formation *(sensu stricto)* hereinafter. This corresponds to units (a) to (f) in the original description of the type section (Bell, 1926) (Table 1). In more complete sections, the top of the McAras Brook Formation *(sensu stricto)* is redefined as the top of the stratigraphically highest basalt lava flow (Fig. 5). The age of the McAras Brook Formation *(sensu stricto)* is Devonian, probably Late Devonian and possibly partly Middle Devonian.

MARTIN ROAD FORMATION

The rocks lying between the unconformity at the top of the McAras Brook Formation *(sensu stricto)* and the base of the Ardness Limestone near Knoydart Point are assigned to a new formation, the Martin Road Formation (Fig. 5), after a road of that name nearby. The type section is the shoreline and includes units (g) to (s) in the original description of the type section of the McAras Brook Formation of Bell (1926, p. 152c-153c). A small thickness of grey shales benearth the Ardness Limestone are included in our Martin Road Formation. Its age is Late and possibly Middle Viséan.

MARSH COVE LIMESTONE

The Marsh Cove Limestone is defined as the 21.3 m thick limestone horizon cropping out on the south side of Marsh Cove. It is regarded as a unit of the Windsor Group, equivalent to the A1 limestone of Sage (1954).

WILKIE BROOK FORMATION

The Wilkie Brook Formation is defined as the succession of conglomerates, sandstones, shales and limestones lying between the unconformity 380 m north of the mouth of Wilkie Brook and the base of the Marsh Cove Limestone. The type section is described in the Appendix. A Late Tournaisian age is indicated for the Wilkie Brook Formation by spores recovered from within it.

HORTON GROUP

The Horton Group was originally defined by Bell (1960) for the type section at Horton Bluff near Windsor, Nova Scotia. It included two formations, the Horton Bluff and the conformably overlying Cheverie Formations, with a Tournaisian to Early Viséan age (Howie and Barss, 1974), an Early Tournaisian age (Higgs, 1975) revised to Late Tournaisian by Clayton *et al.* (1977). Since that time, the Horton Group has been loosely used to include not only these formations or their equivalents, but also all pre-Windsor Group and post-Lower Devonian formations and groups (Howie and Barss, 1974). We believe this obscures the important lithological differences between Middle-Upper Devonian rocks and the pre-Windsor Lower Carboniferous rocks. For example, the Late Tournaisian Wilkie Brook Formation is lithologically similar to rocks of the Horton Group and lies with marked unconformity upon a group of lithologically distinct rocks. We believe these latter rocks should be excluded from the Horton Group. Thus, we prefer to revert to the original definition of the Horton Group (Bell, 1960) and will use the term Horton Group *(sensu stricto)* to distinguish it from the Horton Group *(sensu lato)* of Kelley (1967) and Howie and Barss (1974). In view of the uncertainties in the rocks predating the Wilkie Brook Formation (Boucot *et al.*, 1974) no attempt will be made here to erect another group, and they will be merely referred to as pre-Horton Group *(sensu stricto)* pending remapping of the area.

WINDSOR GROUP

Bell (1929) defined the base of the Windsor Group in Nova Scotia as the first appearance of marine strata of Early Carboniferous age. Using this definition, the Martin Road Formation would be excluded from the Windsor Group because the Ardness Limestone is the lowest Carboniferous marine horizon. The upper limit of the Windsor Group was defined by Bell (1927) as the top of the stratigraphically highest marine stratum. While this definition is sufficient for complete sections of the Windsor Group, it requires modification to include those sections of intercalated marine and continental rocks where unconformities occur locally at the base and/or top of the group, such as at points 1, 2, 3 and 4 in Figure 9. In these cases, the unconformities should logically define the top and bottom of the Windsor Group, even though rocks of continental origin occur at the contacts. This expanded definition allows the Martin Road Formation to be

