Chapter 2 - Stratigraphy

Introduction

Strata within the Carboniferous basins of Nova Scotia have conventionally been assigned to six principal groups defined by Bell (1944), and redefined by Kelley (1967) and Howie and Barss (1975b). In ascending order these include the Horton, Windsor, Canso, Riversdale, Cumberland and Pictou groups (Fig. 2-1). Local group names for Upper Carboniferous coal- bearing strata include the Morien and Stellarton groups. In addition, pre-Horton Group strata (especially those with interstratified volcanics) have locally been assigned to the River John or Fountain Lake groups. Belt (1964, 1965) introduced a major revision of the lithostratigraphy of rocks previously assigned to the Canso and Riversdale groups. These group names were abandoned and the Canso Group was replaced by the Mabou Group. All overlying strata, including those assigned to the abandoned Riversdale Group as well as the Cumberland, Pictou, Morien and Stellarton groups, were included in the informal 'Coarse Fluvial Facies'. These revisions were not widely accepted, and a dual nomenclature (Canso-Mabou) has developed.

Ryan *et al.* (1991) introduced further revisions to these post-Mabou Group strata in the Cumberland Basin, which contains some of the most completely exposed sections of Upper Carboniferous strata in the Maritimes Basin of Atlantic Canada, including type sections for both the Cumberland and Pictou groups and probably one of the best sections of the Riversdale Group. These revisions include: (1) recognition of the abandonment of the Riversdale Group, (2) re-assignment of its constituent formations to the revised Cumberland Group, and (3) relocation of the Cumberland - Pictou group boundary up-section in the original Pictou type section in River John (Bell, 1944) to reflect the lithostratigraphy of the constituent formations.

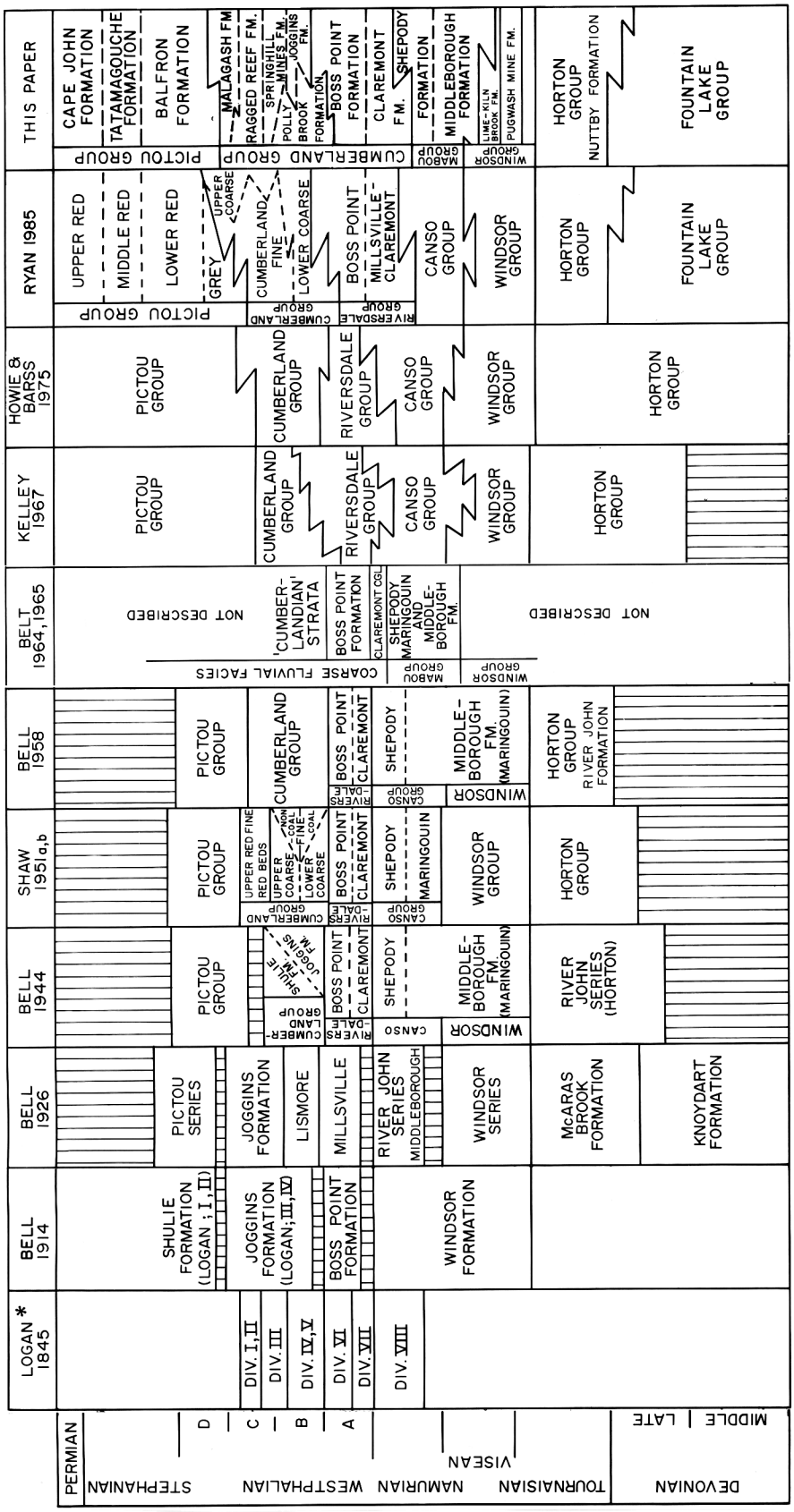
Mappability of these units is demonstrated in a series of four, 1:50 000 scale, colour geological maps of the Cumberland Basin (in pocket). The revised groups were intended by Ryan *et al.* (1991) to contain, as far as possible, naturally related and associated formations.

Geographic names applied to the new units have been reserved with T. Bolton, Geological Survey of Canada, for usage as applied by Ryan *et al.* (1991) and in this report. The nomenclature of the revised groups and formations is similar to the original definitions of Bell (1944), as revised by Kelley (1967) and summarized in the *Lexicon of Canadian Stratigraphy* for the Atlantic Region (Williams *et al.*, 1985). Significant revisions resulting from new subdivisions and re-assignments affect the Windsor, Mabou, Cumberland and Pictou groups and are discussed below.

The following sections describe the principal lithostratigraphic units mapped in the study area. These units are described from oldest to youngest, with emphasis on the Lower Carboniferous units of the Windsor and Mabou groups. The systematic stratigraphy of the Cumberland and Pictou groups has been previously described by Ryan *et al.* (1991) and is only summarized here.

The Windsor and Horton groups in the Cumberland Basin were not previously subdivided, with the exception of informal mapping terminology by Wright *et al.* (1931) and Norman and Bell (1938a, 1938b), and biostratigraphic correlations by Bell (1944, 1958). Horton Group strata do not outcrop within the Cumberland Basin and have not been intersected in deep petroleum exploration drilling. They are inferred to be present in the subsurface based on regional distribution patterns (and adjacent basins) and seismic interpretation. The available data, however, do not allow subdivision or rigorous age assignment and these strata are included in an undivided Devonian-Carboniferous map unit (Ryan *et al.*, 1990). Two new formations of the Windsor Group are recognized in the Cumberland Basin, the Pugwash Mine Formation introduced by Carter (1990) and the Lime-kiln Brook Formation introduced here. Two other regional units are interpreted to be present in the subsurface but have not been confirmed: the Macumber Formation and the informal basal anhydrite.

Criteria used to assign formations to the Windsor Group essentially follow Bell (1929, 1944) and Belt (1965). The Windsor Group is characterized by marine strata, including marine carbonates cyclicly interbedded with dominant evaporites (anhydrite, gypsum, salt and potash), with locally abundant to dominant redbeds (generally nonmarine). Formations, and as a result, group boundaries have been keyed to the laterally persistent marine carbonate members by Giles and Boehner (1979), Keppie *et al.* (1978), Giles (1981) and Boehner (1984). This departure from previous workers



*Joggins section, tied to the lithostratigraphic assignments of this study.

Figure 2-1. Evolution of late Paleozoic stratigraphic nomenclature in the Cumberland Basin between 1845 and 1990.

is relatively minor: only the grey and red mudrock section with thin, discontinuous evaporite interbeds above the highest marine carbonate member of the Windsor Group is excluded. These evaporites are included within the typically conformably overlying Mabou (Canso) Group.

Strata assigned in this study to the Mabou Group have been included by previous workers in the Canso Group and include the Middleborough and Shepody formations (Division 8 of Logan, 1845). The Middleborough Formation, as exposed in the Wallace River section, was correlated with and included in the early Westphalian River John series by Bell (1926). Bell (1927) considered the River John series to be equivalent in age to the Upper Horton. River John Group rocks have subsequently been included in the middle Devonian to early Carboniferous Fountain Lake Group and Falls Formation by Donohoe and Wallace (1980, 1982). Bell (1944) excluded the Middleborough Formation from the Canso Group, presumably because it consists of nonmarine rocks of equivalent age to the Windsor Group. Bell (1958) subsequently included the Middleborough Formation (as well as the Shepody Formation) in the Canso Group in one table of formations, but in another table assigned the Middleborough to the Windsor Group. It is not clear if this was intentional (and reflects uncertainty) or if it was an error. The Middleborough and Shepody formations were assigned by Ryan *et al.* (1991) to the Mabou Group following the precedent of Belt (1964 and 1965). The strata are dominated by fine-grained redbeds, fine sandstone, mudstone, locally interbedded grey mudrocks and rare gypsum, anhydrite and salt in the subsurface.

Shaw (1951a) divided the Cumberland Group in the basin into five major facies divisions: (1) the Lower Coarse Facies; (2) the Fine Coal-Bearing Facies; (3) Fine Non Coal-Bearing Facies; (4) the Upper Coarse Facies; and (5) the Upper Fine Red Facies. This contrasts with the earlier bipartite subdivision of a lower, Joggins Formation (re-instated in this report) and an upper, Shulie Formation which Bell (1938) introduced (Fig. 2-1) and subsequently abandoned (Bell, 1944). The facies divisions of Shaw (1951a) were adapted by Copeland (1959) as a four-part subdivision by merging the fine coal-bearing and non coal-bearing facies resulting in (1) 'lower coarse', (2) 'lower fine', (3) 'upper coarse' and (4) 'upper fine' facies. For mapping, Ryan (1985) subsequently used a simplified threefold subdivision of the Cumberland Group consisting of (1) lower coarse, (2) fine, and (3) upper coarse facies. The Upper Fine Red Facies of Shaw (1951a) has been excluded from the Cumberland Group and is considered to be part of the Pictou Group by several workers, including Belt (1965), Calder (1985a, 1985b), Ryan (1985) and numerous exploration geologists. Ryan *et al.* (1991) assigned the Upper Fine Red Facies to the newly defined Ragged Reef and Malagash formations of the revised Cumberland Group.

On the basis of palynology, Howie and Barss (1975a) clarified the age relationships of the groups and formations (substantially diachronous) in the Maritimes Basin (Fig. 2-1). Ryan (1985) in a preliminary report suggested subdivision of the Pictou Group into four informal lithostratigraphic units: (1) grey beds; (2) lower redbeds; (3) middle redbeds; and (4) upper redbeds. Ryan (1985) also suggested that the Pictou grey beds may be equivalent to the Cumberland Group fine non coal-bearing facies of Shaw (1951a).

Criteria for assignment of formations to the Cumberland and Pictou groups in their type areas in the Cumberland Basin were described by Ryan *et al.* (1991) and are summarized in Table 2-1. The new formations introduced, defined and assigned to appropriate groups by Ryan *et al.* (1990, 1991) using these criteria include: the Cumberland Group, comprising the Polly Brook, Joggins, Springhill Mines, Ragged Reef and Malagash formations as well as the Claremont and Boss Point formations re-assigned from the abandoned Riversdale Group; and the Pictou Group, including the Balfron, Tatamagouche and Cape John formations.

Carboniferous Stratigraphy

Horton Group

Horton Group strata do not outcrop within the Cumberland Basin. A few areas in the adjacent Cobequid Highlands Massif have fault block sections of the Nutby Formation which is interpreted to be equivalent to the Horton Bluff Formation of the Horton Group. The Horton Group is typically made up of fluvial-lacustrine conglomerate, sandstone and mudrocks of latest Devonian to Tournaisian age. In the Cumberland Basin, seismic profiles indicate that the Horton Group occurs at depth in the basin where it underlies the Viséan Windsor Group and overlies the mixed clastic and volcanic beds of the middle to late Devonian Fountain Lake Group. The thickness of the unit varies from 0.2 km to 1.2 km. Figure 2-2 places the Horton Group strata into the stratigraphic context of the Cumberland Basin. Horton Group strata were deposited over basement rocks within the Cumberland

Table 2-1. Lithologic criteria used for defining the revised Cumberland and Pictou groups in their type areas in the Cumberland Basin, northern Nova Scotia.

CRITERIA	CUMBERLAND GROUP	PICTOU GROUP
Coal-bearing:	very common	rare
Red lithofacies:	subordinate	dominant
Grey lithofacies:	dominant	subordinate
Conglomerate:	locally abundant	rare
Fine lithofacies:	subordinate-subequal	dominant
Lateral variation:	rapid, diverse	limited
Contacts:	conformable to disconformable with Mabou Group, unconformable with older Carbonifeorus and basement rocks; conformable to disconformable with Pictou Group strata (dominantly redbeds)	conformable to unconformable with the hetergeneous Cumberland Group and correlatives; unconformable with older Carboniferous strata and basement rocks

Basin and the adjacent highlands. The highland areas were uplifted prior to and during development of the Cumberland Basin in the Late Carboniferous. Erosion of Lower Carboniferous strata from the uplifted areas and the subsequent onlap of Upper Carboniferous units resulted in preservation of the Horton Group rocks being restricted to the subsurface.

Windsor Group

The stratigraphy and correlation of the Windsor Group in the Cumberland Basin has been problematic for several reasons (Boehner, 1988b): (1) Windsor Group rocks outcrop in and adjacent to structurally complex, en echelon diapiric anticlines and several isolated diapiric bodies (Fig. 2-3); (2) exposures of these relatively incompetent rocks are generally limited, represent only small portions of a potentially thick succession, and are locally extensively modified by karstic processes; and (3) difficulty in determining the relationship between complexly folded diapiric evaporites in the lower part of the succession and exposed Windsor sections. In addition to these problems of exposure and deformation, significant facies changes (vertical and lateral) to sections without diagnostic marine rocks compound the other difficulties.

A reasonably complete stratigraphic column for the Windsor Group in the Cumberland Basin has not been previously established, precluding correlation with the lithostratigraphic "Major Cycle" framework of Giles (1981) and Boehner (1986). Correlation has been, and continues to be, difficult in the lowermost part of the Windsor Group because of the lack of outcrop and deep drillhole data.

Only one exploration borehole, Anschutz Wallace Station No. 1, could possibly have penetrated to the stratigraphic base of the Windsor Group. This hole, drilled on the crest of the Malagash Anticline near Wallace (Fig. 2-3), was abandoned after numerous drilling problems in what was interpreted as Horton Group at a depth of 4536.9 m. The section in the lowest part of the drillhole is problematic in several respects. That section, interpreted to be the basal part of the Windsor Group, is a cherty-siliceous grey shale (MacDonald, 1973). Thus, the regionally extensive basal carbonate of the Windsor Group (Macumber or Gays River Formation) is apparently not represented in the Cumberland Basin, nor is the equally extensive basal anhydrite (typically 100-400 m thick). Identification of the Horton Group (4267-4536.9 m) was partially based on the presence of arkosic sandstone and fine conglomerate; these rock types also occur locally within Windsor Group sections exposed in the Cumberland Basin. Paleontological results reported in MacDonald (1973) were inconclusive.

The interpretation of 'Horton Group' salt in the interval 4432-4536 m is questionable, as there is no apparent geophysical response typical of salt in the gamma ray and sonic logs run in the interval. Salt chips

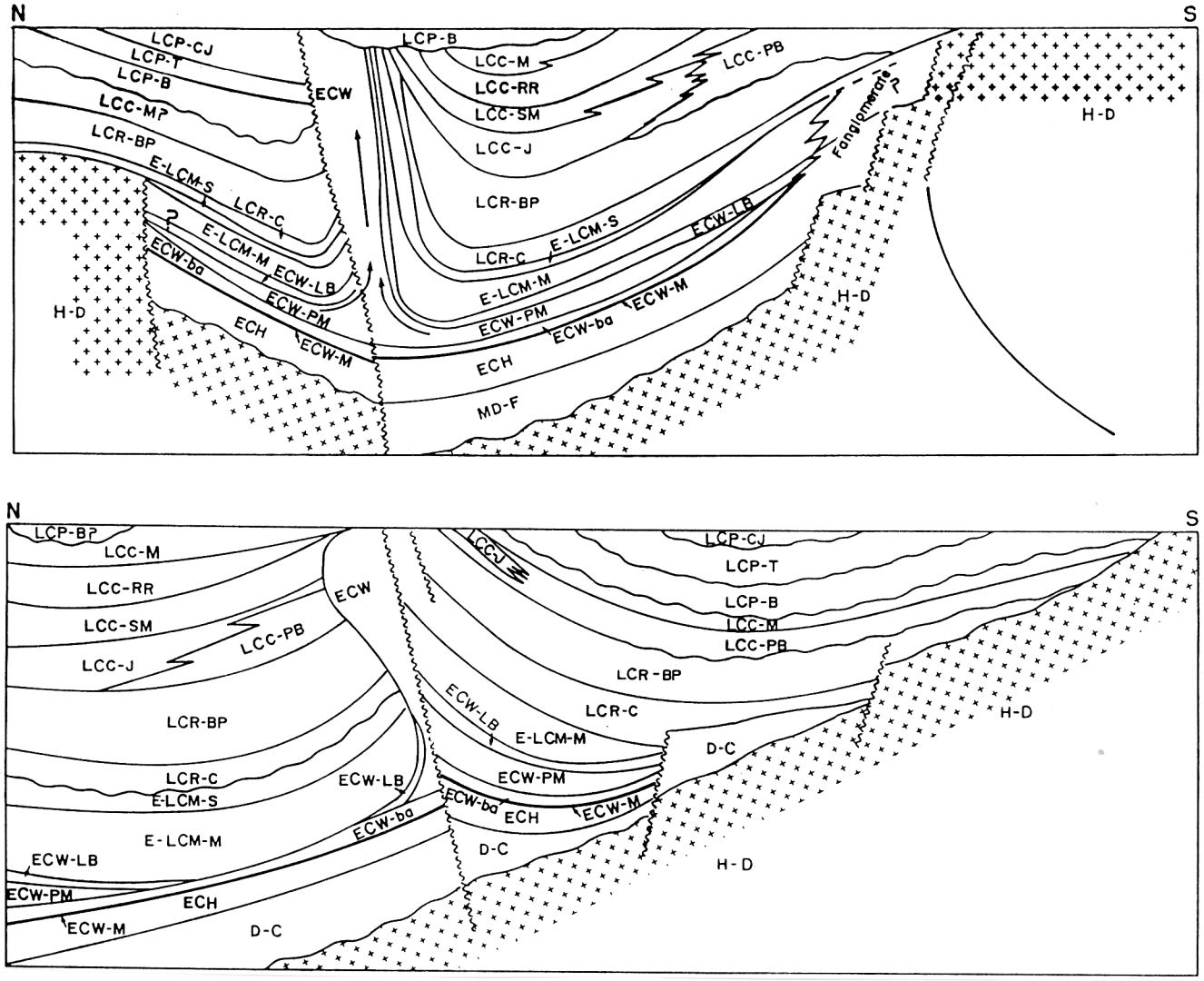


Figure 2-2. Diagrammatic stratigraphy in the top eastern and bottom western parts of the Cumberland Basin.

recovered may represent caved or plucked material from higher in the well. In summary, data to support the interpretation of the interval from 4267-4536.9 m as Horton Group are inconclusive, therefore the Wallace Station No. 1 drillhole could be interpreted as having been abandoned within the Windsor Group. If this is true, then the base of the Windsor Group has not been intersected anywhere in the Cumberland Basin in Nova Scotia; this is the position taken by the present authors.