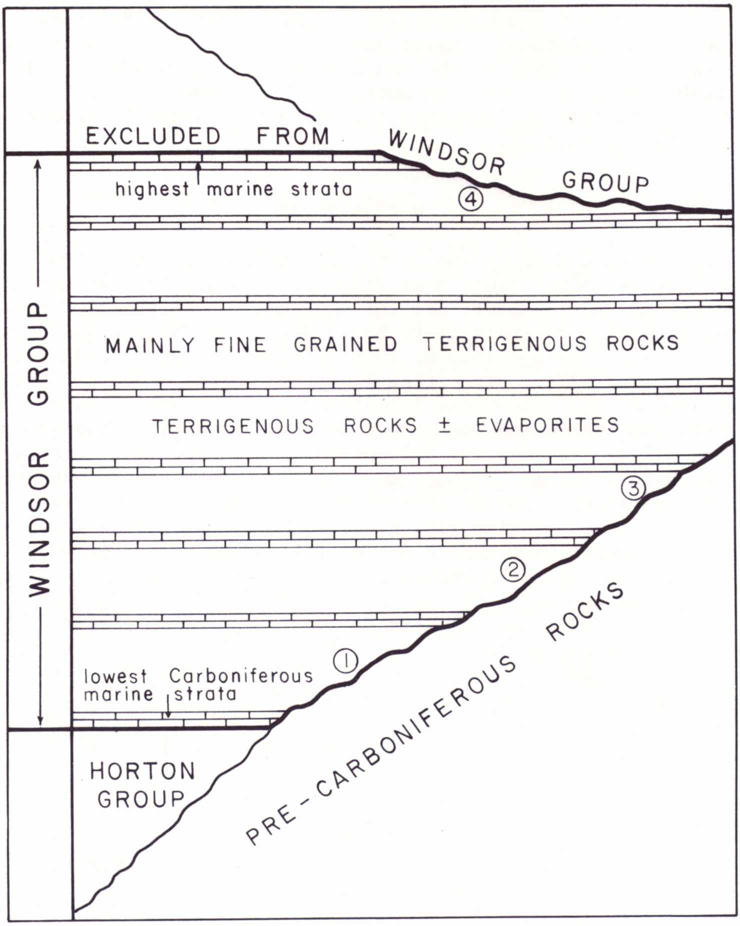


Figure 9 - Proposed expanded definition of the Windsor Group.

included within the Windsor Group. Rocks which are totally non-marine facies-equivalents of the Windsor Group are excluded from the Windsor Group as defined above, on the grounds that they should represent major and distinct mappable units.

CONCLUSIONS

All previous workers have assigned the Wilkie Brook Formation to the Windsor Group and several have also included the McAras Brook Formation *(sensu stricto)* within the Windsor Group (Table 2). In order to account for the obvious lithological differences between these formations and the "typical" Windsor rocks, facies changes have been inferred and accounted for by progressively complex facies models (Murray, 1960; Schenk, 1975). However, this study provides evidence that these rocks are of different ages and cannot be considered facies equivalents. The McAras Brook Formation *(sensu stricto)* is Late(?Middle) Devonian in age, and the Wilkie Brook Formation is Late Tournaisian whereas the Windsor Group is Middle-Late Viséan. Thus, the section between the mouth of Wilkie Brook and Ballantynes Cove (Fig. 6) cannot be used to demonstrate facies changes and paleogeographic models in the Windsor Group. Data demonstrating age equivalence of rocks are a prerequisite to inferring facies changes. This does not imply that facies changes are not present in the Windsor Group elsewhere. Indeed a facies change in the lower part of the Windsor Group is present in the Musquodoboit Valley (Boehner and Giles, 1976; Boehner, 1977; Giles and Boehner, in prep.).

The section west of the mouth of McAras Brook provides evidence important to the understanding of Middle to Late Viséan paleogeography. Here the Upper Viséan Martin Road Formation rests with angular discordance upon the McAras Brook Formation *(sensu stricto)* (Fig. 5). The absence of rocks equivalent to the Lower Windsor Group may be interpreted in two ways. Either they were not deposited here, or they were eroded away during a period of uplift between their deposition and the deposition of the Martin Road Formation. In either case an upland area was present here. Paleocurrent data presented by Fralick (1977) for the Martin Road Formation (Fralick's upper member of McAras Brook Formation) suggests a source area to the northwest. This upland is provisionally called the Northumberland Strait Landmass. Its areal extent is not clearly delineated. However, the presence of typical Lower Windsor rocks in the H.B. Fina F-25 well, the A1 limestone at Marsh Cove and in the Antigonish and Pictou basin areas, suggests outer limits for its extent in southerly and easterly directions.

This study reveals that Middle to Late Devonian rocks are more extensive around the Antigonish Highlands than formerly recognized. Most of these rocks have been mapped as Horton Group *(sensu lato)* or as Rights River Formation on recent maps (Benson, 1970, 1974). We believe that this obscures the essential differences between the rocks of Middle Devonian and Early Viséan age, e.g. between the McAras Brook Formation *(sensu stricto)* and the Wilkie Brook Formation. In order to partly overcome this difficulty we propose that the term Horton Group be restricted to comply with its usage in the type area (Bell, 1960) where it includes the Horton Bluff and Cheverie Formations, of Early Tournaisian age. In fact the term Horton Group *(sensu stricto)*, representing a distinctive mappable rock unit, may not be applicable to rocks of the same age in the Cape George area. Of course, remapping of the Horton Group *(sensu lato)* around the Antigonish Highlands is necessary in order to understand these Middle Devonian to

Early Viséan rocks. Consequently, no attempt has been made here to name all of the rocks encountered during this preliminary study (Fig. 5).

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APPENDIX

TYPE SECTION OF THE WILKIE BROOK FORMATION

(Described in Descending Order)

Fault Zone

Contact with apparently overlying rocks not exposed; intermittent exposure of limestone, conglomerate and schistose gypsum blocks are found to the north of the limestone outcrop and probably occur in a fault zone.

Unit 75	8.0 m	Limestone, light grey-brown, vuggy to cavernous, bedding not apparent; contains 1-5 cm angular fragments of medium brown limestone and a few siltstone pebbles; vuggy nature is due in part to the removal of these fragments and subsequent enlargement of the cavities.
Unit 74	0.68 m	Limestone, light grey-brown, vuggy to laminated; appears to be a transitional rock type; passes laterally into and is truncated by Unit 73.
Unit 73	0.85 m	Limestone, light brown, finely laminated, deformed with small kink and box folds; deformation is not apparent in the underlying massive vuggy limestone.
Unit 72	2.25 m	Limestone, light grey-brown, highly vuggy and porous, appears to have been in part dissolved; several 10-30 cm blocks of unaltered laminated limestone similar to the overlying unit are present in the unit; these appear to have been deformed and occur in diverse orientations; vugs are present and are irregular in shape, up to 10 cm in diameter and have calcite druse linings.
Unit 71	0.5 m	Limestone, light grey to brown; appears to be a transitional rock type between the well laminated and the porous vuggy types; the unit is obscurely bedded with small vugs along bedding planes.
Unit 70	3.0 m	Covered interval.
Unit 69	2.5 m	Limestone, light grey to brownish grey, highly porous vuggy texture, bedding not discernable; unit is equivalent in part to Unit 68 and appears to be an alteration product of the laminated limestone which it replaces laterally.
Unit 68	3.54 m	Limestone, light brown with light grey-brown weathering, thin bedded in beds 0.5 cm thick; lower contact with conglomerate concealed in 0.5 m covered interval; the lowest exposed part of the unit appears to be disrupted and bedding is irregular.

TOP OF WILKIE BROOK FORMATION

(Base of A_1 Limestone (Sage, 1959), contact concealed but condordant)

Unit 67	0.26 m	Conglomerate, clasts in both pebble and cobble size, light grey to grey-green, well indurated and calcareous.
Unit 66	36.1 m	Conglomerate, flat pebble with minor cobble, fine sandstone to siltstone matrix, dark red to maroon in colour; clasts have a surface coating of hematite; unit is poorly stratified and has fair induration; cross-bedding is present but is poorly developed; sandstone occurs locally as thin lensoidal interbeds and coarser cobble conglomerate interbeds are common in upper part of unit.
Unit 65	25.0 m	Covered interval with intermittent exposure of weathered conglomerate.
Unit 64	5.5 m	Conglomerate, medium red, pebble-sized clasts in a sandy matrix; channeled, with gently dipping cross-bedding; thin lensoidal sandstone interbeds throughout.
Unit 63	6.0 m	Covered interval.
Unit 62	24.0 m	Conglomerate, pale reddish to grey in colour, clasts pebble-size with thin cobble zones, sandstone matrix; both trough and tabular cross stratification present; fair to well sorted subrounded clasts, some composed of oolitic limestone near base of section; gritty sandstones more common toward top associated with thin coarse conglomerate beds; parallel stratification predominates with some gently dipping cross-bedding toward top of unit.
Unit 61	0.10 m	Limestone, white to reddish, coarsely oolitic; upper surface displays symmetrical ripple marks with wave length of 18 cm and amplitude 4 cm; ripple crests trend 141 degrees.
Unit 60	0.93 m	Sandstone, red, medium to coarse-grained, thick bedded, pebble-cobble conglomerate lensoidal beds 30-40 cm, cross-bedded; a small high angle fault with offset of approximately 2.5 m can be seen at this position in the section.
Unit 59	0.62 m	Siltstone, medium red, shaly weathering with several thin sandy beds as discontinuous lenses; poorly indurated.
Unit 58	0.89 m	Sandstone, medium grained with some fine conglomeratic lenses, red in colour; thinly bedded and calcareous near top.
Unit 57	0.95 m	Siltstone, medium red, shaly weathering, with a few 2-4 cm thick calcareous sandstone interbeds.