Paleontological dating of the Major Cycle 1 section has been inconclusive. Palynology samples from the Pugwash Mine and drillholes in the Nappan and Oxford areas yielded long ranging assemblages typical of the NS to early AT Zones (Utting, 1987) of the Windsor Group (Dolby, personal communication, 1987) but were of insufficient quality and quantity to confidently establish the position in the lower part of the Windsor Group.

Placement of the Windsor Group - Mabou (Canso) Group boundary (Fig. 2-1) has historically been a problem in the Cumberland Basin, especially in the Minudie - Nappan area. Bell (1944, 1958) placed the base of the Middleborough Formation, which is considered the base of the Mabou Group in the Cumberland Basin, at the top of the highest carbonate unit in the main carbonate zone. Bell (1944) first interpreted the contact as conformable, but later as disconformable (Bell, 1958). Problems and questions related to this boundary are as follows: (1) explanation for the apparent absence of Upper Windsor Group limestone members (numbering more than 10) that are

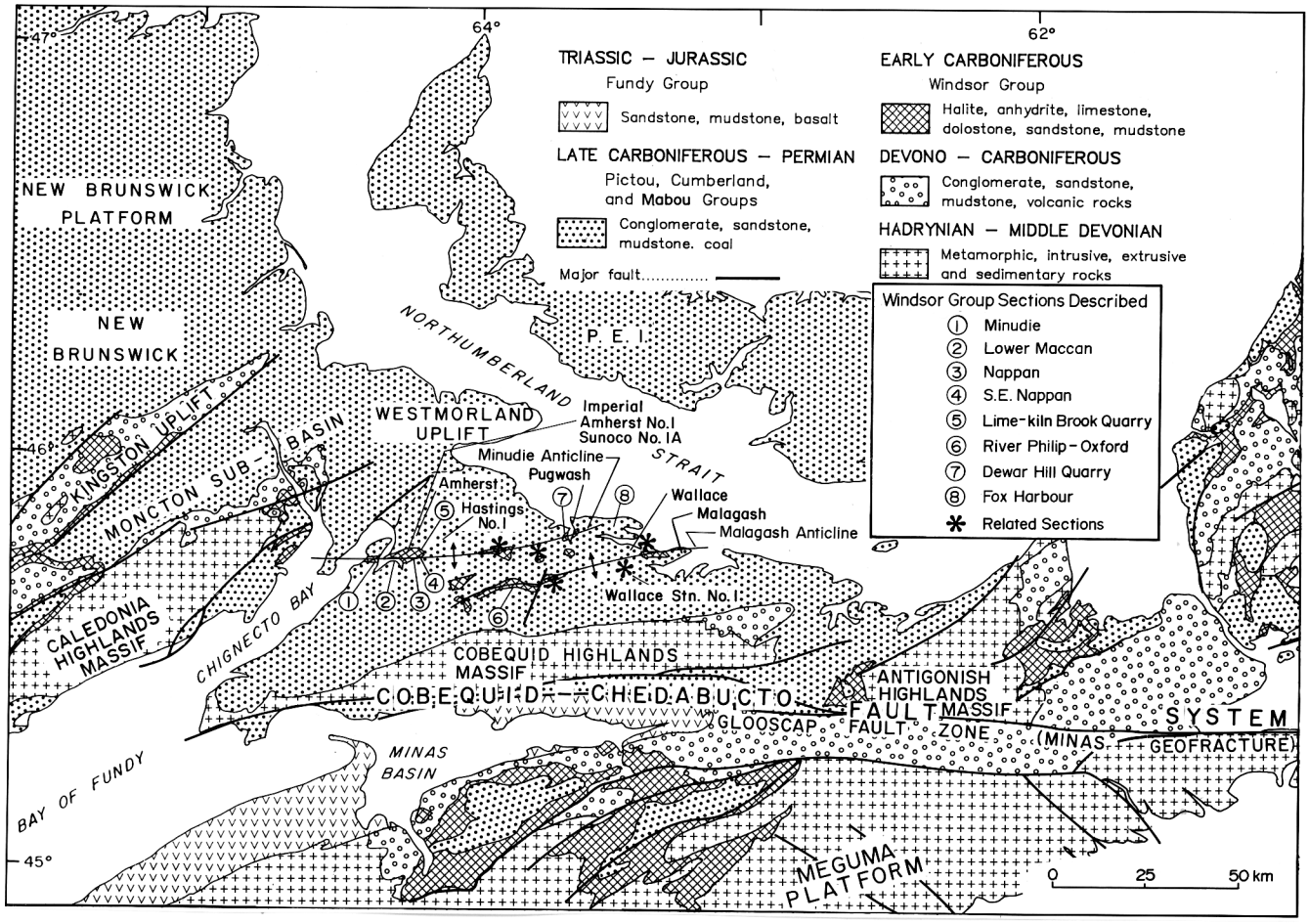


Figure 2-3. General geology and location map of Windsor Group stratigraphic sections.

well documented elsewhere in Nova Scotia, (2) definition of the Windsor - Mabou boundary when the Windsor undergoes facies change involving pinch-out of the diagnostic marine limestone members, especially early in the depositional history and (3) the redbeds of the Windsor Group and Mabou Group are apparently indistinguishable, making any lithostratigraphic separation arbitrary.

This situation is not unique in Nova Scotia. Keppie *et al.* (1978) faced a similar situation and proposed a definition of the Windsor Group that placed the top of the group at the top of the stratigraphically highest marine stratum. This was further specified to be a marine carbonate by Giles (1981). Using this approach, the boundary definition is relatively straightforward as long as undocumented, stratigraphically higher marine strata, specifically carbonates, are not encountered later. The nonmarine redbeds, even though they are facies and age equivalents of the Windsor Group above the limits imposed by the marine strata, are given separate lithostratigraphic status and in the Cumberland Basin are included in the Middleborough Formation (Mabou - Canso Group; Fig. 2-4). In New Brunswick, the name Hopewell Group has been applied to this nonmarine interval of the Carboniferous section dominated by coarse to fine redbeds (late Viséan to early Westphalian) overlying distinctive marine Windsor Group rocks (or basement) and underlying grey sandstone of the Boss Point Formation (Fig. 2-4). The Hopewell Group, therefore, may be age and facies equivalent with all or part of the Windsor Group (upper), Mabou Group (all), and Cumberland Group (lower). If applied in the same sense to the Cumberland Basin stratigraphy in Nova Scotia (Fig. 2-4) the Hopewell Group would include (be correlative with) units identified as the Middleborough, Shepody and Claremont formations.

Marine carbonates and evaporites typical of Major Cycles 3-5, although widespread in Nova Scotia

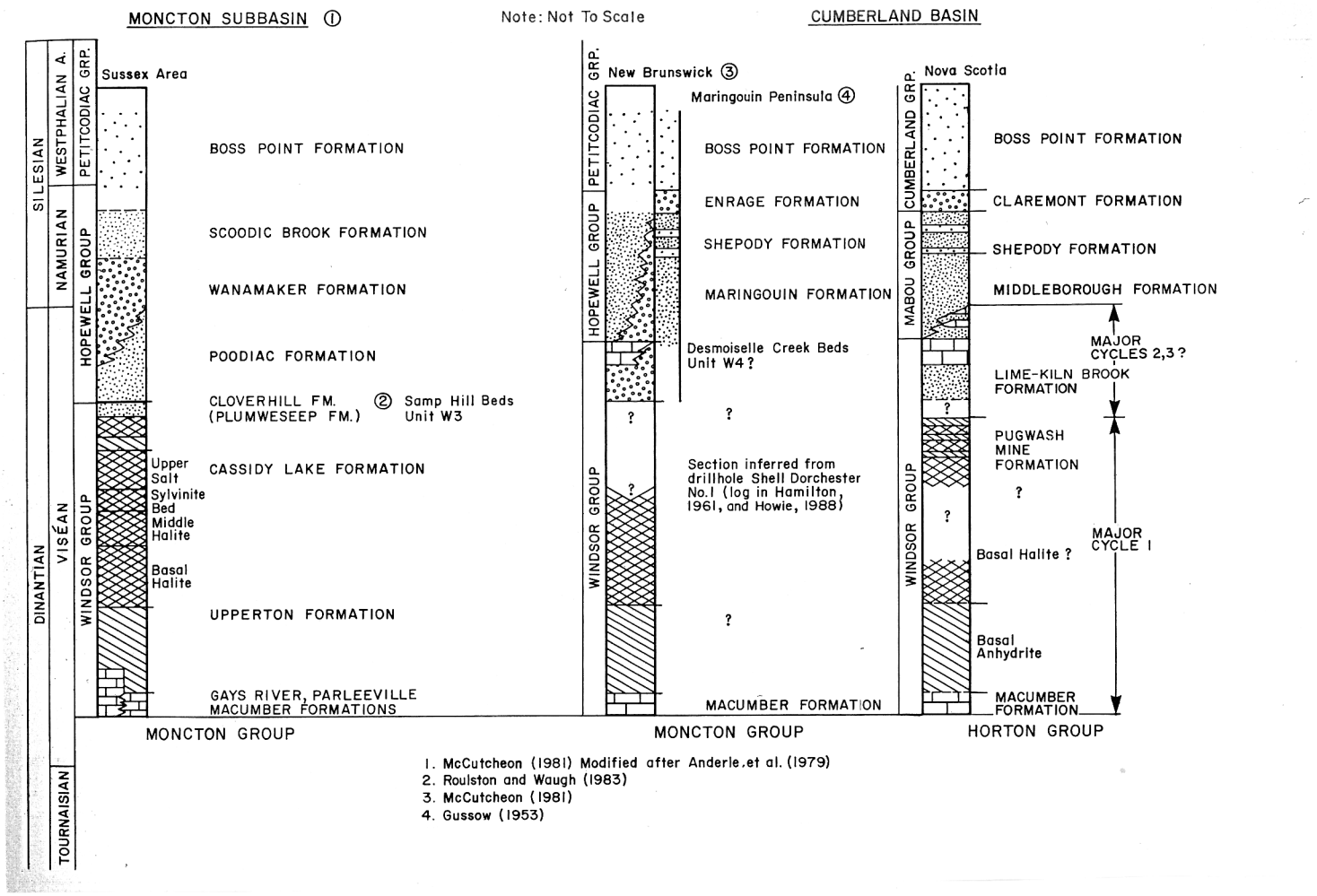


Figure 2-4. General correlation of the Viséan to Namurian Mabou and Windsor groups in the Cumberland Basin area.

(Giles, 1981), are not recognized (not present?) in the Cumberland Basin or in southern New Brunswick. A profound facies change, probably reflecting regional paleo-geography, is indicated whereby the marine carbonate facies of the middle to upper parts of the Windsor Group (Major Cycles 2-5, B-subzone to E-subzone) are restricted in lateral extent or not present in northern Nova Scotia and probably most of New Brunswick. Fine- to coarse-grained continental redbeds (depending upon the area considered) apparently dominated deposition throughout the late Viséan and Namurian to the early Westphalian in this tectonically active area of the Maritimes Basin.

Formal Nomenclature

Windsor Group

Age

Early Carboniferous, early to late Viséan (Utting, 1988; Giles, 1981)

Author

Dawson, 1873; redefined Bell, 1944; Kelley, 1967.

Description

Strata of this group are poorly exposed in the study area. Outcrops occur only along the axis of the Claremont and Minudie anticlines and near evaporite diapirs. The stratigraphy and correlation of Windsor Group rocks have been described by Wright *et al.* (1931), Roliff (1932), Bell (1944 , 1958), Evans (1972), Carter (1987) and Boehner (1988b). The Windsor Group is a complex cyclic sequence of interstratified evaporites, dominantly halite, anhydrite and gypsum with minor potash (sylvite and carnallite); redbeds; fine sandstone to mudstone; rare grit and minor grey to green mudstone; and minor fossiliferous marine limestone and dolostone (Boehner, 1984). Two new lithostratigraphic units, the Pugwash Mine Formation (Carter, 1990) and Lime-kiln

Brook Formation (introduced herein) are the principal subdivisions of the Windsor Group in the Cumberland Basin.

Thickness and Distribution

Evaporite tectonics has severely altered the original thickness and distribution patterns of the Windsor Group in the Cumberland Basin. Fragmented, incomplete sections indicate a probable original thickness in the range of 1000 m to perhaps as much as 1500 m; bowever, attenuated sections could be as thin as 500 m due to erosion or evaporite flowage and removal.

Relationship to Other Units

In the Cumberland Basin, the contacts between the Windsor, Horton and Mabou groups are absent or poorly exposed at surface. Elsewhere within the Maritimes Basin, the Windsor Group either conformably or unconformably overlies the Horton Group or older strata, whereas the Mabou Group commonly conformably overlies and is diachronous with tbe Windsor Group (Fig. 2-4).

Subdivisions

Macumber Formation: (Inferred but unconfirmed application in the area)

Age

Early Carboniferous; early to middle Viséan; (Utting, 1987; Giles, 1981)

Author

Weeks, 1948; extensive descriptions by Schenk, 1967; McCutcheon, 1981 and Geldsetzer, 1978.

Type Area

Type locality not designated, type area is in the general vicinity of Cheverie, Hants County, Nova Scotia.

Description

Buff to light grey-brown to dark grey, pelletal limestone to dolostone, variably argillaceous and arenaceous; well developed laminations are characteristic.

Thickness and Distribution

The Macumber Formation in the Maritimes Basin varies widely in thickness, from 1 to 18 m. It is a relatively tbin unit but is widely distributed as the basal Windsor Group carbonate in Atlantic Canada.

Relationship to Other Units

The Macumber Formation, also known as the A_1 or Ribbon limestone, or Ship Cove Formation and other names, overlies concordantly and conformably(?) to unconformably, older Carboniferous rocks including Horton Group or older Devonian to Carboniferous rocks. It is conformably overlain by, and often transitional with, a thick anhydrite sequence informally referred to in the Cumberland Basin as the basal anhydrite.

The Macumber Formation and basal anhydrite units have not been confirmed to be present in outcrop or drillholes in the Cumberland Basin in Nova Scotia. Their presence is inferred based upon: (1) their regional persistence and distribution, (2) probable occurrence as a distinctive seismic unit in seismic lines throughout the basin, and (3) their interpreted presence near Dorchester, New Brunswick, in the Shell Dorchester No. 1 drillhole log reported by Hamilton (1961) and Howie (1988). The Macumber Formation and basal anhydrite are also probably present in drillhole HB Fina F25 drilled between Nova Scotia and Prince Edward Island (Keppie *et al.*, 1978).

Basal Anhydrite: (informal, presence inferred but not confirmed, see also above)

Age

Early Carboniferous; early to middle Viséan; (Utting, 1988; Giles, 1981)

Author

None, informal reference only.

Description

The basal anhydrite is dominated by thick, massive, nodular to poorly stratified anhydrite with minor thin carbonate, halitic or mudstone interbeds. Variably hydrated to gypsum in near-surface environments.

Thickness and Distribution

The thickness varies from 100-300 m and the unit is regionally distributed throughout Atlantic Canada.

Relationship to Other Units

The basal anhydrite conformably and transitionally overlies tbe Macumber Formation. Correlative units in the region include: Carrolls Corner, Bridgeville, White Quarry and Upperton formations. The basal anhydrite unit is commonly overlain by a very thick salt sequence referred to as the Pugwash Mine Formation (new name) in the Cumberland Basin.

History

The name basal anhydrite has been used informally

for general reference to the thick anhydrite unit at the base of the Windsor Group.

Pugwash Mine Formation (New name)

Age

Early Carboniferous; early to middle Viséan; (Dolby, 1989)

Author

Carter, 1990, 1991.

Type Locality

A composite type section described by Carter (1990) is exposed in workings and drillholes in the Canadian Salt Company Limited Pugwash Mine, Pugwash, Cumberland County, Nova Scotia. Additional reference sections are in less clearly documented drillholes including: Pacific Fox Harbour C-96V (Fig. 2-5), Sunoco No. 1A and Domtar Nappan Nos. 5, 6 and 7. Detailed stratigraphic interpretations of these isolated drillhole sections are hindered by structural complexity within the Windsor Group evaporite diapirs.

Description

The Pugwash Mine Formation is a complexly folded and disrupted, stratified evaporite sequence. It is dominated by salt (halite) with interbedded anhydrite, subordinate redbeds and grey mudstone (especially near the top), with local minor potash (sylvite and carnallite). The lithology, stratigraphy and structure are best, but incompletely documented at the type area in the Pugwash Mine (Carter, 1987; Evans, 1972). Details of the rock types at the upper and lower contacts are uncertain. Carter (1985a, 1989, 1991) described a stratigraphic succession with three distinct recognizahle anhydrite units 15-30 m thick, in ascending order the Shaft, Borate and Cap (third) anhydrite members. They occur as variably broken and disrupted interbeds, interstratified with plastically deformed salt units of varying thickness, comprising halite with varying anhydrite and mudstone impurity content. The salt units are variegated in colour, red-brown to grey; less pure salt sections contain abundant mudstone and locally potash interbeds in the upper part of the type section. The lower part of the type section is dominated by white, grey to clear salt with varying anhydrite content occurring as interbeds, laminations, fragments and disseminations. The third anhydrite, positioned locally on the flanks of the Pugwash Diapir, is interpreted to be cap rock (Carter, 1989).

Thickness and Distribution

The Pugwash Mine Formation forms the dominant evaporite component in the diapiric structures in the Cumberland Basin. The complex structure makes a detailed accurate assessment of original stratigraphic thicknesses impossible. Carter (1987, 1989) and Evans (1972) were able to piece together a 300 m thick composite section by removing the fold repetition and compromising plastic fold thickening and attenuation. The section is incomplete at the top and base, and therefore the thickness may be considered a minimum. Structural thickness (see isopachs of Howie and Barss, 1975a) locally exceeds 6000 m in the diapirs where the dips in sheath and or curtain folds are nearly vertical and plastic deformation-flowage of the evaporites is extreme.

The Pugwash Mine Formation is inferred to be widely distributed at depth in the Cumberland Basin. Evaporite tectonics, with movement into the major diapiric anticlines and diapirs, probably has severely altered or obliterated the original thickness and distribution patterns.

Relationship to Other Units

The contact between the Pugwash Mine Formation and the basal anhydrite unit inferred to underlie the formation has not been intersected or documented in the Cumberland Basin of Nova Scotia. The upper stratigraphic contact of the formation is also problematical due to the disrupted relationship with overlying faulted-intruded strata. The contact with the overlying Lime-kiln Brook Formation in Pacific Fox Harbour C-96V is difficult to determine due to the predominance of redbeds and the inferred large scale fold repetition (Boehner, 1988b). Large scale fold repetition of the Major Cycle 1 section (Fig. 2-5) is suspected in the interval from 2518-3003.2 m (8260-9853 ft.). The inferred repetition is based on the broad symmetrical pattern of the geophysical log signatures and general lithology about a hypothetical antiform axis at a depth of approximately 2735-2740 m (8000 ft.). Five zones of symmetry are identified on Figure 2-5: (1) a broad interval of rock salt and siltstone-mudstone with a general trend of decreasing salt upward and downward; (2) an interval of mudstone with erratic, decreasing velocity with depth on sonic and gamma ray signatures; (3) a distinctive triplet of anhydrite beds; (4) a mudstone interval similar to (2) but less irregular; and (5) an isolated rock salt interval. This symmetry is suspicious but not unique or conclusive. The scale and style of fold repetition about horizontal to vertical fold axes has,

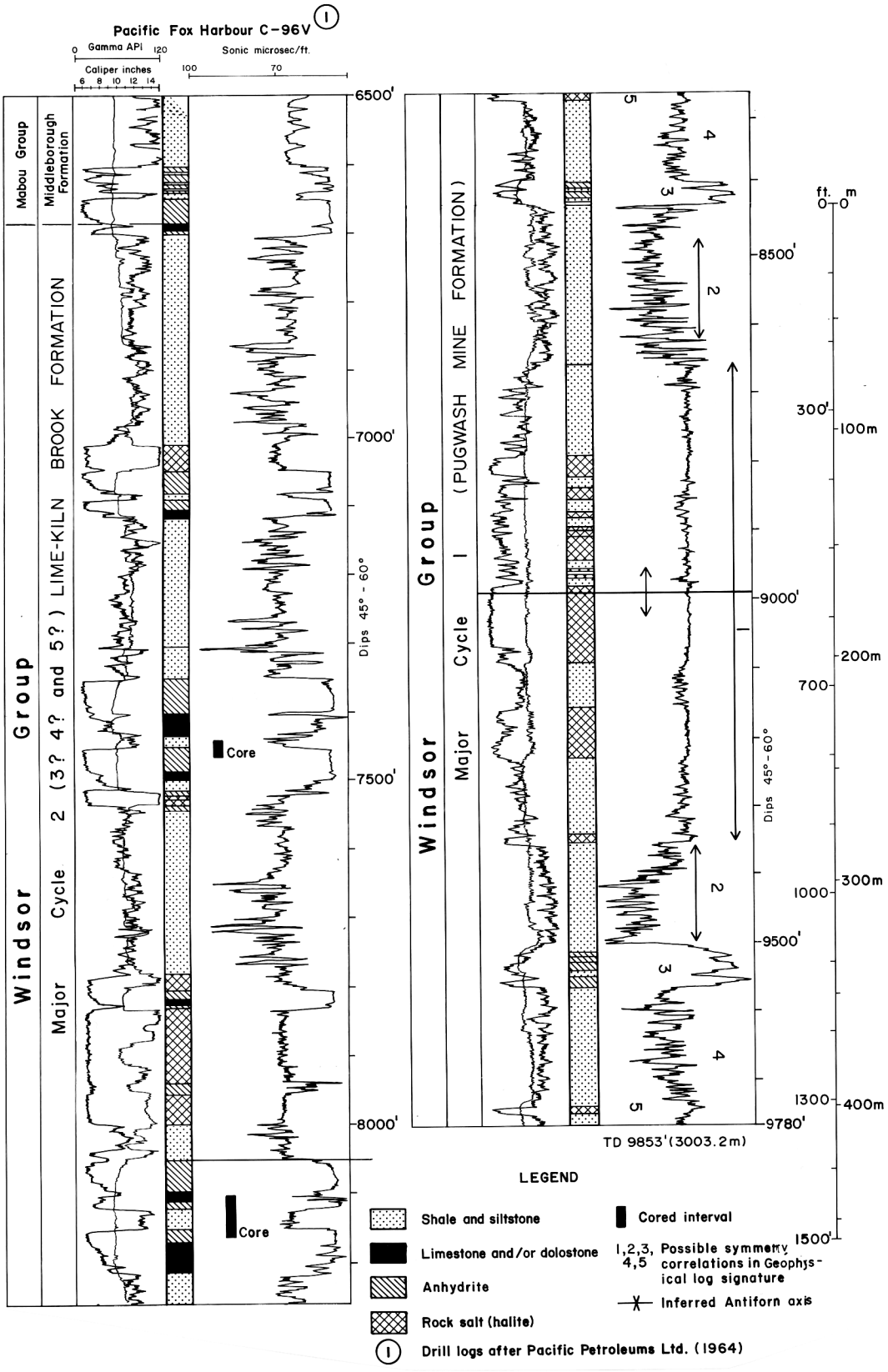


Figure 2-5. Stratigraphy of the Windsor Group intersected in Pacific Fox Harbour drillhole C-96V.

however, been well documented in several deformed Carboniferous basins (Boehner, 1986; Carter, 1989, 1990).

The upper part of the Pugwash Mine Formation, as picked in drillhole C-96V and by interpolation in Pugwash and Nappan, has a large proportion of redbeds and grey mudstone in addition to the salt and anhydrite. The inclusion of this siliciclastic-rich section in the Pugwash Mine Formation (at least tentatively) is consistent with the trend to increasing mudstone and muddy salt near the top of the type section. The upper contact is designated as the top of the salt-dominated section. The base of the overlying Lime-kiln Brook Formation is consequently co-defined and coincident with the top of the Pugwash Mine Formation. This compromise boundary therefore results in the inclusion in the Lime-kiln Brook Formation of a 200-300 m thick section of redbeds beneath the lowermost marine carbonate.

The Pugwash Mine Formation is approximately correlative with the Cassidy Lake Formation in the Sussex area of New Brunswick. It is probably equivalent to the thick salt section in Shell Dorchester No. 1 (Howie, 1988) and in H. B. Fina F25 (Keppie *et al.* 1978), and the Stewiacke Formation in central mainland Nova Scotia. The Pugwash Mine Formation together with the underlying Macumber Formation and basal anhydrite constitute Major Cycle 1 of the Windsor Group (Giles, 1981).

History

Rocks now included in the Pugwash Mine Formation were first mapped and described in the Nappan - Minudie area by Wright *et al.* (1931) as unit W-2 of the Lower Windsor Group. They were first intersected in deep oil wells on the Minudie Anticline in 1931 by Imperial Oil (Amherst No. 1) and in 1945-1947 in the Sunoco No. 1A drillhole by Sun Oil Company. Roliff (1932) assigned these rocks to the A Subzone of the Windsor Group. The unit was formally introduced by Carter (1990, 1991) for the halite- and anhydrite-dominated diapiric evaporites in the Pugwash Mine and correlative rocks in the Cumberland Basin.

Lime-kiln Brook Formation (New Name)

Age

Early Carboniferous; middle Viséan; (Dolby, 1988; Bell, 1944)

Author

New name, defined herein.

Type Locality

The type area is designated as the area drained by Lime-kiln Brook near Nappan, Fenwick and Brookdale. The type section is located in the Lime-kiln Brook Quarry and contiguous outcrops in Lime-kiln Brook east of the quarry. Reference sections are designated in the Dewar Hill Quarry near Pugwash, and in drillhole NSDME LMA88-1 at Lower Maccan (depth 800-1425 ft.; 244.0-434.3 m). In drillhole LMA88-1, bedding dips are 60° to the core axis (bedding dips are approximately 25-30°) and a calculated stratigraphic thickness is 165 m (540 ft.). Another reference section is designated in Pacific Fox Harbour C-96V, near Wallace, at a depth of 2036-2676 m (6680-8780 ft.). This interval thickness is 640 m (2100 ft.) but bedding dips are in the range of 45-60° and a calculated stratigraphic thickness is approximately 384 m (1260 ft.) This also assumes there is no faulting or fold repetition within the intersection in borehole PFH C-96V.

Description

The Lime-kiln Brook Formation comprises fossiliferous marine limestone and dolostone interstratified with redbeds, including fine-grained sandstone, mudstone and locally minor grit to fine pebble conglomerate, and evaporites including anhydrite, gypsum and salt. The formation is typically dominated by nonmarine redbeds with subordinate marine carbonates and evaporites. The diagnostic and distinctive marine carbonates are variably fossiliferous with bivalves, brachiopods, algae, cephalopods (see Bell, 1944, 1958) and as yet unidentified hollow tube, possibly algal fossils. Locally there are abundant well developed oncolites and columnar algal stromatolites. Facies change within the carbonates may be rapid and incomplete exposure of some sections remains a hindrance to more precise correlations.

The Lime-kiln Brook Formation is characterized by an interstratified succession of at least three and probably up to eight or more separate limestone - dolostone members. These are generally separated by redbeds (siltstone, sandstone and locally fine conglomerate), and the occurrence of gypsum and anhydrite is indicated by sinkholes and recent drilling near Lower Maccan and outcrops in the River Philip - Oxford area. Gypsum and anhydrite appear to be more extensive in the subsurface, but are largely removed by karst processes in near-

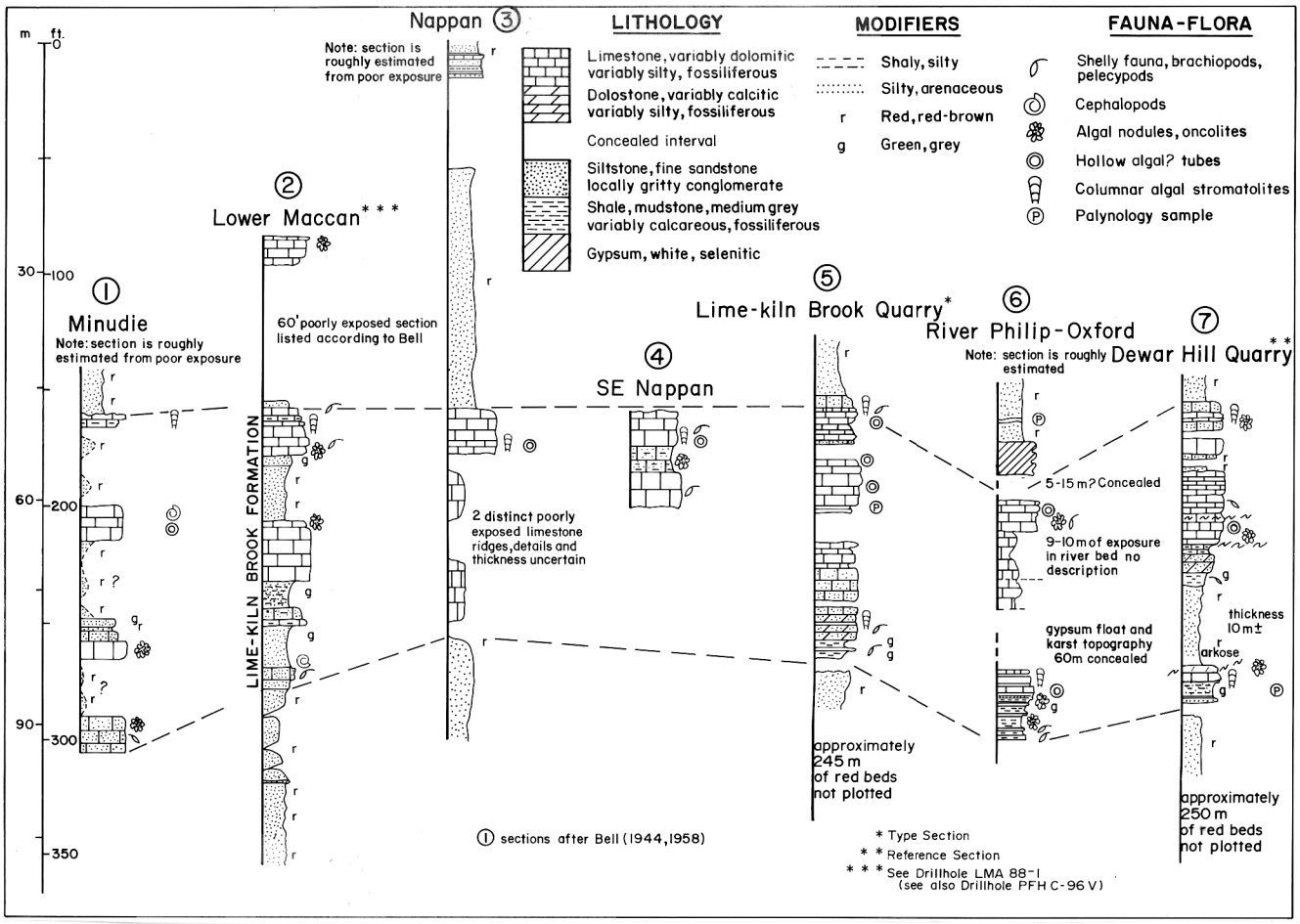


Figure 2-6. Stratigraphy and general correlation of (Windsor Group) Lime-kiln Brook Formation sections with marine carbonates.

surface and outcrop areas. The basal part of the carbonate section at Dewar Hill is marked by a 10-25 m thickness of calcareous grey shale with abundant marine fauna and flora. Distinctive columnar algal stromatolites form the principal lithofacies of the lowermost marine carbonate and are well exposed at Dewar Hill Quarry (Fig. 2-6, section 7). Carbonates of the interval constitute one or more zones of variably silty limestone, typically dense, hard and crystalline, and irregular nodular-oncolytic (1-10 cm) limestone near contacts. Distinctive hollow, possibly algal tubes 1-1.5 cm in diameter and 3-6 cm long are ubiquitous in the limestone. The upper part of the main carbonate interval is generally marked by a columnar algal stromatolite unit with a distinctive tilted growth form which makes an axial angle of 45-60° to the bedding plane.

Details of the stratigraphy of the uppermost marine carbonate units are generally unclear. Thin, poorly exposed carbonate units are known at Nappan (Fig. 2-6, section 3), Lower Maccan (Fig. 2-6, section 2) and perhaps at the top of the Dewar Hill Quarry near Pugwash (Fig. 2-6, section 7) where two or three carbonate units in a complex section are not yet fully documented. Approximately eight carbonate beds constituting five distinct members are recognized in drillhole LMA88-1 (Boehner, 1990) drilled near Lower Maccan on the south limb of the Minudie Anticline (Figs. 2-7 and 2-8). Correlation on a bed-by-bed basis with the outcrop sections at Lower Maccan, Minudie, Nappan and Pugwash is not clear. Several factors are evident: (1) it is apparent that evaporite interbeds present in the subsurface in drillhole LMA88-1 are selectively removed by dissolution-karst processes in the near-surface and outcrop environment, and (2) the carbonate zone illustrated by Boehner (1988b) probably contains carbonate members representing different portions of the thicker stratigraphic section of the Lime-kiln Brook Formation.

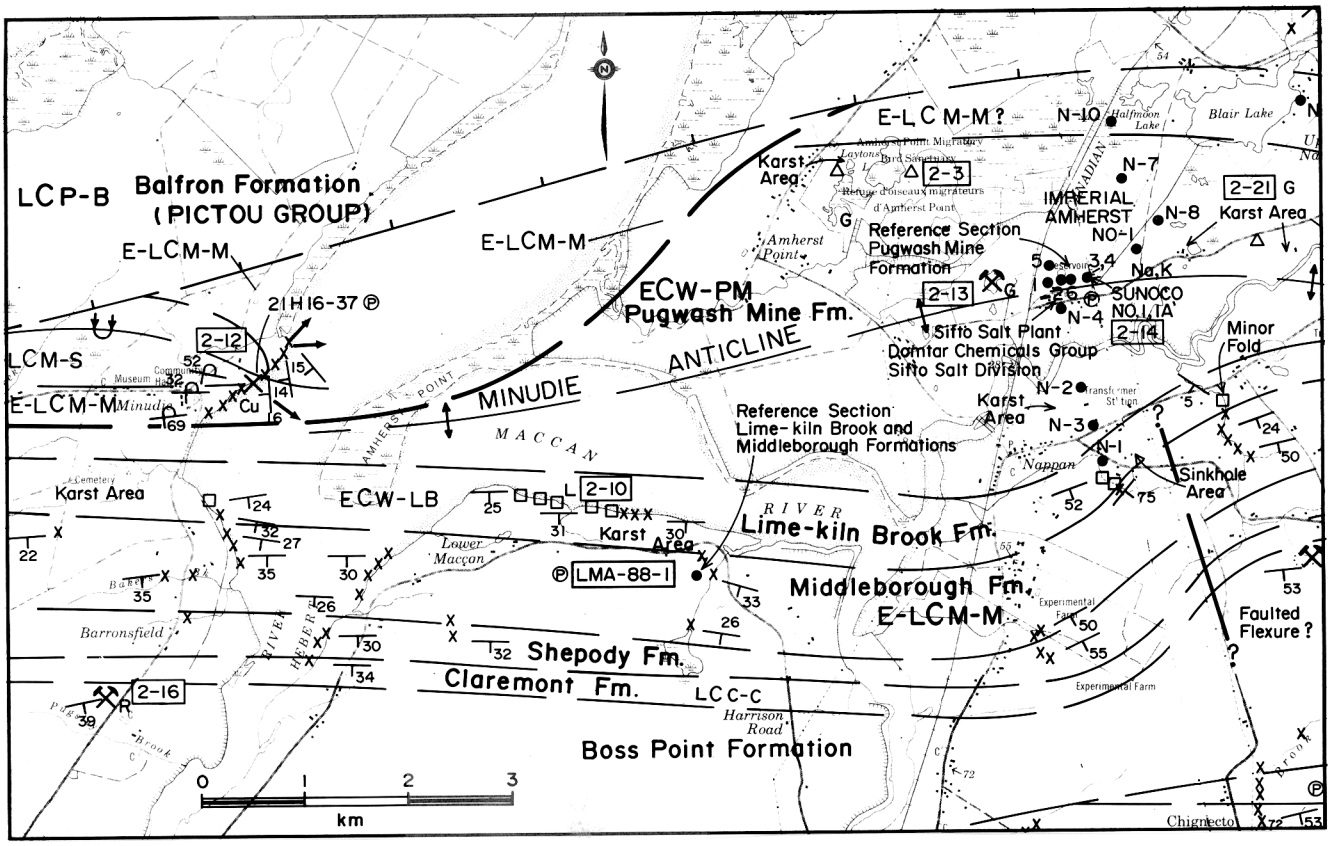


Figure 2-7. General geology and location of NSDME drillhole Lower Maccan LMA 88-1.

Thickness and Distribution

The incomplete type section in the Lime-kiln Brook Quarry is 35 m thick for the carbonate-bearing part of the section plus an additional estimated 250 m thickness of underlying redbeds. In the reference section at Lower Maccan, drillhole LMA88-1, it is 165 m thick (Fig. 2-9) and incomplete at the base (including approximately 55 m of redbeds) and perhaps at the top. It is substantially thicker, 640 m, and apparently more complete (if not repeated) in the Pacific Fox Harbour drillhole C-96V.

The Lime-kiln Brook Formation has a relatively wide distribution within the narrow Windsor Group outcrop areas, which are confined to the major anticlines in the Cumberland Basin. The stratigraphy is relatively intact as these rocks have generally behaved like the younger, nondiapiric strata. Outcrop patterns tend to be parallel with Mabou - lower Cumberland units typically relatively continuous on the south limbs of the anticlines. The Mabou and lower Cumberland rocks, however, occur only rarely as fault blocks on north limbs or in complex situations within the isolated diapirs. The formation is inferred to be widely distributed in the subsurface; however, drilling has rarely been deep enough to establish this continuity.

Relations to Other Units

The lower contact with the Pugwash Mine Formation, as discussed previously, is not well documented due to the nature of diapiric evaporites. Where undisturbed it is inferred to be a transition zone of redbeds and evaporites. Rocks in this transition zone could be assigned to either formation, but given the available data would be difficult to justify as a separate formation. Normally, and with better data, the base of the lowermost marine carbonate unit would be the optimum boundary. The uncertainties of identification and correlation as well as the limited available data, however, preclude a conclusive recognition of a specific carbonate member. In the absence of a distinctive marker, the boundary in this apparent transition zone is placed at the top of the evaporite-dominated (salt and sulphate) section which is assigned to the Pugwash Mine Formation. This incorporates a 200-300 m thick section, dominated by redbeds beneath the lowermost marine carbonate, into the Lime-kiln Brook Formation. An uncertain thickness, 200 m or more, of evaporites and redbeds are included at the top of the Pugwash Mine Formation. It is apparent that parts of the redbed section of the Pugwash Mine Formation have not behaved the same structurally as the mobile salt-dominated parts,

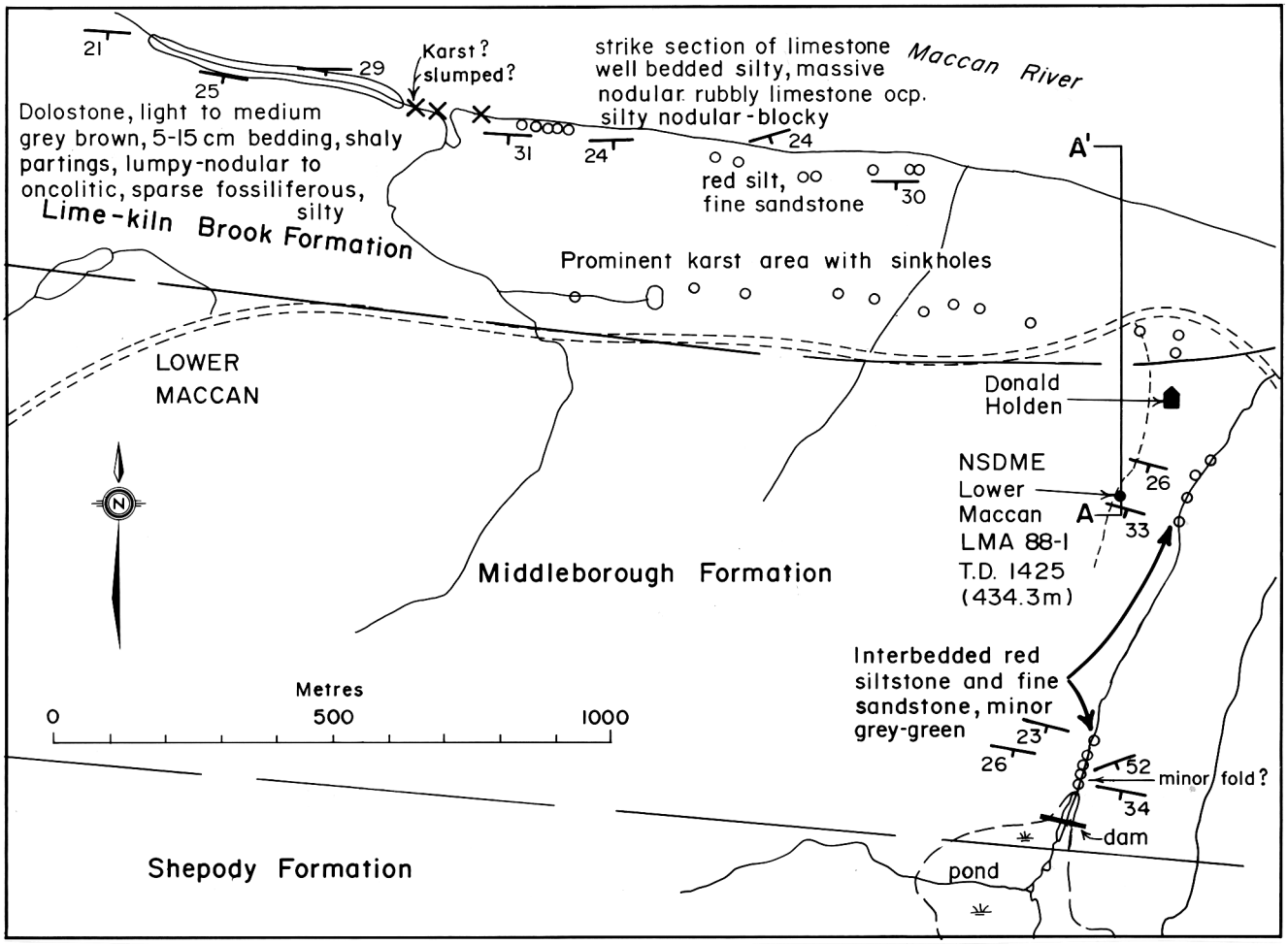


Figure 2-8. Detailed geology and location of NSDME drillhole Lower Maccan LMA 88-1.

resulting in a structural break based upon contrasting ductility. Because of uncertainties at this stratigraphic-structural contact zone, flexibility is available for future revision, as and when new data are available.