Unit 56	0.48 m	Sandstone, slightly calcareous, medium red; medium bedded, cross-laminated with thin shaly siltstone partings near top.
Unit 55b	1.12 m	Interbedded red siltstone and white nodular limestone; siltstone becomes calcareous near the top and base of the unit; the unit is predominantly creamy white lumpy limestone in the central portion; this lumpy zone thins abruptly into the more typical thinly bedded sequence; sample for petrographic study, WB-55b-24.
Unit 55a	0.56 m	Sandstone, medium to light red; consists of 5-6 beds which are lensoidal and discontinuous; unit is calcareous in its upper parts.
Unit 54	0.95 m	Limestone, creamy white with reddish siltstone-sandstone interbeds; irregular to lumpy bedding near base, well bedded near top in beds 0.5-2 cm thick; calcareous sandstone abundant near top; bedding is wavy to planar, lumpy beds near base are lenses? 25-40 cm diameter and 10-15 cm thick and have shale in interstices; upper contact is irregular; samples for petrographic study, WB-54-22 and WB-54-23.
Unit 53	0.92 m	Sandstone, medium to coarse-grained, medium to dark red in colour; flaggy bedded in beds 1-10 cm thick; basal part appears to be part of a trough with siltstone pebbles present near base; planar cross-bedded near top; upper contact sharp.
Unit 52	0.30 m	Sandstone, fine-grained, medium red, shaly weathering, with thin coarse sandstone interbeds; unit is poorly indurated; upper contact irregular.
Unit 51	0.98 m	Sandstone, medium to coarse-grained, medium; appears to be a channel filling; basal 39 cm weakly bedded; middle 37 cm parallel bedded and the upper portion cross-bedded.
Unit 50	1.34 m	Sandstone, fine-grained, medium red, with shaly partings; locally slightly calcareous, with fair to poor induration.
Unit 49	0.50 m	Sandstone, medium to coarse-grained, with thin flaggy bedding in beds 1-2 cm thick; biconvex pinch and swell lensoidal bedding also noted; unit cross bedded (tabular) and well indurated, and becomes calcareous near the top.
Unit 48	2.14 m	Interbedded red shaly siltstone and red sandstone, medium-grained; beds 5-10 cm thick; rare thin calcareous grey sandstone present; unit is brecciated in part.
Unit 47	1.47 m	Interbedded shaly siltstone, medium red in colour, with light grey calcareous sandstone which is finely conglomeratic near the base of the sequence; sandstones

display pinch and swell bedding with planar bases and convex tops; some trough cut and fill present near the top of the unit; sample for petrographic study, WB-47-21.

Unit 46 0.30 m — Sandstone, medium-grained, light red, medium bedded, slightly calcareous; lower contact abrupt, upper contact gradational.

Unit 45 1.29 m — Shale and siltstone, red to maroon, with thin scattered calcareous sandstone beds 5-10 cm thick; unit is poorly indurated.