It is interesting to note that redbeds at the top of Major Cycle 1 (Fig. 2-9) approximate the inferred position of the Tennycape Formation in the Windsor Group type area (Giles, 1981) and the Cloverhill Formation in the Sussex area of New Brunswick (McCutcheon, 1981).

Despite the distinctive appearance of specific carbonate members in outcrop and in drill core it is not possible to precisely correlate the Lime-kiln Brook Formation sections 1-7 in Figure 2-6 into the Pacific Fox Harbour C-96V drillhole. This is due to uncertainties related to chip logs and geophysical log responses to the specific carbonate members and because of possible fold repetition in subsurface sections. At best, using general lithological character, a possible correlative interval is chosen from 2454-2518 m (8050-8260 ft.). In view of possible repetition in PFH C-96V (Fig. 2-5), the correlation is considered tentative. The vertical relationships of minor cycle lithological components, however, are consistent with a normal right-way up pattern. Although no clear symmetries of lithology or geophysical log response patterns indicative of repetition are apparent, the presence of repetition in the Lime-kiln Brook Formation section has not been eliminated.

Outcrops in the Minudie to Lime-kiln Brook Quarry area are relatively common and without apparent major structural disruption, although the section is incomplete both at the top and base. In addition, there is a profound regional facies change at the formation level within the Cumberland Basin whereby the marine carbonates pinch out and the section becomes dominated by redbeds. In

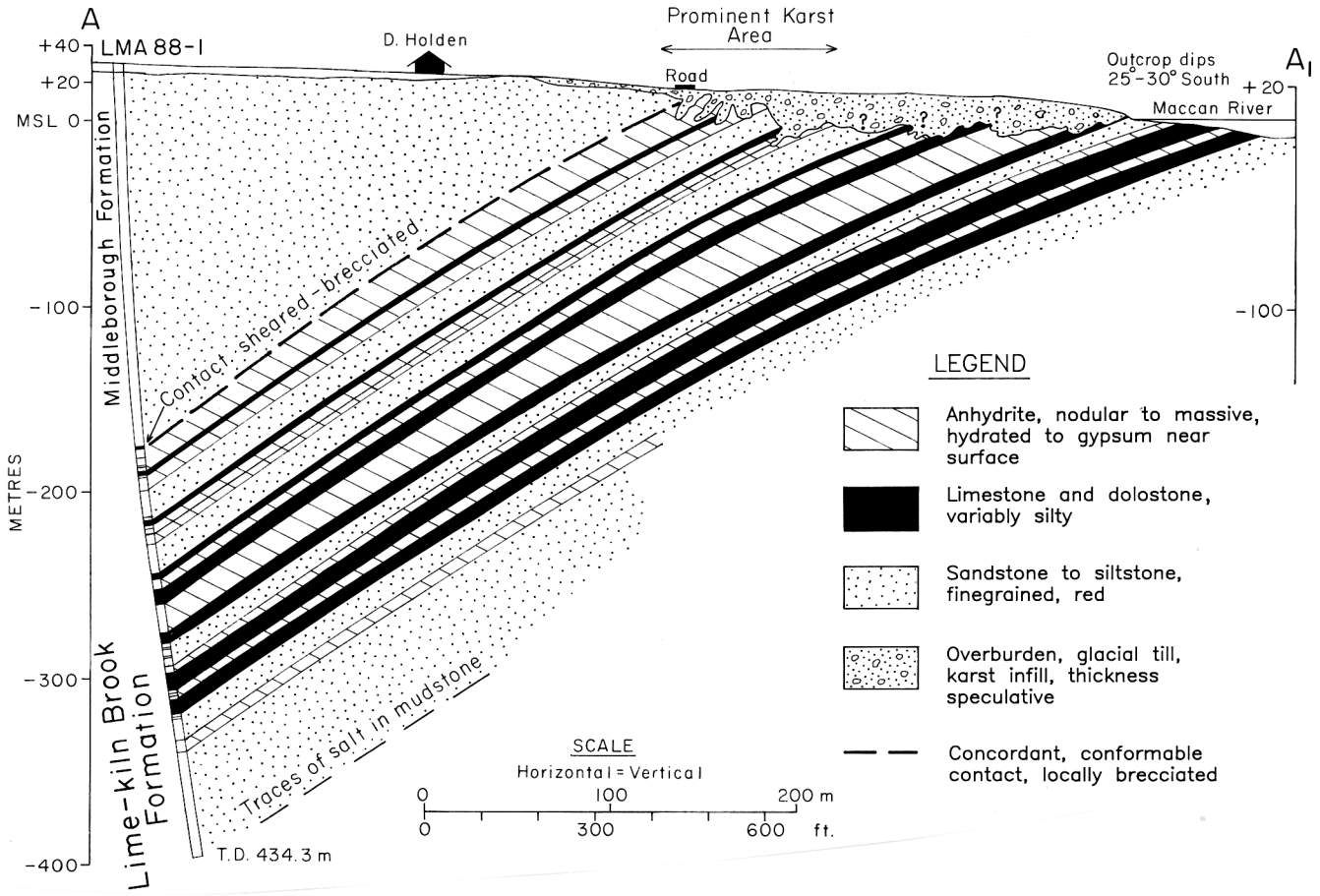


Figure 2-9. North-south cross-section A-A_1 through NSDME drillhole Lower Maccan LMA 88-1.

the Cumberland Basin the top of the uppermost marine carbonate unit is designated as the top of the Lime-kiln Brook Formation. This also coincides with the top of the Windsor Group and, by default, the base of the Middleborough Formation at the base of the Mabou Group. In drillhole LMA88-1, the contact is placed at a sheared-disrupted anhydrite at a depth of 244.0 m. It is uncertain if the carbonate member (top at 253.95 m) is the highest one, as others may have been removed by faulting.

The Lime-kiln Brook Formation of the Windsor Group (Fig. 2-6, sections 1-7) is very similar to and probably correlative with the Demoiselle Creek beds described in the Hopewell Cape area of southern New Brunswick by McCutcheon (1981). At Hopewell Cape, McCutcheon (1981) described a 30 m thick section of Lower Windsor rocks (subzone B) with two thin grey units comprising variably siliciclastic, oncolitic, stromatolitic limestone, separated by a thick central unit comprising polymictic conglomerate, sandstone and minor mudstone. Underlying strata, although very poorly exposed, are fine- to medium-grained redbeds. This stratigraphy is generally similar to sections 1-7 in Figure 2-6. The overlying strata are primarily coarse-grained conglomerate, assigned to the Hopewell Group, whose detailed age and stratigraphic relationships to the Upper Windsor Group or Mabou Group are uncertain. Consequently, a precise correlation with the finer grained Middleborough Formation in Nova Scotia cannot be established.

History

Rocks now included in the Lime-kiln Brook Formation have been previously described by Wright *et al.*, 1931; Roliff, 1932; Bell, 1944, 1958; and Boehner, 1988b. The stratigraphic sections, general correlations and biostratigraphic age (revised after Moore and Ryan, 1976) of sections 1-7 (Fig. 2-6) were delineated by Bell (1944, 1958) and have been confirmed and refined in this study.

Mabou Group (Canso Group, abandoned)

Age

Late Carboniferous; late Viséan to Namurian (Neves and Belt, 1970; Howie and Barss, 1975a).

Author

Formerly Canso Group of Bell, 1927; redefined by Bell, 1944, and revised by Kelley, 1967; Canso Group formally abandoned (as well as Riversdale Group) and replaced by Mabou Group by Belt, 1964, 1965; both group names are currently in use (nearly synonymous) in the Maritimes Basin.

Description

Mabou Group rocks are relatively incompetent and poorly exposed in the study area. Limited exposures of red siltstone, fine-grained sandstone, and mudrocks are found primarily along the axial areas of the anticlines. In the western part of the Cumberland Basin strata of the Mabou Group are exposed along the shore at Joggins, where there are two distinct units, one red fine-grained unit, the Middleborough Formation, and another the coarser-grained Shepody Formation with distinctive interbeds of grey to grey-red sandstone.

In the eastern part of the basin there is relatively good but incomplete exposure in the Middleborough Formation type section in the Wallace River which cuts through the axis of the Claremont - Malagash Anticline.

Subdivisions

Middleborough Formation

Age

Early to Late Carboniferous; Late Viséan to Early Namurian (Bell, 1958; Mamet, 1970; Dolby, 1989).

Author

Norman and Bell, 1938a, 1938b.

Type Locality

The type locality is along the Wallace River for approximately 2 km downstream from a point 150 m north of Nova Scotia Highway 368, where it crosses the river near Middleborough, Cumberland County (Fig. 2-10).

Reference Locality

Reference localities are designated in the most northerly part of the Joggins Section between the Shepody Formation and Mill Cove, and in the upper part of drillhole NSDME LMA88-1, located at Lower Maccan (interval 12.5-244.0 m; Fig. 2-9).

Description

The Middleborough Formation comprises red to red-brown and locally grey-green mottled mudstone, siltstone, and fine- to medium-grained litharenite with rare, thin, polymictic conglomerate interbeds (nonmarine).

Thickness and Distribution

This formation is 968 m thick at the type section (Bell, 1944) and approximately 300 m thick in the incomplete reference section at Joggins (Ryan, 1988). It is widely distributed in outcrop and in the subsurface throughout the Cumberland Basin.

Relationship to Other Units

The Middleborough Formation conformably overlies the Windsor Group and is conformably overlain by the Shepody Formation or disconformably overlain by the Claremont or Boss Point formations of the Cumberland Group. Bell (1944a, 1944b) and Boehner (1988b) considered the formation to be, in part, time equivalent to the upper part of the Windsor Group. Bell (1958) also considered the unit to be a lithostratigraphic equivalent of the Maringouin Formation (Fig. 2-4) of the Mabou (Canso) Group in southern New Brunswick. Bell (1944) correlated the unit with the lower part of the Joggins section, Division 8 of Logan (1845).

History

The Middleborough Formation was defined by Bell (1944) and includes redbeds that are probably age equivalent with the uppermost part of the Windsor Group. Rocks of this unit were initially correlated with the River John Series (Group) by Bell (1926). They are included in the Mabou Group by Belt (1964, 1965) and that assignment is followed in this report.

The relative stratigraphic position, general lithology and probable age similarity indicate the Middleborough Formation is probably correlative with all or parts of the fine-grained redbeds of the Hopewell Group, including the Maringouin Formation in the extension of the Cumberland Basin in southern New Brunswick as well as the Poodiac Formation of Anderle *et al.* (1979) in the Sussex area of south-central New Brunswick (Fig. 2-4). These finer-grained units are apparently the basinward facies equivalents of coarser basin margin facies, including undivided coarse-grained rocks of the Hopewell Group and Wanamaker Formation according to McCutcheon (1981). Similar, but as yet unclearly

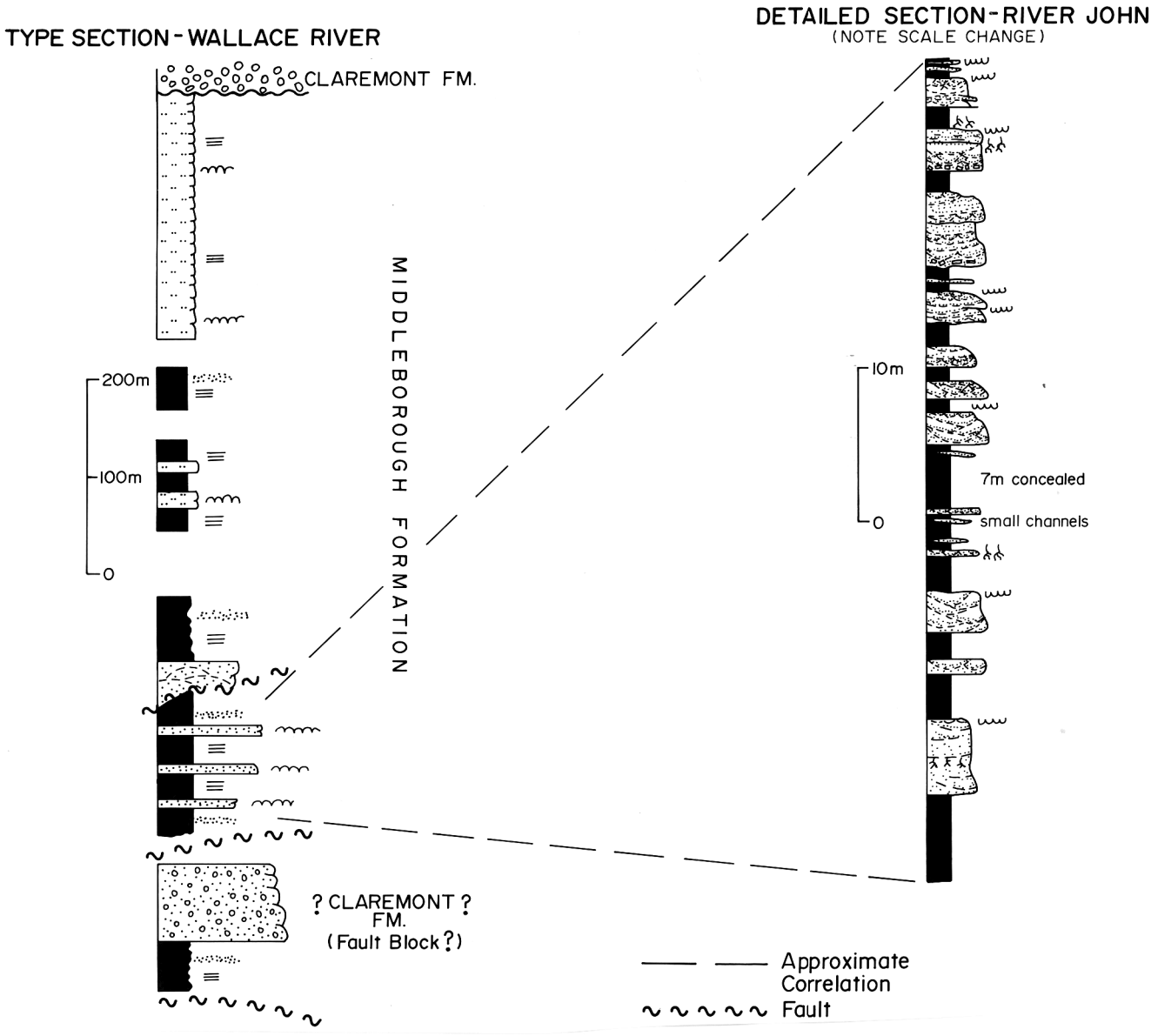


Figure 2-10. Middleborough Formation type section in the Wallace River near Middleborough.

documented coarse facies of this age (middle-late Viséan to Namurian) may occur in Nova Scotia in the vicinity of the northern and eastern parts of the Cobequid Highlands (Millsville conglomerate?, Falls Formation?).

Shepody Formation

Age

Late Carboniferous; Namurian A (Bell, 1944) to early Westphalian A (Dolby, 1987, 1989).

Author

Norman, 1941.

Type Locality

Shoreline cliffs on the southwest side of the Maringouin Peninsula, at a location from about 800 to 1500 m north of Cape Maringouin, Westmorland County, New Brunswick.

Reference Locality

The Joggins section, which lies along the shoreline east and north of Downing Cove toward Mill Cove, Cumberland County, Nova Scotia is an excellent reference locality of this formation.

Description

The Formation comprises greenish-grey, medium-grained sandstone with variable plant debris and minor calcareous mudchip channel lag conglomerate, ripple laminated fine-grained grey to red sandstone, interbedded with dominant red mudstone and siltstone. The sandstone to siltstone ratio (strata coarser than sand/strata silt size or finer) is approximately 1.4. Plant detritus is common in sandstone and malachite after chalcocite is locally abundant in the grey (reduced) channel lags.

Thickness and Distribution

The unit is approximately 700 m thick at the type section and has a limited distribution in the Cumberland Basin. The thickness is maintained in the area of the Minudie Anticline east of Downing Cove; however, thickness decreases dramatically toward the southwest. Recognition of this unit in the eastern Cumberland Basin is unclear, as distinction from the Boss Point Formation is impossible without good exposures of the overlying or underlying contact relationships and especially the presence of the distinctive Claremont Formation.

Relationship to Other Units

Bell (1944) correlated this unit with the upper part of Logan's (1845) Division 8. The difficulties in distinguishing this unit from the Boss Point Formation, in the absence of stratigraphic control, probably has resulted in its inclusion in Boss Point Formation in the eastern Cumberland Basin. The unit conformably overlies the Middleborough Formation and is disconformably to conformably overlain by the Claremont Formation (where present) of the Cumberland Group.

History

Prior to Norman (1941a), rocks of the Shepody Formation were considered to be "new red sandstone" (Gesner, 1836), the upper part of Division 8 (Logan, 1845) or the Windsor Formation (Bell, 1914). Gussow (1953) was the first to give a comprehensive description of the Shepody Formation.

Upper Carboniferous Stratigraphy

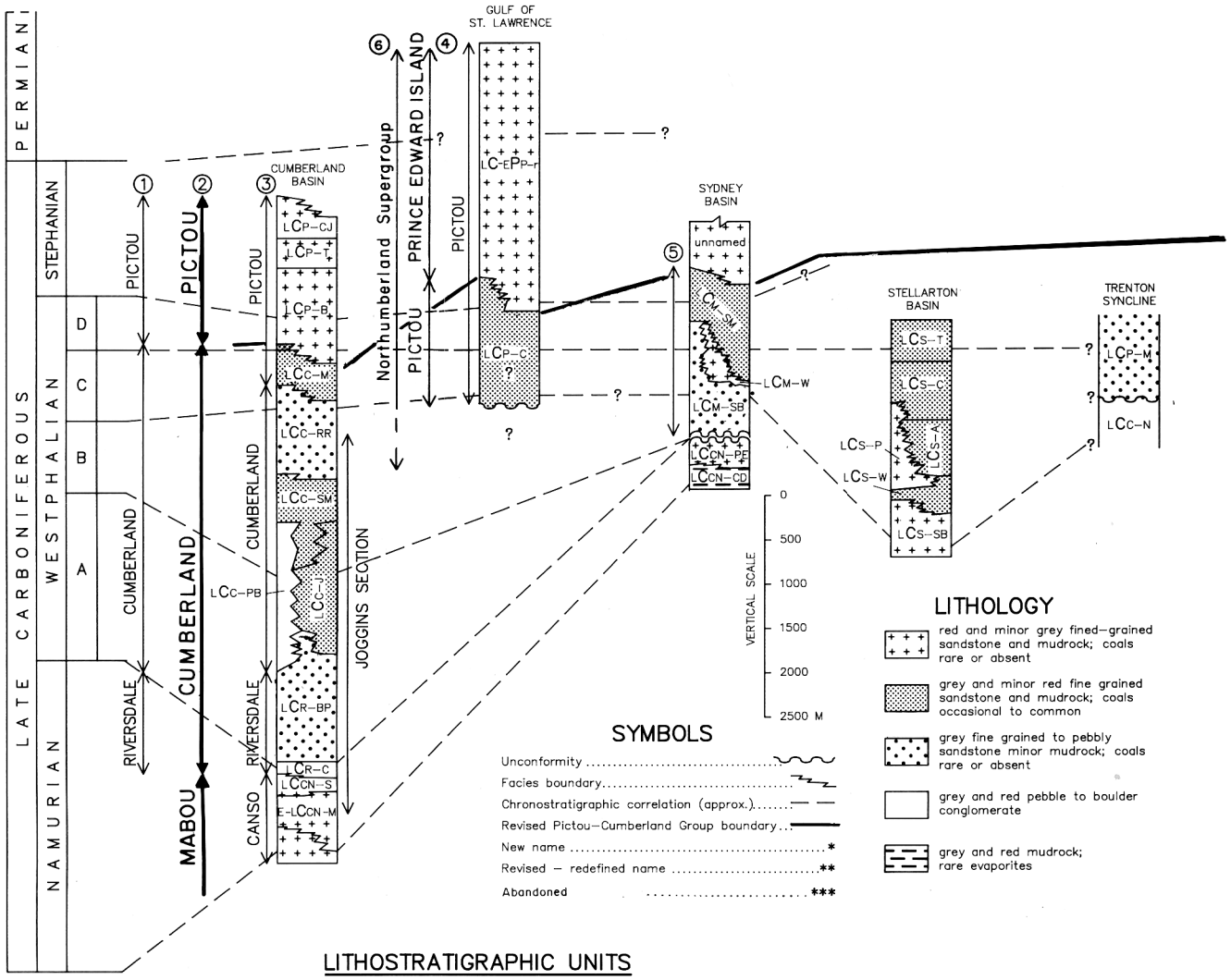
The Cumberland Group in the Cumberland Basin comprises seven formations (Ryan, *et al.*, 1990, 1991), is up to 3900 m thick in the incomplete type section and locally may be in excess of 5000 m thick. It comprises a broad lithologic range from red and grey conglomerate-dominated strata to red and grey mudrock-dominated strata. Belt (1964, 1965) previously included all post-Mabou Group strata, including the diverse formations formerly assigned to the Riversdale, Cumberland, Morien and Pictou groups, in the informal 'Coarse Fluvial Facies'.

Strata of the Boss Point Formation (Fig. 2-11) were originally included by Bell (1927) in the Cumberland Series. The Boss Point Formation included strata later called the Claremont Formation at the base and comprised Divisions 6 and 7 of Logan (1845), see also Bell (1914). The upper strata in this section were assigned by Bell (1927) to the Joggins Formation of the Cumberland Series; correlation of the Boss Point Formation to the Riversdale Series was not recognized at that time. Bell (1944) subsequently, and without explanation, included in a redefined Riversdale Group: (1) the Boss Point Formation and Claremont Formation (Norman and Bell, 1938a, 1938b) comprising the top 282 feet of Division 7 and all of Division 6 of Logan (1845) in the Joggins section, and (2) the Millsville conglomerate. Rocks of similar lithology were included by Belt (1964, 1965) in his Coarse Fluvial Facies. Ryan *et al.* (1991) introduced, defined and assigned existing and new formations to appropriate groups using the criteria outlined in Table 2-1. This included the Claremont and Boss Point formations from the Riversdale Group, which was abandoned by Belt (1964, 1965). The following sections describing the Cumberland and Pictou groups and their constituent formations are extracted from Ryan *et al.* (1991).

Cumberland Group (Revised, Ryan *et al.*, 1991)

The Cumberland Group (revised) comprises a heterogeneous collection of formations of Late Carboniferous age (late Namurian-Westphalian A to late Westphalian C - early D). The type area is in the Joggins and Springhill coalfields in the western part of the Cumberland Basin (Fig. 2-12), Cumberland County, Nova Scotia. The type section (Figs. 2-13 and 2-14) is located along the shore of Chignecto Bay from Downing Cove, 6.5 km north of Joggins, to Squally Point, 51 km southwest; the shoreline between Sand Cove and Lower Cove is the most complete, continuous section. The shore section has nearly continuous exposure; however, folding and faulting in the gently dipping strike section south of Sand Cove have resulted in several repetitions of the upper parts of the section.

The group is of heterogeneous lithology comprising: red and grey, boulder to pebble polymictic conglomerate; grey medium- to coarse-grained trough cross-stratified subarkose to sublitharenite; grey to reddish grey coarse-grained arkose; grey to reddish-brown mudstone



LITHOSTRATIGRAPHIC UNITS

CUMBERLAND BASIN

PICTOU GROUP

- LCP-CJ CAPE JOHN FORMATION**
- LCP-T TATAMAGOUCHE FORMATION*
- LCP-B BALFRON FORMATION*

CUMBERLAND GROUP

- LCC-M MALAGASH FORMATION*
- LCC-RR RAGGED REEF FORMATION*
- LCC-SM SPRINGHILL MINES FORMATION*
- LCC-J JOGGINS FORMATION**
- LCC-PB POLLY BROOK FORMATION*

RIVERSDALE GROUP ***

- LCR-BP BOSS POINT FORMATION
- LCR-C CLAREMONT FORMATION

*** CANSO (MABOU) GROUP

- LCCN-S SHEPODY FORMATION
- E-LCCN-M MIDDLEBOROUGH FORMATION

GULF OF ST. LAWRENCE REGION

PICTOU GROUP

- LC-EPP-r 'P.E.I. redbeds'
- LC-EPP-C 'COAL MEASURES' (CORR. MORIEN GP.)

SYDNEY BASIN

MORIEN GROUP

- LCM-SM SYDNEY MINES FORMATION
- LCM-W WADDENS COVE FORMATION
- LCM-SB SOUTH BAR FORMATION

CANSO (MABOU) GROUP

- LCCN-PE POINT EDWARD FORMATION
- LCCN-CD CAPE DAUPHIN FORMATION

① Ryan and Boehner (1989)
② This jet al. (1989)
③ Bell (1944)
④ Pictou Group (Barss & Hacquebard, 1967; Hacquebard, 1986)
⑤ Morien Group (Boehner and Giles, 1982)
⑥ van de Poll (1989)

STELLARTON BASIN

STELLARTON FORMATION (GROUP)

- LCS-T THORBURN MEMBER
- LCS-C COAL BROOK MEMBER
- LCS-A ALBION MEMBER
- LCS-P PLYMOUTH MEMBER
- LCS-W WESTVILLE MEMBER
- LCS-SB SKINNER BROOK MEMBER

TRENTON SYNCLINE

PICTOU GROUP

- LCP-M MERIGOMISH FORMATION

CUMBERLAND GROUP

- LCC-N NEW GLASGOW CONGLOMERATE

Figure modified after Ryan et al. (1991).

Figure 2-11. Summary of Upper Carboniferous lithostratigraphic nomenclature and correlation between northern Nova Scotia, Gulf of St. Lawrence area, and the Sydney Basin, Cape Breton Island.

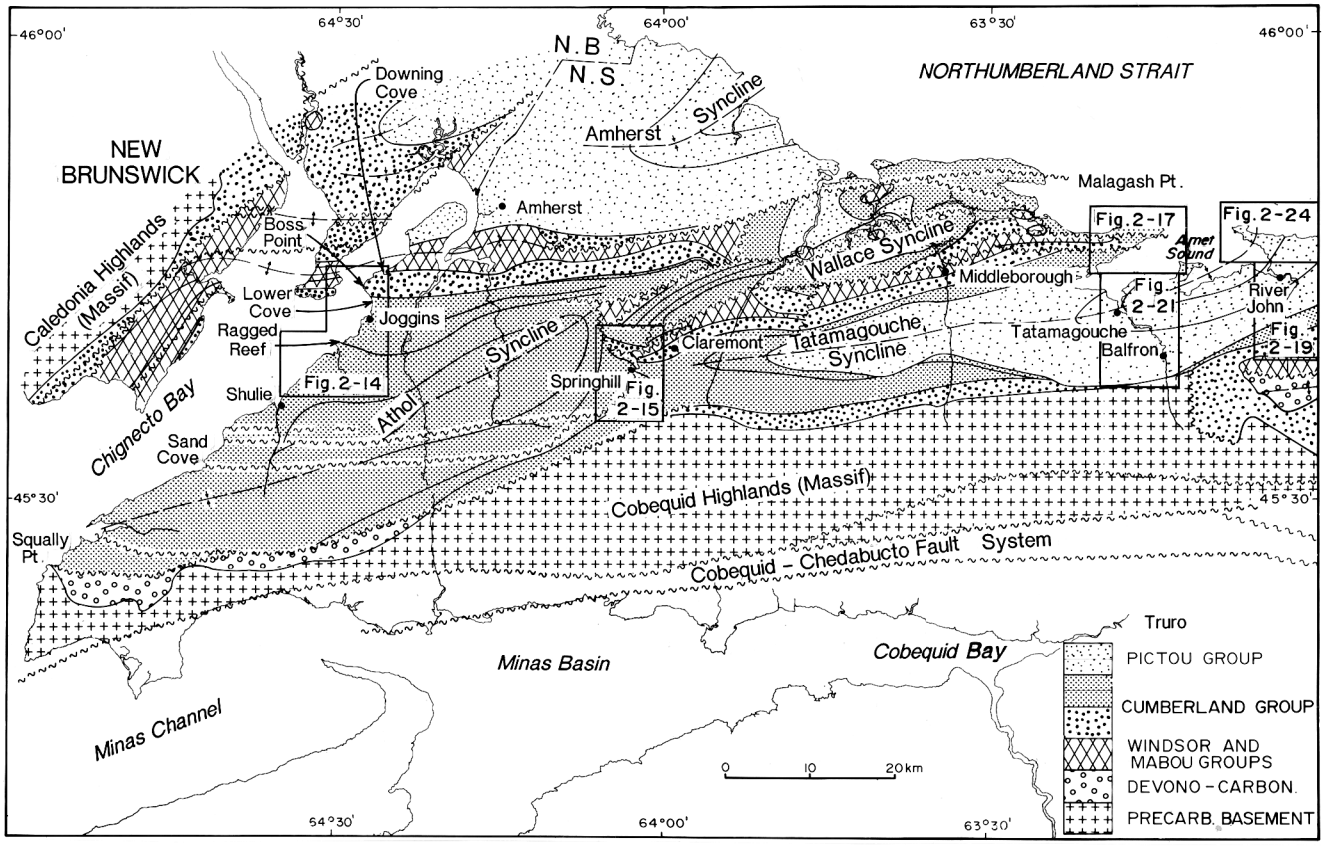


Figure 2-12. General geology and index map of detailed type sections of Upper Carboniferous units in the Cumberland Basin.

and siltstone; red to grey fine-grained litharenite; coal seams from 0.01 m to 3.5 m thick; and thin bituminous limestone (locally fossiliferous) and shale. Seven formations are formally designated within the group in the Cumberland Basin; in approximate ascending order they are the: (1) Claremont; (2) Boss Point; (1 and 2 were formerly assigned to the Riversdale Group), (3) Polly Brook (new); (4) Joggins (reinstated); (5) Springhill Mines (new); (6) Ragged Reef (new) and (7) Malagash (new) formations. Many of these formations are similar to the facies terminology used by Shaw (1951a, 1951b). Although all seven occur in the western part of the Cumberland Basin, only five have been recognized in the eastern part (Tatamagouche Syncline area) of the basin.

Recognition and boundary placements are speculative or inferred for most of the area between the Malagash - Claremont and Minudie anticlines, especially between Canfield Creek and Salt Springs. This may be attributed to several factors, including lateral variation, structural complications, and scarcity of outcrop and drillhole data. The Cumberland Group has a variety of contact relationships including: concordant but unconformable contact with the underlying Mabou Group strata; unconformity where it onlaps basement rocks of the Cobequid Highlands; and angular unconformity with underlying Windsor Group strata.

The Cumberland Group is conformable to disconformable with overlying Pictou Group rocks. Using the criteria proposed by Ryan *et al.* (1991), in conjunction with those proposed for the Pictou Group, formations constituting all or part of the Morien Group and Stellarton (Group) Formation would be correlative with and/or subdivisions of the Cumberland Group. A brief discussion of the formations is presented here; for a more complete description see Ryan *et al.*, 1991.

Claremont Formation

The Claremont Formation is late Namurian to early Westphalian A in age and is named for Claremont, the location of a prominent hogsback ridge of resistant but virtually unexposed conglomerate. There are, however, limited outcrop sections nearby the type area such as in the Black River area along Deep Brook, northeast of

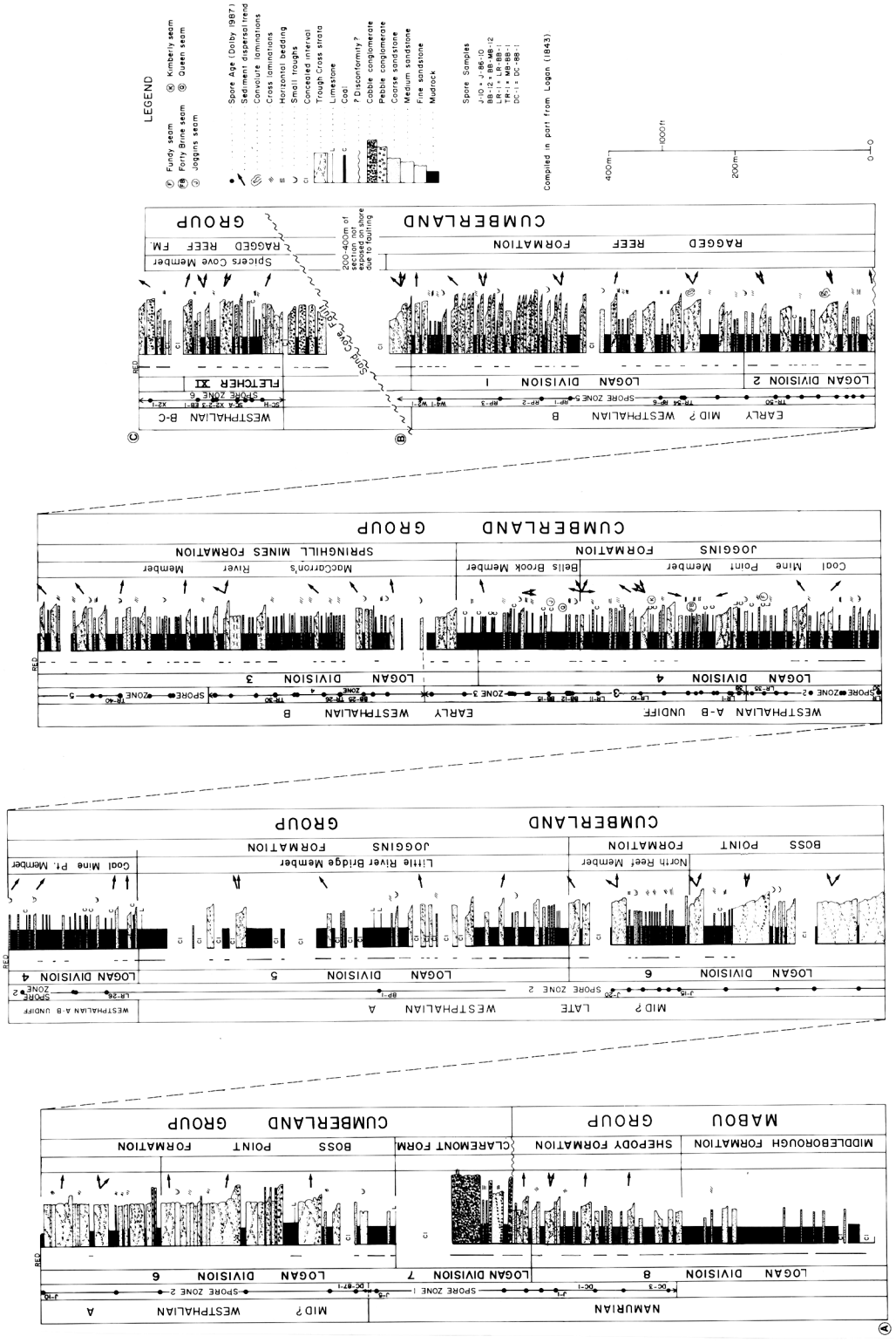


Figure 2-13. Stratigraphy of the classic Joggins Section (adapted from Logan, 1845), type section of the Cumberland Group, Boss Point, Joggins and Ragged Reef formations; reference section of Claremont and Springhill Mines formations, and reference sections of the Mabou Group, Middleborough and Shepody formations.

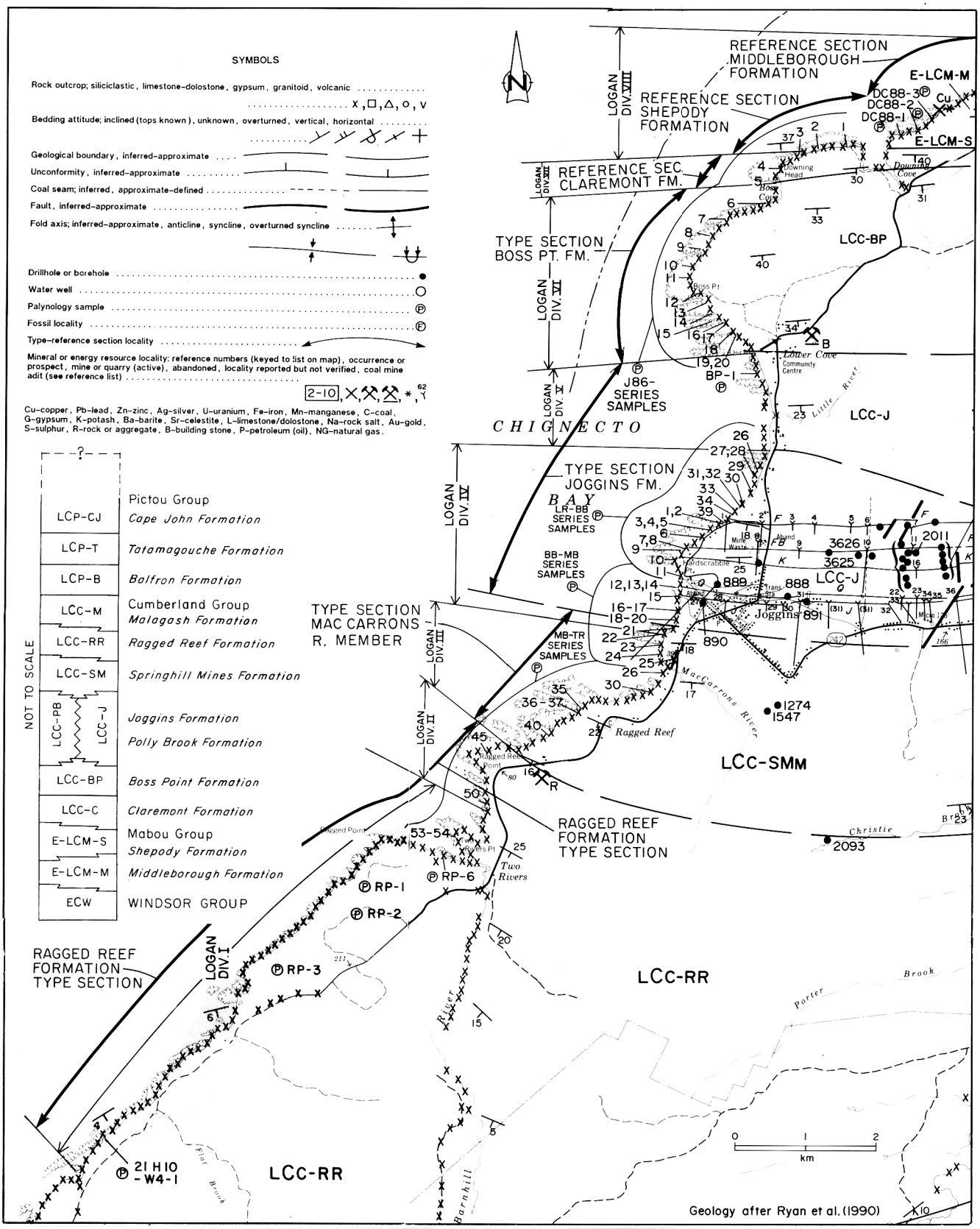


Figure 2-14. Geology and location map with legend of the Joggins Section, the type section of the Cumberland Group, and reference sections of the Mabou Group, and Middleborough and Shepody formations.