Note: Unit 44 is a lateral stratigraphic equivalent of Unit 43. Since the major thickness of Unit 44 crops out on the beach, and since the intervening interval shoreward toward Unit 43 is not exposed, the nature of the contact between the equivalent units is not discernable. The contact near the top of the units, however, is exposed over a distance of 1.5 m. In this instance the contact is very sharp and steeply dipping with a limited nodular transition zone into Unit 43 red siltstones. The top of Unit 44 lies 0.5 m below the top of Unit 43. It appears probable that the limestone of Unit 44 developed with significant relief in its upper portion, and was subsequently covered by Unit 43. The lower portion may exhibit limited inter fingering, but it is apparent that the facies change is very rapid and occurs over an interval of only a few metres. The base of Unit 44 may extend downwards into Unit 42, and the top might extend upwards locally at least to the base of the overlying unit.

Unit 44 0?-7.3 m — Limestone, light grey, creamy to reddish; irregular lumpy to nodular weathering; silt occurs as discontinuous stringers; bedding weakly defined.

Unit 43 7.12 m — Interbedded siltstone and fine sandstone, medium red in colour; shaly weathering in subunits 10-35 cm thick with medium-grained locally calcareous well indurated red sandstone in beds 5-10 cm thick; several greenish bands 20-35 cm in thickness at base; a few thin beds of grey limestone with reddish cast are present; samples for petrographic study, WB-43-18 (limestone) and WB-43-19 (calcareous sandstone).

Unit 42 1.1 m — Shale, grey-green, with yellowish weathering, fine sandstone interbeds 5-8 cm in thickness.

Unit 41 0.41 m — Shale, grey-green, interbedded with siltstone green; two thin impure oolitic limestone beds are present, lower is 4-5 cm thick and the upper one 10-20 cm thick; limestone beds appear to interfinger with the shale; samples for petrographic study, WB-41-16 and WB-41-17 (oolite beds).

Unit 40 4.08 m — Shale, bluish to grey-green, moderately fractured; similar to Unit 38 but has several 5-8 cm thick limey interbeds near base which are similar to Unit 39; lower contact transitional by interbedding; elongate nodules 5-20 cm in diameter and 3-5 cm thick are abundant in the lower 1.5 m; several steeply dipping, thin fault or joint planes are present and have calcite filling; unit is abundantly ostracodal within thin 1-2 cm discontinuous lenses and pods; samples for petrographic study, WB-40-13 (concretion) and WB-40-14 (ostracodal shale).

Unit 39 0.26 m — Limestone, light yellowish to grey, arenaceous; tabular bedded near top; minor fault with offset of 30 cm noted in exposure; sample for petrographic study, WB-39-12.

Unit 38 3.40 m — Shale, bluish to grey-green with scattered calcareous nodules and concretions 5-20 cm in diameter; poorly indurated, fractured in part.

Unit 37 2.3 m — Conglomerate with sandy matrix, and sandstone, red to grey calcareous, in discontinuous, lensoidal interbeds; mainly pebble-size clasts with scattered cobbles; irregularly stratified, with poorly sorted, subrounded clasts; the northeastern portion of the exposure displays 6-7 sets of normal graded beds 10-30 cm thick; a channel 2-3 m wide and 0.9 m deep is also exposed in this interval cutting through the bedded units; trough cross-bedding is also present in this unit; the upper part of the unit is marked by a 29 cm thick bed with tabular foreset bedding with strike 134 and dip 13° SW.

Unit 36 1.30 m — Shale, silty, medium red, poorly indurated.

Unit 35 1.5 m — Sandstone, medium to coarse-grained, red, slightly calcareous at base; gritty and pebbly beds occur at 5 discrete graded horizons; unit is thick bedded becoming more thinly bedded near top; possible mega-ripples with minor channeling and scouring near top.

Unit 34 0.34 m — Sandstone, medium to coarse-grained, red, calcareous; interbedded with red shale in beds 5-10 cm thick; sandstone beds thicken toward the northeast with development of conglomerate lenses and channeling.

Unit 33 0.63 m — Sandstone, medium-grained, medium red, variably calcareous; some arenaceous limestone interbeds near upper contact; indistinctly cross laminated; scattered conglomerate pebbles in the centre of the unit.

Unit 32 1.34 m — Limestone, light grey to reddish, oolitic; undulatory discontinuous bedding with interbeds of red shaly siltstone; limestone beds 5-15 cm thick, shale beds 2-5 cm thick.

Unit 31 4.07 m — Siltstone, fine-grained, and shale, grey-green and red; scattered thin discontinuous light grey to reddish arenaceous limestone beds; unit is poorly indurated.

Unit 30	1.55 m	Conglomerate, pale red to light grey in colour, calcareous, with subangular pebbles and lensoidal interbeds of calcareous red sandstone and shales; channel 2 m wide present; the unit appears to coarsen toward northeast in the exposure; the upper part of the unit consists of arenaceous limestone with pebble conglomerate lenses; unit is well indurated.
Unit 29	2.87 m	Similar to Unit 27, limestone interbeds more abundant (up to 6-7/m), and up to 8 cm thick; shales show dessication cracks.
Unit 28	0.26 m	Limestone, light grey arenaceous with 2 sub-central conglomeratic beds 3 cm and 5 cm thick; the upper bed is a medium pebble conglomerate and the lower bed is a fine pebble conglomerate; unit is obscurely bedded and the upper contact is undulatory.
Unit 27	2.1 m	Shale, red, poorly indurated with thin (3-5 cm) arenaceous limestone in lensoidal interbeds numbering approximately 3/m; basal 15 cm of the unit is grey-green arenaceous limestone.
Unit 26	1.0 m	Covered interval, probably red shale.
Unit 25	0.30 m	Shale, red, poorly indurated.
Unit 24	0.47 m	Shale, red, with two interbeds of light grey to reddish arenaceous limestone; fractures filled with dolomite; bases of limestone beds have well developed groove casts.
Unit 23	1.4 m	Siltstone, medium red with a local light green mottle; slightly calcareous and poorly indurated.
Unit 22	0.25 m	Limestone, very arenaceous and conglomeratic; locally calcareous fine pebble conglomerate present; colour is light grey with reddish cast; sample for petrographic study, WB-22-9.
Unit 21	2.20 m	Shale, red to grey-green with slightly calcareous limey beds; similar to Unit 18.
Unit 20	0.27 m	Limestone, very arenaceous, reddish to grey, with a central pebble-cobble conglomerate 6 cm thick; rippled top and bottom; base of unit has well developed chevron groove casts with a trend of 48°.
Unit 19	1.40 m	Sandstone, fine-grained, red, calcareous; 5-10 cm thick beds interbedded with red siltstone in 10-15 cm thick beds; locally contains thin calcareous sandstone beds (arenaceous limestone?); sample for petrographic study, WB-19-8.
Unit 18	3.68 m	Interbedded sequence of red shale, grey shale, silty limestone and light grey calcareous sandstone;

limestone beds 3-8 cm in thickness, shale beds 10-20 cm thick; sandstone and limestone more abundant in the lower 2.5 m; samples for petrographic study, WB-18-6 and WB-18-7.

Unit 17 8.5 m Covered interval.

Unit 16 0.51 m Sandstone, coarse-grained with pebble conglomerate lenses, light grey-brown in colour; poorly bedded with vague cross-bedding locally; unit is well indurated and slightly calcareous.

Unit 15 1.57 m Conglomerate, light grey, pebble-size clasts in a sandy matrix; thin discontinuous sandy interbeds, calcareous locally; thickly stratified with subangular to subrounded pebbles 1-3 cm in longest dimension; locally exhibits reverse graded bedding; upper contact irregular.

Unit 14 2.05 m Shale, pale reddish in colour with minor grey-green; basal 10 cm consists of well indurated, calcareous, thin bedded green siltstone; unit is similar to Unit 12, with thin irregular concretion-rich beds; unit is poorly indurated excepting the concretions which are resistant to weathering; concretions are absent in the upper 1.2 m.

Unit 13 0.45 m Conglomerate, light brown to grey, with a few thin lensoidal interbeds of coarse sandstone; weakly stratified; clasts poorly sorted, granule to boulder size, and subangular to subrounded; upper contact irregular.

Unit 12 3.80 m Shale, light grey, with reddish interbeds near top, containing a few thin 3-5 cm calcareous siltstone beds numbering 3/m, decreasing in number upwards; shale is poorly indurated whereas the calcareous beds appear as discontinuous pillows or nodules; upper contact irregular.

Unit 11 0.82 m Siltstone, light grey-green, finely micaceous, calcareous, locally very arenaceous; thinly bedded with approximately 5 thin (5-7 cm thick) interbeds of silty limestone; bedding is pillow-like and lensoidal to tabular, and becomes thinner toward the top of the unit; pillows are 15-20 cm in diameter and 5-8 cm thick; upper contact gradational with shale; samples for petrographic study, WB-11-3 (limestone) and WB-11-4 (possible fossil).