Springhill, and it is well exposed along the Wallace River near Middleborough and on River John. Finer-grained arkosic grit, granule and fine pebble conglomerate are well exposed in the Joggins section at Downing Cove (Figs. 2-13 and 2-14). The reference locality is designated on River John, 600 m downstream of the junction of the East and West Branches of River John. The unit has been mapped as the Millsville "Conglomerate" or "Formation" (Gillis, 1964; Ryan, 1984). It is, however, indistinguishable from the Claremont or the Falls formations and the name Claremont Formation is applied to these rocks. The Claremont Formation comprises red and minor mottled green boulder to pebble polymictic conglomerate, with minor interbeds of coarse-grained arkosic grit and sandstone. The conglomerate is subangular to subrounded, weakly cemented with moderate to poor sorting, and can either be matrix supported or clast supported. Clasts lithology varies from area to area but the conglomerate usually contains locally derived clasts typical of the nearby highlands.

The thickness and distribution of this unit are extremely variable. In the eastern Cumberland Basin the thickness varies from a few metres to at least 1000 m. The greatest thickness is present near marginal basin areas adjacent to the Cobequid Highlands. The formation is absent to very thin and distinctly finer grained in much of the northeastern part of the basin.

The Claremont Formation conformably to disconformably overlies the Mabou Group (Shepody, Middleborough or Marigouin formations). It forms the lowermost basal conglomeratic portion of the Cumberland Group and is conformably overlain by the Boss Point Formation. It is correlative with the Enrage Formation in southeastern New Brunswick. The Claremont Formation is only recognized in the Cumberland Basin and contiguous Scotsburn Anticline at the eastern end of the Cobequid Highlands. In southern New Brunswick, Claremont Formation equivalent (Enrage Formation) and older rocks were assigned to the Hopewell Group.

Boss Point Formation

The Boss Point Formation in Nova Scotia is late Namurian to middle Westphalian A in age. Westphalian C ages reported by McLeod (1980 and personal communication) from southern New Brunswick are questionable, and perhaps may be a misidentification of lithologically similar rocks equivalent in age to parts of the upper Cumberland Group (i.e. Ragged Reef or Malagash formations). The thick grey fluvial sandstone sequences typical of the Boss Point Formation may have been deposited on a nearly continuous basis from the Westphalian A through to the Westphalian C in New Brunswick. Similar lithofacies occur as correlatives of the Joggins and Springhill Mines formations in drillholes OXBP-5, 6, 7 and 8 drilled in the west-central part of the Wallace Syncline (unassigned Cumberland Group). The type locality is at Boss Point, from Lower Cove to Downing Head, Cumberland County, Nova Scotia (Figs. 2-13 and 2-14). Reference sections are designated at the end of Cape Maringouin, directly across from Boss Point; at Dorchester Cape on the west side of the Peticodiac River, New Brunswick; and in the Wallace River section between Middleborough and North Middleborough.

The Boss Point Formation comprises grey to greenish-grey, yellowish weathering, quartz-rich sublitharenite, limestone (rhizoconcretion-calcrete) and mud-chip conglomerate, and minor quartz pebble conglomerate. Sandstone is generally medium grained, and trough cross-stratified (Fig. 2-13). Sandstone is interbedded with grey and minor red, fine-grained sandstone and mudstone, especially at the top of the formation. Rare, impure coal seams and bituminous limestone are present. Coalified plant debris, calcrete, and calcareous mudchip conglomerate are locally abundant, especially as lag deposits near the bases of channel sandstones. The sand (coarser than sand) to silt (finer than silt) ratio in the formation is 2.2. Sandstone bodies greater than 1 m thick are usually multistoried and multilateral. Sandstone bodies can be up to 45 m thick and average approximately 35 m in thickness at the base of the formation and 5-10 m in thickness at the top. Thinner splay deposits and small channel sandstones occur as interbeds within the mudrock sequence. The ratio of fine to coarse particles is relatively low, at approximately 0.4.

Bell (1944) reported the type section had a thickness of 1174 m. The exact boundaries were not clearly stated and recent measurements and boundary placement by Ryan *et al.* (1990) indicate a thickness of 982 m for the type section. In the southeastern Cumberland Basin the Boss Point Formation varies in thickness from 200 to 650 m (Ryan, 1985). Interpretations of seismic data indicate the thickness may be substantially greater, especially within the Athol Syncline area. The Boss Point Formation is widely distributed and occurs in outcrop and in the subsurface throughout the Cumberland Basin.

The Boss Point Formation at the type section conformably overlies and interfingers, in part, with the Claremont Formation. Elsewhere in the basin the unit overlaps all of the older basin-fill units and the basement rocks of the highland massifs, with contacts being disconformities, angular unconformities, and nonconformities. The Boss Point Formation is conformably, disconformably or unconformably overlain by strata of the Cumberland or Pictou groups. Angular discordance of the unconformities is usually low and the contact is best characterized as a paraconformity.

Polly Brook Formation

The Polly Brook Formation contains strata of late Westphalian A to middle Westphalian B age. The type area is in Polly Brook, near River Philip, Cumberland County, Nova Scotia. The type section extends along Polly Brook from Smiths Pond on the Rodney Road, downstream (northeast) for approximately 3 km (Fig. 2-15). Additional exposure occurs along Polly Brook downstream to approximately 550 m from the mouth of the brook at the junction with River Philip. The formation comprises an intermediate to marginal, polymictic conglomerate unit of the Cumberland Group. The ortho- and paraconglomerate units range in clast size from boulder to pebble and are moderately to poorly rounded and sorted. Clast lithology is variable, but commonly comprises rhyolite, granite, diorite, and metamorphic rocks derived from the Cobequid Highlands Massif. Reworked Carboniferous sedimentary clasts, especially of Boss Point Formation rocks (quartz-rich sublitharenites), locally form a significant component and distinguish this unit from the Claremont Formation, which is dominated by igneous and metamorphic clasts. Near the top of the formation, pebbly immature cross-stratified sandstones, 5-10 m thick, occur intercalated with the conglomerate. Mudrocks are rare. In the type area of the Springhill Mines Formation, the top of the Polly Brook Formation is a finer-grained transition marked by thinly interstratified, poorly sorted granule conglomerate and silty mudrock.

The Polly Brook Formation displays rapid thickness variation with a maximum of 1400 m estimated in the type area (incompletely exposed). It thins dramatically east, west, and north of the Springhill area. Calder (1985b) estimated a thickness of 600 m for the unit in the Springhill area. The unit appears to be absent in the eastern part of the Tatamagouche Syncline and along the shore at Joggins, and is best developed in the south-central parts of the basin near the Cobequid Highlands. The formation is laterally equivalent to and probably interfingers with the Joggins Formation and the lower beds of the Springhill Mines Formation (Calder, 1984b). The contact with the underlying Boss Point Formation is not well exposed in outcrop or in drill core. The contact on Black River near Deep Brook was interpreted by Bell (1938, 1944) to be a pronounced unconformity, but this contact has been disrupted by faulting; therefore, caution is required in the interpretation of the contact relationship. In the River Philip area the formation is transitional to disconformable with the Boss Point Formation. In the Donaldson's Mill Brook area the contact exhibits an angular discordance with Boss Point strata. The Polly Brook Formation also nonconformably overlies basement rocks of the Cobequid Highlands Massif in the western part of the Cumberland Basin. The unit is transitional laterally into the finer-grained rocks of the Joggins and the Springhill Mines formations.

Joggins Formation

The Joggins Formation contains strata of late Westphalian A to early Westphalian B age. The type section is at Joggins, Cumberland County, Nova Scotia, along the southeast side of Chignecto Bay from Bell Brook, at the Joggins Fossil Cliffs near the village of Joggins, north along the shoreline to Lower Cove (Figs. 2-14 and 2-13). The strata are well exposed in the cliff face and in the broad intertidal zone.

The Joggins Formation comprises grey and minor red (predominantly in the lower half of the section) mudstone, shale and siltstone, and grey, medium-grained, cross-stratified sublitharenite in multistoried bodies averaging 6 m in thickness (Fig. 2-13). There are numerous, thin (less than 1 m) fine- to medium-grained sublitharenitic to litharenitic sandstones interbedded with the mudrocks as well as many thin humic and sapropelic coal seams typically less than 1 m thick. Bivalve-bearing (ostracods and pelecypods) black shale, with varying organic and carbonate content, which commonly overlies the coal seams is a definitive lithology of the formation. Rare calcareous mud chip conglomerate occurs near the base of the sandstone sequences. Locally, as in the area north of the Claremont Anticline, the coal and calcareous shale are rare to absent. The fine (< sand) to coarse (> sand) ratio is approximately 2.0 for the Joggins coastal section. The formation is 1433 m thick at Joggins, may be thicker in the central part of the Athol Syncline, but generally thins toward the south and the east. It appears to be absent in the Tatamagouche Syncline area and thus has a distribution restricted to the western part of the basin.

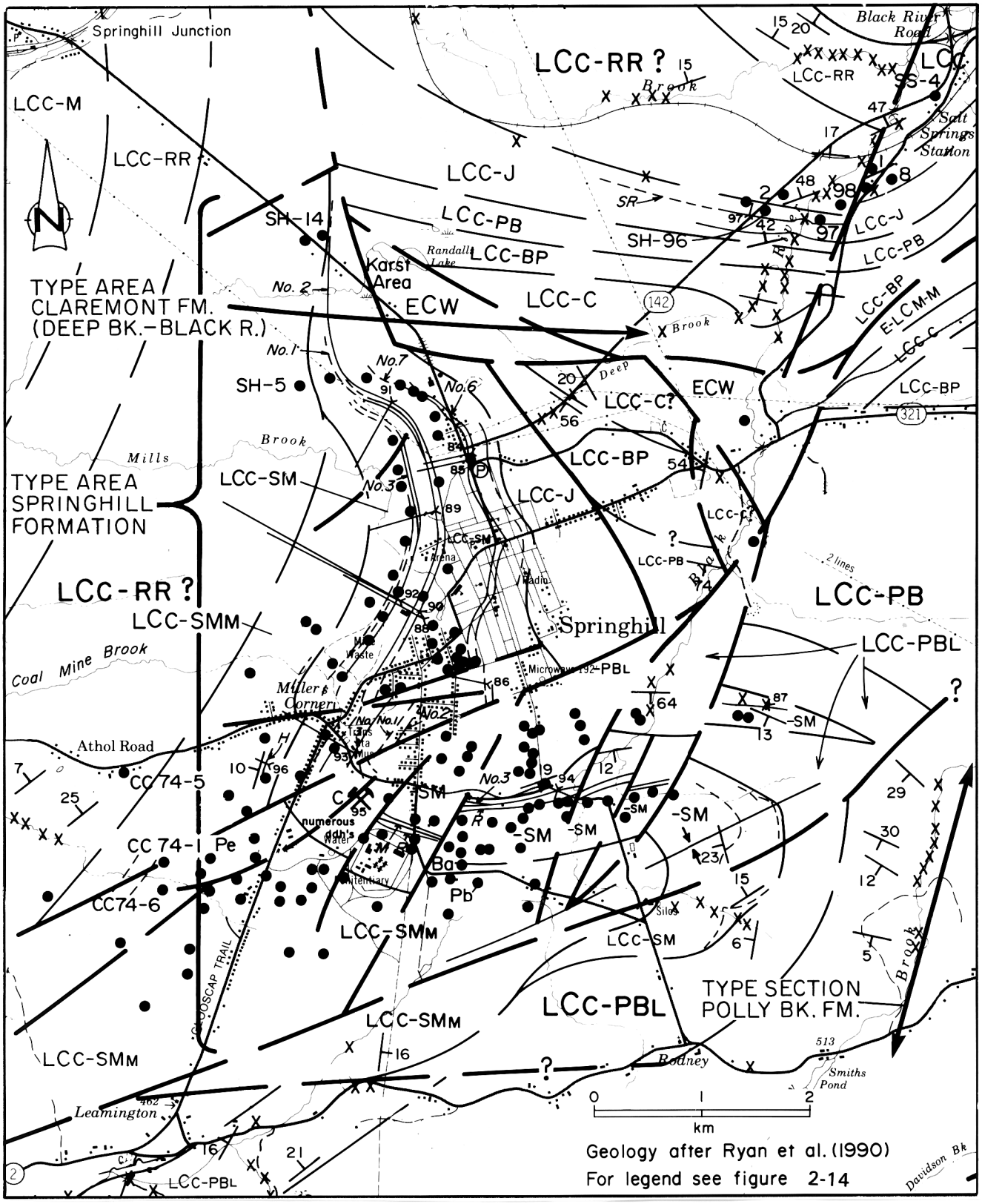


Figure 2-15. Geological and location map, type section of the Polly Brook Formation and type areas of the Springhill Mines and Claremont formations.

The Joggins Formation at the type section is conformable with the underlying the Boss Point Formation but in the south and east is conformably underlain by the Polly Brook Formation. The Joggins Formation is conformably overlain by the Springhill Mines Formation. The unit is probably the fine-grained basinward (distal) equivalent of the conglomeratic Polly Brook Formation which dominates in the south-central part of the basin.

Springhill Mines Formation

The Springhill Mines Formation contains strata of early to late Westphalian B age. The type locality is located in the Springhill area, Cumberland County, Nova Scotia (Figs. 2-15 and 2-16), but is scarcely exposed in outcrop. Outcrops occur along Coal Mine Brook just west of the town of Springhill. Due to limited accessability and outcrop exposure (extensive sewage contamination) a composite section has been designated from diamond-drill holes in the Springhill area. Rocks characteristic of the upper Springhill Mines Formation in the type area are splendidly exposed along the shore of Chignecto Bay, from a point 400 north of MacCarron River southward to a point 500 m north of Ragged Reef (Fig. 2-14). The formation comprises interstratified grey sublitharenitic sandstones, commonly medium grained; grey sidertic mudrocks, with numerous thin coal seams locally up to 4.3 m thick in the type area; and rare limestone, commonly cone-in-cone. At Joggins, the section is characterized by rhythmic interstratification of poorly developed coal seams, abundant red mudrock (increases upsection), and numerous thin (up to 2 m) sandstones. The fine to coarse ratio varies from 1.4 at Joggins to as high as 4.3 at Springhill. Sandstone bodies can be as thick as 22 m, where they occur as multistoried sandstone sequences, or as thin as ~1 m where they occur as solitary planar-bedded sheets.

The formation is 660 m thick in the type section, and at the reference section at Joggins - McCarrons River it is approximately 610 m thick. Seismic data in the central Athol Syncline indicate that the unit may thicken in the subsurface near the axis of the syncline. The unit is not exposed at surface in the eastern part of the basin; however, it may occur in the subsurface in the Wallace Syncline area where drillholes OX-BP 5, 6, 7, and 8 intersected equivalent strata. The Springhill Mines Formation in the type area is laterally transitional to upper portions of the Polly Brook Formation. At the southern basin margin the unit conformably overlies and interfingers with the Polly Brook Formation; to the west it conformably overlies the Joggins Formation in the Joggins section where the Polly Brook Formation is absent. The unit is conformably overlain by the Ragged Reef Formation. In the type area the contact with the Ragged Reef Formation is transitional, with increasing red mudrocks and a concomitant decline in the abundance of coal seams up-section.

Ragged Reef Formation

The Ragged Reef Formation contains strata of middle Westphalian B to early Westphalian C age. The type locality (Figs. 2-14 and 2-13) is in the Joggins section along the Chignecto Bay shoreline, from a point 500 m north of Ragged Reef at the top of the Springhill Mines Formation, southward to the highway bridge over the Little Shulie River north of Shulie, Cumberland County, Nova Scotia (Fig. 2-14). Reference sections are designated in drillhole NSDME SA 88-1 drilled near South Athol (Deal, 1990), and in the Spicers Cove area.

The Ragged Reef Formation comprises moderately to well sorted, coarse-grained grey and red sublitharenitic and subarkosic, sandstone, and polymictic pebble to cobble conglomerate, interbedded with red and grey mudstone and siltstone. The sandstone and conglomerate are trough cross-stratified and form multistoried, multilateral sandstone-conglomerate sequences up to 30 m thick. Mudstone is interbedded with fine-grained red to grey planar-stratified sandstones, ranging from 0.5 to 2 m in thickness. The formation may be locally dominated by coarse sandy facies or by the red mudstone facies; the latter predominates in the southeast area of the Athol Syncline near Springhill (Deal, 1990). Rare, thin bituminous limestone and coal seams occur locally. The fine to coarse ratio is approximately 0.7 but may be as high as 2.0 in the fine-grained facies in the central part of the Athol Syncline.

The Ragged Reef Formation is widely distributed in the basin, occurring in most of the major synclines with the exception of the Tatamagouche Syncline and perhaps parts of the Amherst Syncline. The 677 m thickness in the type section does not include the entire thickness of the unit, as the top of this unit is not exposed along the shore. Incomplete extensions of the section inland at Shulie, and correlations with the Spicers Cove area, indicate an additional 200-300 m of strata, giving a total thickness of approximately 1000 m. The unit thins toward the eastern part of the Cumberland Basin and is absent or very thin in the Tatamagouche Syncline area. The unit occurs as a thin coarse-grained lithofacies in parts of the Wallace Syncline in the eastern Cumberland Basin; however, the thickness does not appear to exceed

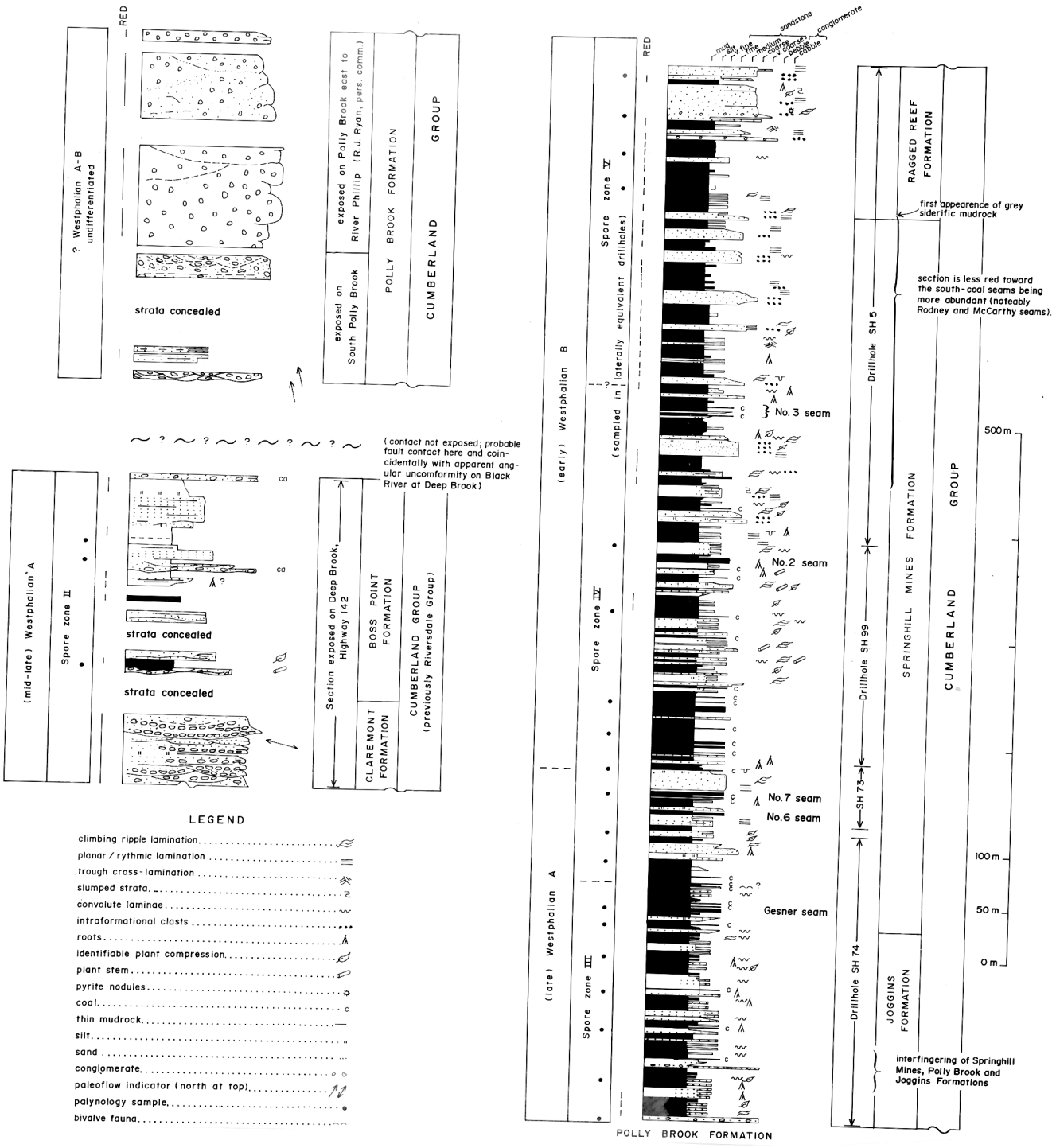


Figure 2-16. Stratigraphy of the type section, Springhill Mines Formation, and type-reference sections of related units including the Polly Brook, Claremont and Boss Point formations.

350 m. The unit conformably overlies the Springhill Mines Formation, with an interfingering transition possible in the subsurface. The unit is conformably overlain by the Malagash Formation and is probably correlative with the Tynemouth Creek Formation of southern New Brunswick (Plint and van de Poll, 1982).

Malagash Formation

The Malagash Formation contains strata of Westphalian C-D age. The type section (Figs. 2-17 and 2-18) is located at Malagash Point, Cumberland County, Nova Scotia, along the shore of the Northumberland Strait. The section starts 190 m south of the most easterly promontory and extends to the sand spits to the north. The best reference locality is in the Pictou Group type section designated by Bell (1926), specifically that portion located along River John from the junction of Mine Brook to a point 1.6 km downstream at Welsford, Colchester County, Nova Scotia (Figs. 2-19 and 2-20). This formation is made up of grey to greyish-brown subarkosic sandstone, red and grey mudstone, and calcareous mud-chip conglomerate at the base of the coarse-grained sequences (Fig. 2-18). The unit is characterized by the presence of variably distributed red coloration (diagenetic alteration) in some of the sandstones. Laterally persistent, thin limestone beds and coal seams are present. The sandstone and conglomeratic bodies represent multistoried, multilateral trough cross-stratified units with thicknesses typically between 5 and 20 m. Thin (>1 m) red sublitharenitic to subarkosic sandstone layers with planar bedding occur within the mudstone-dominated sequences. The fine to coarse ratio in the Malagash Formation varies from 2.0 to 0.5. The Malagasb Formation is widely distributed in the Cumberland Basin, occurring in outcrop and in the subsurface of all the major synclines. The thickness of this unit at the type section is approximately 450 m; however, the upper contact relationship is not exposed and the section is incomplete. In the River John section in the eastern part of the basin, the unit is bounded by disconformities and has a thickness of approximately 250 m. These observations indicate that the thickness of this unit is the most consistent of the Cumberland Group formations exposed within the basin.

The Malagash Formation conformably overlies the Ragged Reef Formation in the western Cumberland Basin and disconformably overlies the Boss Point Formation. It may locally overly the Claremont Formation of the Riversdale Group in the Tatamagouche Syncline area in the eastern part of the basin. The Malagash Formation is disconformably overlain (low angle unconformity) by the Balfron Formation redbeds of the Pictou Group. The Malagash Formation is approximately stratigraphically equivalent to the Cumberland Fine Non-coal Bearing Facies of Shaw (1951), the Pictou Grey Beds of Ryan (1985), and the Merigomish Formation of Yeo (1985). These units are all time equivalent and lithologically indistinguishable. They are grouped together into this unit for the purpose of this study. The lack of continuity in outcrop between the type areas of the Merigomish and the Malagash formations may represent a logical rationale for separation of the units but there is a high probability that the two are lithostratigraphically equivalent. The Malagash Formation in the reference section, River John, was originally included in the Pictou Group as defined by Bell (1926, 1944). Because of lithological, stratigraphic and sedimentological similarities these strata were reassigned and included as part of the Cumberland Group by Ryan *et al.* (1991). This reassignment is problematic because the formation is at the transition between the Cumberland and Pictou groups. In addition, it represents the historical basis for the inclusion of late Westphalian (C and D) grey fluvial strata (characteristically non-coal-bearing) in the Pictou Group of Bell (1944).

Pictou Group (Revised, Ryan *et al.*, 1991)

The Pictou Group comprises strata of Late Carboniferous to Permian (Westphalian D to Early Permian) age. The type locality is on the West Branch River John, downstream from the mouth of Mine Brook, in the Tatamagouche Syncline area of the eastern Cumberland Basin (Fig. 2-19). As stated previously the lower grey strata of Bell's (1926, 1944) type section includes beds that were reassigned to the uppermost formation of the Cumberland Group (Malagash Formation).

The Pictou Group consists predominantly of redbeds with varying proportions of sandstone and mudstone. Rock types include coarse- to fine-grained subarkose and sublitharenite, mudstone, siltstone, calcareous mud-chip conglomerate, rare thin coal seams, and light grey limestone (Fig. 2-20). Mudrocks are commonly interbedded with thin (<1 m) beds of fine-grained sandstone with planar stratification. These planar stratified beds contrast with the thicker (10 m) trough cross-stratified sandstone and conglomerate. The overall sand (sandstone and coarser) to silt (siltstone and finer) ratio is approximately 0.4. The group is approximately 1650 m thick at the type locality (Ryan, 1985); however, it may be as thick as 3000 m in Prince Edward Island (Howie and Barss, 1975b). The Pictou Group is the most widespread of all the Upper Carboniferous strata and occurs throughout the Maritimes Basin.

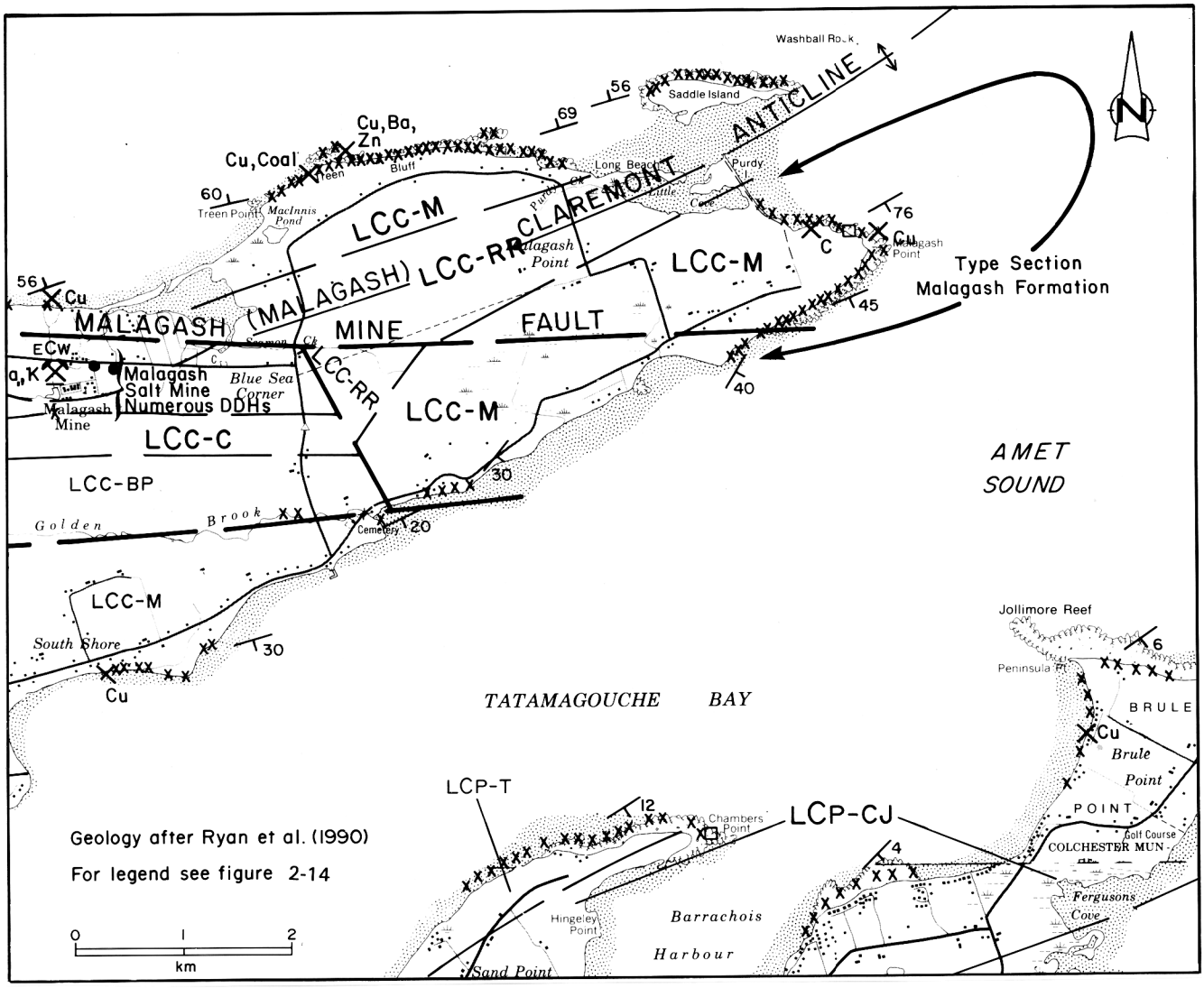


Figure 2-17. Geological and location map, type section of the Malagash Formation near Malagash Point.

The Pictou Group may overlie any of the Carboniferous units or basement rocks with disconformities, low angle paraconformities, angular unconformities, or nonconformities at its base. Formations are assigned to the Pictou Group using these criteria (Table 2-1): (1) typically non-coal-bearing; (2) dominated by redbeds; (3) stratigraphic position conformably to unconformably overlying Cumberland Group strata and may onlap older Carboniferous or basement rocks; (4) dominantly fine-grained rocks; and (5) rare coarse-grained conglomeratic strata. This group has previously been correlated with or encompassed all or parts of regional and local units including the Morien Group, the Stellarton Group, and the Prince Edward Island Redbeds. Ryan *et al.* (1991) concluded the following could probably be included in the revised Pictou Group: the Prince Edward Island Redbeds, recently defined formally as the Prince Edward Island Group (including Miminegash, Egmont Bay, Kildare Capes, Hillsborough River and Orby Head formations) by van de Poll (1989), the Tormentine Formation at the top of the Petitcodiac Group in New Brunswick (Gussow, 1953), the Cap-aux-Meules Formation in the Magdalen Islands, and undivided Permo-Carboniferous redbeds in the Sydney Basin. In addition, the Broad Cove Formation in western Cape Breton Island would be included in the Pictou Group. The group has been subdivided in the type area into three formations by Ryan *et al.* (1991), in ascending order: Balfron, Tatamagouche and Cape John formations. Complete descriptions of these formations can be found in Ryan *et al.*, 1991. A brief summary of the characteristics of these formations follows.

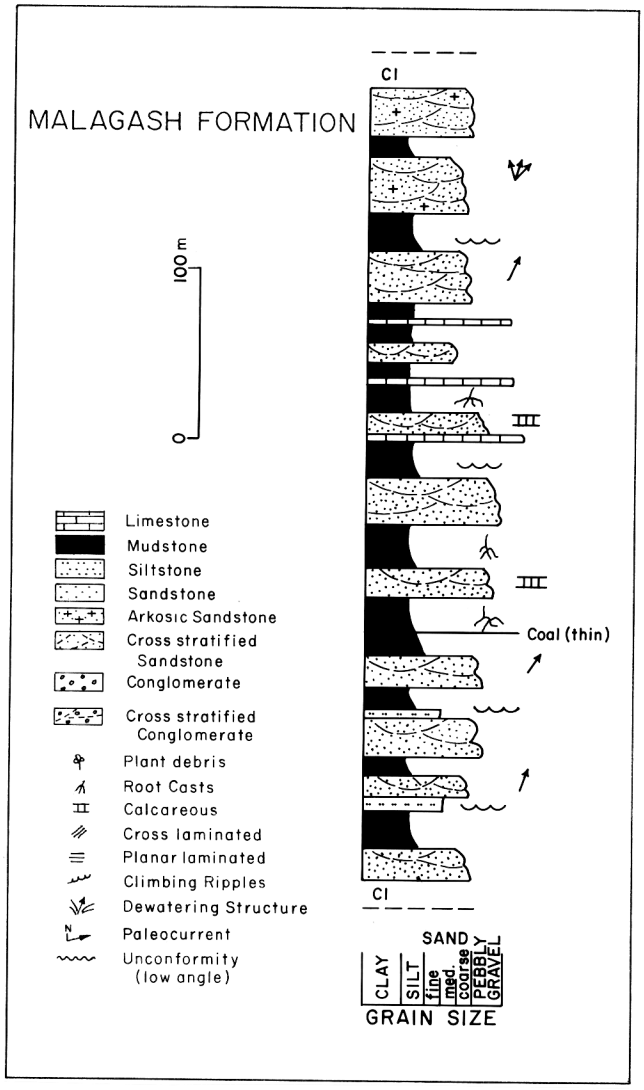


Figure 2-18. Stratigraphy of the type section, Malagash Formation.

Balfron Formation

The Balfron Formation comprises strata of late Westphalian D to Stephanian age. The type locality is along Waugh River near the village of Balfron, Colchester County, Nova Scotia (Fig. 2-21). The section starts at a point 600 m downstream from The Falls bridge and extends for 6 km downstream to the highway bridge at the village of Waughs River. Excellent exposure of this formation occurs along French River from Central New Annan downstream to a point 2.5 km southwest of the town of Tatamagouche, Colchester County (Fig. 2-21).

The formation comprises red-brown subarkosic sandstone, mudrock, minor pebbly sandstone, calcareous mud-chip conglomerate, minor grey beds, and rare, thin, discontinuous limestone beds (Fig. 2-22). The fine to coarse ratio is approximately 1.0. The thicker sandstone bodies (>1 m) are typically trough cross-stratified. Sandstones is usually coarse- to medium-grained, except where it occurs as thin interbeds with the mudrocks, in which case it is fine-grained. The thicker (up to 40 m) sandstone bodies are multilateral and multistoried. The multilateral nature of the sandstone bodies gives them a sheet sand morphology and individual sandstone horizons can be traced for several kilometres along strike. The sandstone - conglomerate packages are typically 10-15 m thick but can locally attain thicknesses in excess of 40 m. The formation varies from 800 to 900 m in thickness within the Tatamagouche Syncline in the eastern part of the Cumberland Basin. This unit is widely distributed in the eastern parts of the complex Wallace Syncline, as well as in the Amherst Syncline covering most of the northern part of the basin. It also occurs in the upper part of the Gulf *et al.* Hastings No. 1 well drilled near Amherst.

The Balfron Formation overlies, at various localities, all of the older Carboniferous units in the basin and also may onlap pre-Carboniferous basement rocks of the Cobequid Highlands Massif. The contact relationships vary from disconformities, angular unconformities, to nonconformities. The contact with the overlying Tatamagouche Formation is a paraconformity or conformable.

Tatamagouche Formation

The Tatamagouche Formation contains strata of Stephanian age. The type locality for the Tatamagouche Formation is along the Waugh River and the shoreline Tatamagouche Bay. It extends from the village of Waugh River to Weatherbies Bank, north of the town of Tatamagouche, Colchester County, Nova Scotia (Fig. 2-21). The best reference section for the Tatamagouche Formation is located along the shore of the Northumberland Strait, between Skinners Cove and Seafoam near the village of Melville, Pictou County. There is also a good section exposed along the shore at Sand Point, Colchester County, Nova Scotia. Numerous diamond-drill holes have intersected the formation within the Tatamagouche Syncline area. The most complete reference section of this formation is in core from diamond-drill hole NT-47, drilled by Noranda Exploration and stored at the Nova Scotia Department of Natural Resources Core Library at Stellarton, Nova Scotia.

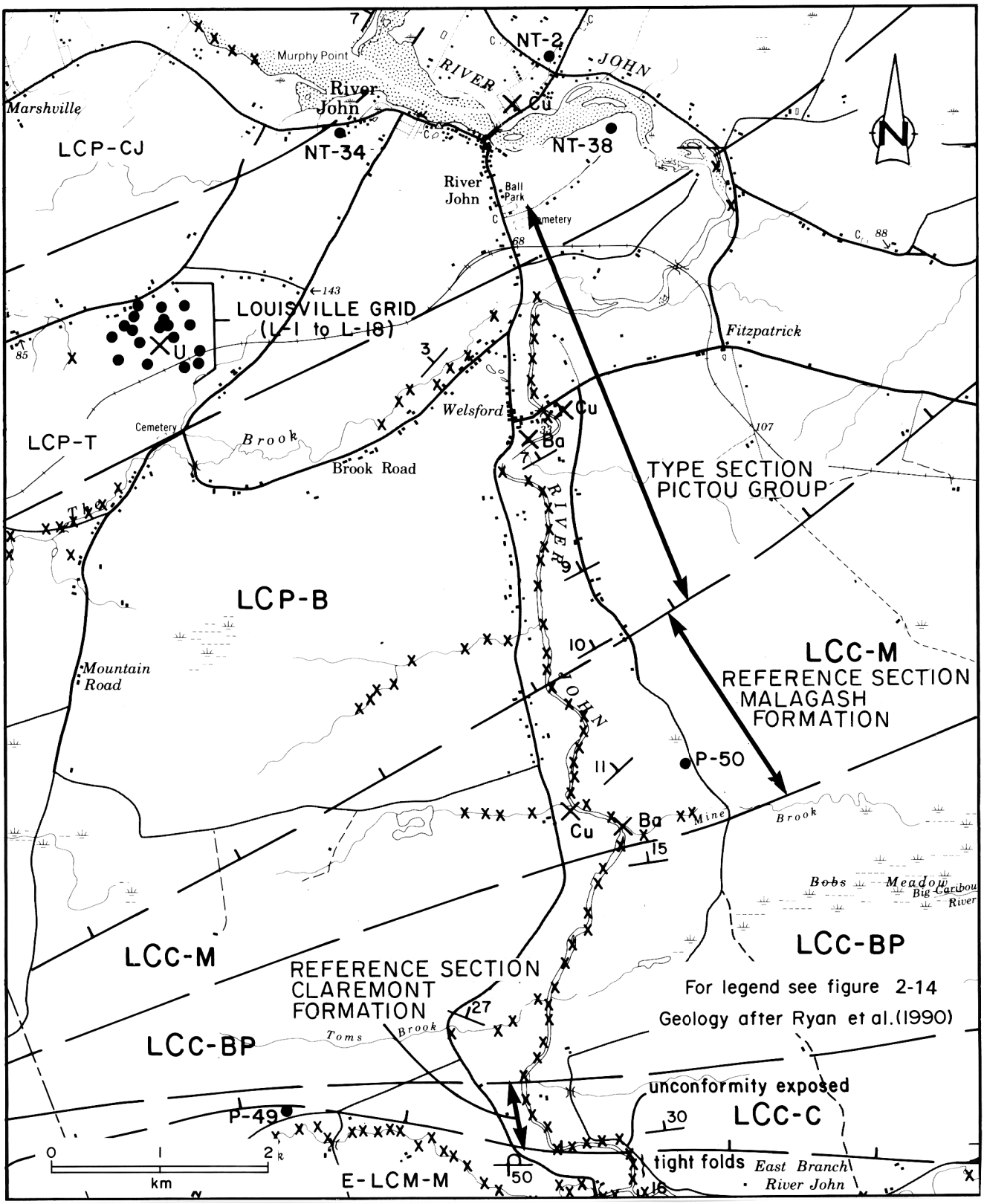


Figure 2-19. Geology and location map, type section of the Pictou Group, River John. Note: Bell,1944 originally included in the Pictou Group rocks now assigned to the Malagash Formation.