Unit 10 0.33 m Siltstone, light green with some red mottle; finely laminated with shaly parting; a few thin calcareous beds are present; fair to poor induration.

Unit 9 0.97 m Siltstone and limestone interbedded, siltstone medium red, slightly to moderately calcareous, limestone arenaceous, light grey to reddish grey; beds 3-8 cm in thickness; beds tabular at base becoming discontinuous and lensoidal upwards; lensoidal limestone beds locally intermesh to form subtabular beds with internal shaly partings; siltstone is poorly indurated and limestone is well indurated; sample for petrographic study, WB-9-2 (limestone bed).

Unit 8 0.92 m Sandstone, medium to coarse-grained, medium red, with scattered pebbles; calcareous in part, beds 15-20 cm thick with thin internal partings; interbedded with poorly indurated red siltstone in beds up to 10 cm in thickness with brick red shaly partings; lower contact irregular and erosional, upper contact wavy with oscillation ripple marks.

Unit 7 1.15 m Conglomerate (sandy) and sandstone, pebbly, interbedded, medium red; with scattered limestone clasts similar in lithology to the limestone in Unit 6; several sequences 15-30 cm thick of normally graded conglomerate; sandstone obscurely cross-bedded; lower contact shows a channel into Unit 6.

Unit 6 0.70-0.99 m Sandstone, fine-grained, with some siltstone and several 4-5 cm thick limestone beds; sandstone medium red with rare thin grey mottled beds, limestone beds grey-white in colour; limestone beds lensoidal and well indurated; upper contact of unit locally channeled to depths reaching 29 cm, with channel width up to 90 cm; channels infilled with sandy pebble-cobble conglomerate of the overlying unit; ripple marks apparent on uppermost bedding surface, trend of ripple crests 140°, wave length 45 cm, amplitude 9 cm; sample for petrographic study, WB-6-1 (limestone bed).

Unit 5 1.50 m Sandstone, conglomeratic, medium to coarse-grained, medium red; larger material pebble size with rare boulder size (up to 35 cm longest dimension) in basal 20 cm; calcareous cement locally; lensoidal bedding present in beds 10-30 cm thick; unit is well indurated.

Unit 4 1.45 m Sandstone, medium-grained, medium red with minor light green mottle; flaggy bedded, bed thickness 3-5 mm in basal 10 cm, increasing to 3-5 cm and up to 10 cm in upper portions; upper and lower contacts are sharp and erosional in nature; unit has fair induration.

Unit 3 2.00 m Conglomerate, fine to medium pebble size, red with irregular light green mottle, fine to medium sandstone matrix; obscurely cross stratified, thins and fines toward the west and becomes a thickly bedded conglomeratic sandstone; unit is well indurated and locally has a calcareous matrix or cement.

Unit 2 2.65 m Sandstone, fine to medium-grained, medium red with green mottle in discontinuous pods along bedding planes; interbedded in lensoidal beds 10-20 cm thick with fine to medium-grained pebble conglomerate in beds up to 30 cm thick; unit appears to be more fine-grained to the west (in exposure) with finer and thinner conglomerate beds and locally thin shaly siltstone beds near the top; unit has fair induration and is lithologically similar to Unit 1.

Unit 1 0.75 m — Conglomerate, cobble and pebble-size clasts in lensoidal and discontinuous beds; poorly stratified; matrix medium to coarse clay-rich sandstone with fair sorting, locally with calcareous cement and iron oxide stain; colour medium red with minor green mottle; unit is well indurated and contains conglomerate clasts of cobble size (up to 10 cm longest dimension) which appear to have been derived from the underlying succession; clasts are rounded to subrounded and consist mainly of phanoritic igneous and metamorphic rocks with lesser volcanic rock fragments; normal and reverse graded bedding present.

BASE OF THE WILKIE BROOK FORMATION

Angular Unconformity

MIDDLE TO LATE DEVONIAN SUCCESSION

Undivided red and grey-green sandstone, shale, and conglomerate.

Paper 78-4 Some Middle Devonian to Lower Carboniferous Rocks of Cape George, Nova Scotia