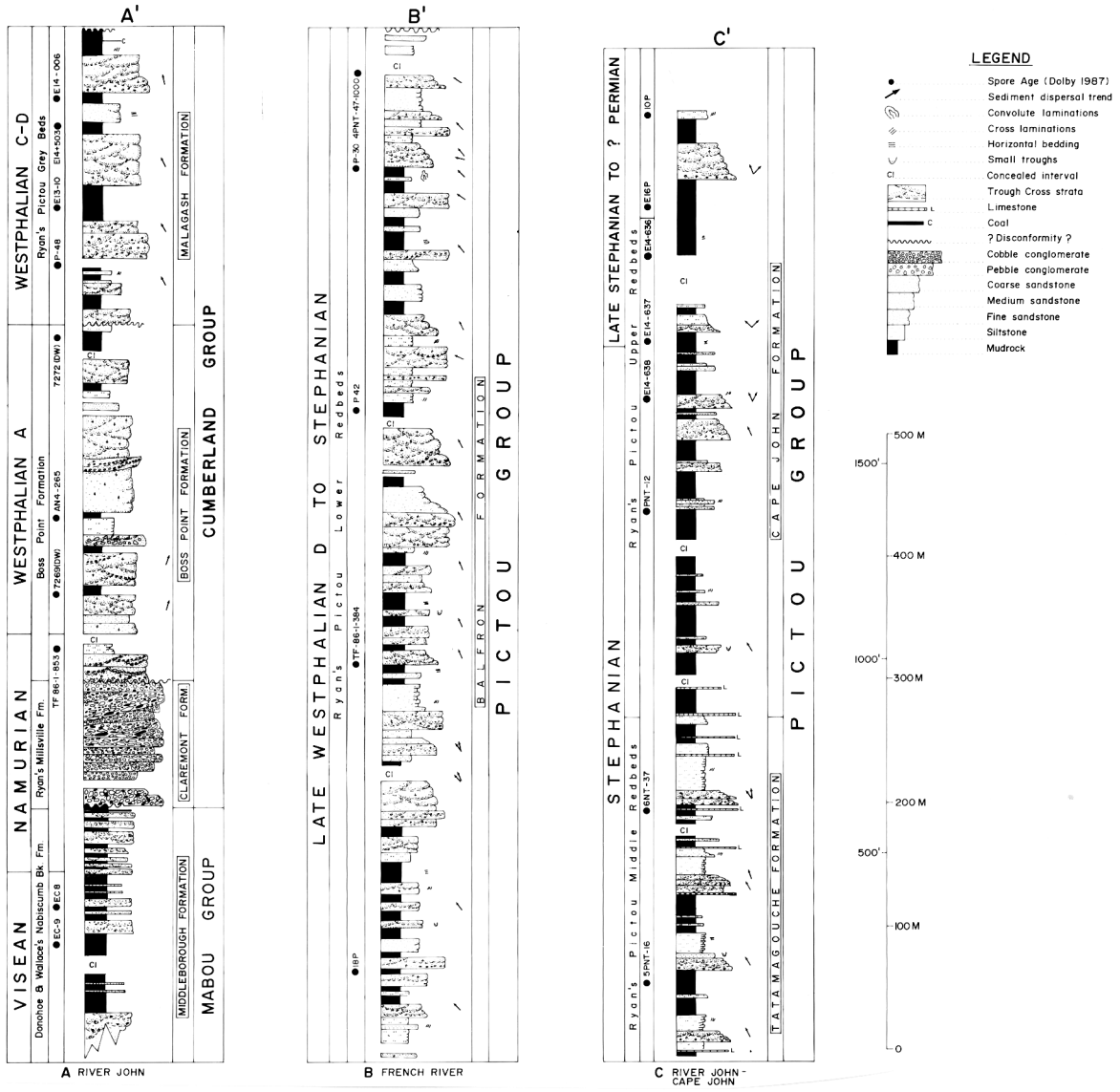


Figure 2-20. Composite stratigraphy of the Pictou Group type area, including the type section for the Cape John Formation, River John, Tatamagouche - Cape John area.

This formation is dominated by red-brown mudrocks with subordinate, medium- to coarse-grained sublitharenite, minor pebbly sandstone, minor grey beds, and calcareous mud-chip conglomerate (Fig. 2-23). Thin, laterally persistent, light grey limestone beds locally are important marker beds. The formation has a fine to coarse ratio of approximately 3.0. Thick sandstone beds (>1.5 m) are trough cross-stratified, whereas thinner sandstone beds are planar bedded or ripple cross-laminated. Thicker sandstone sequences (up to 30 m) form sheet-like bodies that can be traced for tens of kilometres along strike. The sand bodies are multilateral and multistoried. Sequences typically fine upwards and the scale of sedimentary structures decreases upwards as well. Unlike the Balfron Formation, the Tatamagouche Formation has more abundant mudrocks and laterally persistent limestone beds. Thickness of the Tatamagouche Formation varies from 300 to 350 m. The distribution of this unit outside of the Tatamagouche Syncline area in the eastern Cumberland Basin is unclear, although it is inferred that some of the redbeds exposed in the north-central part of the basin, including the Amherst Syncline, are equivalent to this unit.

The contact with the underlying Balfron Formation is probably a paraconformity, as is the contact with the

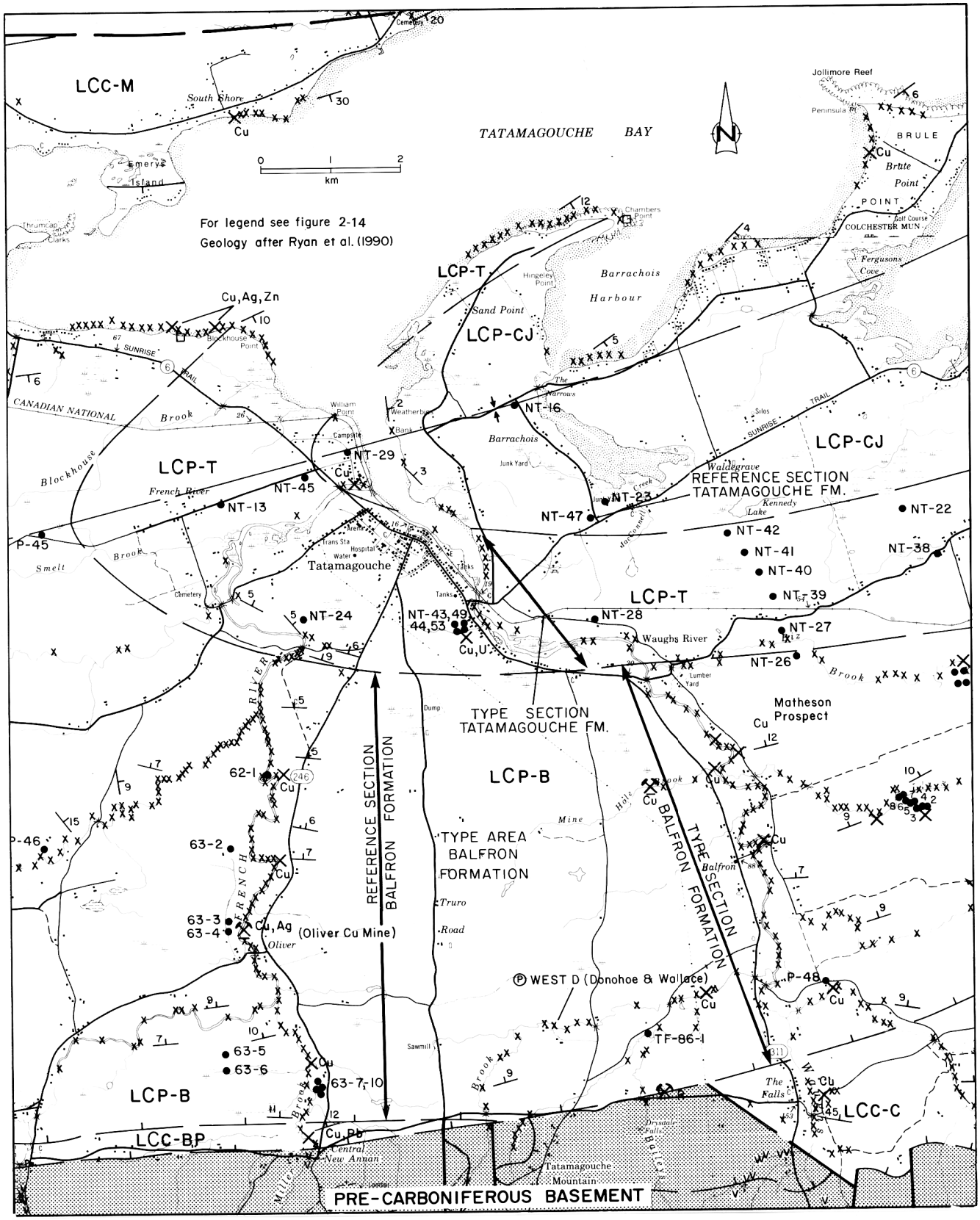


Figure 2-21. Geological and location map, type section of the Balfron and Tatamagouche formations, near Tatamagouche.

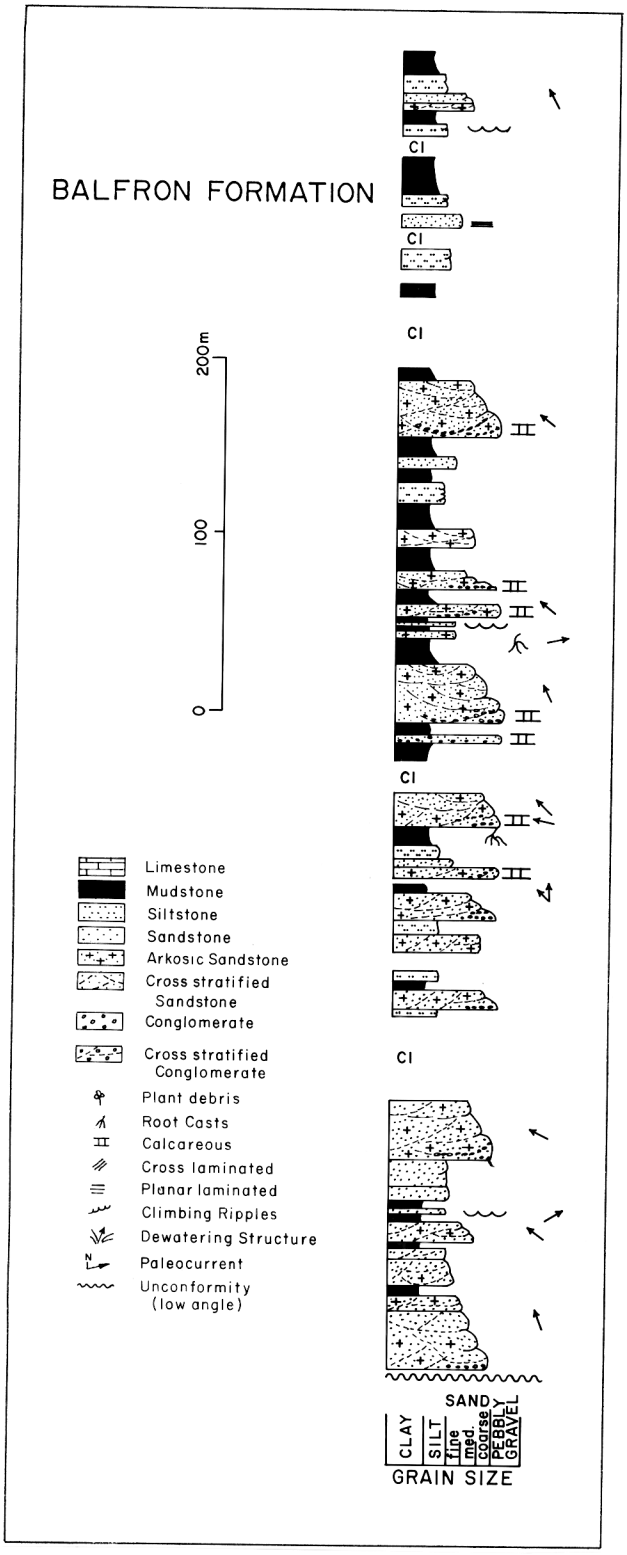


Figure 2-22. Stratigraphy of the type section, Balfron Formation.

overlying Cape John Formation. These low angle unconformities (paraconformities) are extremely difficult to map at individual outcrops due to the low angular discordance and the cross-stratified nature of the sandstone bodies; however, differences in strike of the units are discernable on satellite imagery.

Cape John Formation

The Cape John Formation contains strata of Late Stephanian to Autunian age. The type locality for the Cape John Formation is the structurally disturbed (faulted and folded) section along the shoreline of Cape John peninsula, from Cape John 3 km southeast to Salisbury Point, Pictou County, Nova Scotia (Fig. 2-24). There are numerous reference localities with good exposure of this formation along the Amet Sound shoreline, including Brule, Rocky Point and Brule Point. The most complete section of the formation can be derived from the Noranda Exploration diamond-drill hole NT-47, combined with the nearby outcrop section at Rocky Point, Pictou County.

The Cape John Formation is composed of red-brown mudstone and siltstone, coarse-grained arkose to subarkose, pebbly sandstone, minor grey beds, and rare, thin, but laterally persistent limestone beds (Fig. 2-20). The fine to coarse ratio is approximately 5.0. Sandstone sequences composed of pebbly sandstone, arkose and subarkose with inter-cross- stratified, calcareous mud-chip conglomerate. Sandstone sequences can be up to 35 m thick, and are multistoried and multilateral. The multilateral nature of the sandstone bodies is not as well developed as in the other Pictou Group formations and the sandstone sheets can only be traced for one or two kilometres along strike. Most of the strata are red to red-brown in colour; however, locally both sandstone and mudrocks are grey. The Cape John Formation differs from the other underlying Pictou Group formations by the lack of laterally continuity of sandstone bodies and by the greater abundance of mudrocks. The Cape John Formation is at least 400 m thick at the type locality. The top of the formation in the eastern Cumberland Basin is incomplete due to erosion, which limits the outcrop area to the axis of the Tatamagouche Syncline. The unit also occurs as limited outcrop in the poorly defined axial area of the Amherst Syncline near Coldstream Head, north of Pugwash along the shore of the Northumberland Strait in the northern part of the study area. Here it is inferred to be approximately the same thickness as the type area.

The Cape John Formation constitutes the youngest strata exposed in northern Nova Scotia and is probably correlative to the lower part of the Prince Edward Island

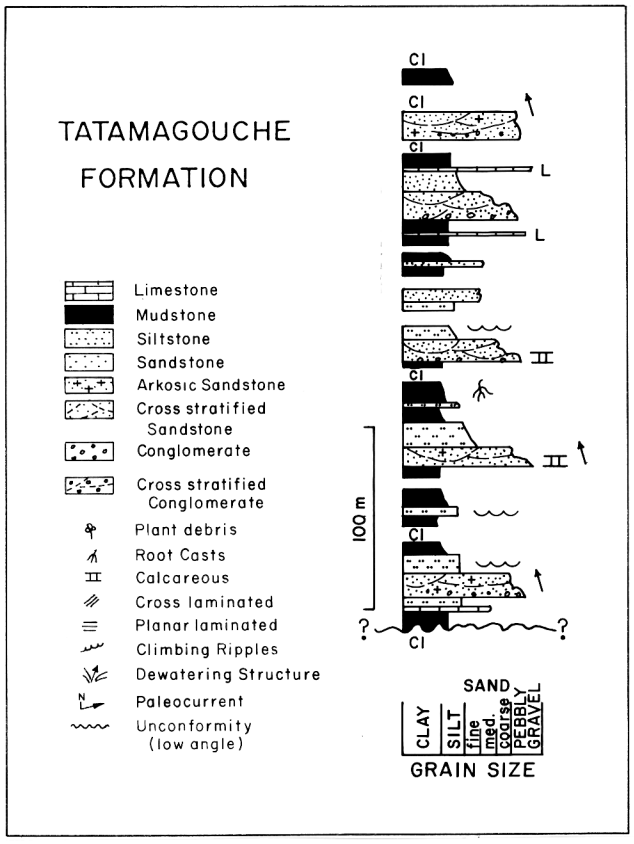


Figure 2-23. Stratigraphy of the type section, Tatamagouche Formation.

Redbeds (Group) of the Pictou Group in Prince Edward Island. The formation overlies the Tatamagouche Formation with a possible paraconformity occurring at the contact. Distribution of the strata is restricted to the northern and eastern part of the Cumberland Basin.

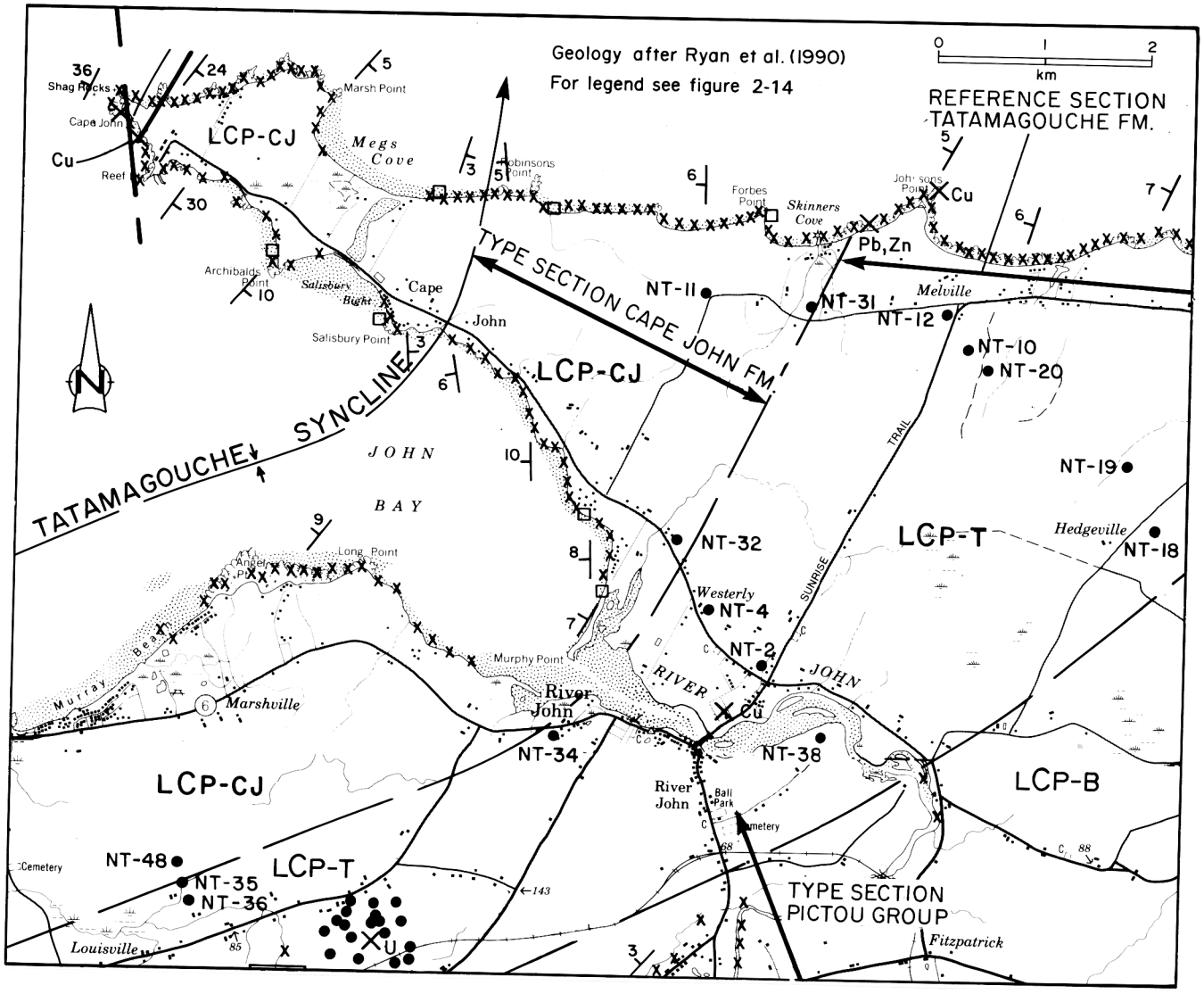


Figure 2-24. Geological and location map, type section of the Cape John Formation, near River John.