Stratigraphy of the Horton Group, Guysborough and Antigonish Counties[1]

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Introduction

The Nova Scotia Department of Natural Resources (NSDNR) and the Geological Survey of Canada (GSC-Atlantic) are working together to complete a 1:50 000 scale geological map of NTS area 11F/11. This work forms part of a federally funded Targeted Geoscience Initiative (TGI) to evaluate the mineral resource potential of southeastern Cape Breton Island and the Strait of Canso area. Concurrent with the TGI project is mapping undertaken by Paul Tèniére, in support of his M.Sc. thesis, on parts of NTS areas 11F/05, 06, 11, 12 and 11E/08 (Fig. 1). Collectively, these two projects have afforded the opportunity to carry out a detailed analysis of the stratigraphy and structure of the Horton Group in Antigonish and Guysborough Counties. This report summarizes the preliminary results of work in the southwest corner of NTS 11F/11, and the additional area covered by Tèniére's thesis.

General Geology

The Horton Group is a Late Devonian to Early Carboniferous (Tournasian) siliciclastic succession that can be found throughout the Maritimes Basin of eastern Canada. Sedimentation took place in a series of sub-basins that include localized fault-bounded half-grabens (Kilfoil, 1988; Hamblin and Rust, 1989; Miller *et al.*, 1990, Durling and Marillier, 1993; Martel and Gibling, 1996; Pascucci *et al.*, 2000) and more regionally, extensive "sags" (Durling and Marillier, 1993). Despite being relatively isolated from each other, many of the Horton sub-basins have broadly similar basin-fill patterns suggesting that sedimentation was influenced by regional tectonic processes (Martel and Gibling, 1996). In general the basin-fill consists of an upper and lower alluvial-fluvial succession separated by a lacustrine unit (Murray, 1960; Hamblin and Rust, 1989; Martel and Gibling, 1996). Fluvial and lacustrine deposits commonly coarsen laterally toward basin margins where they become interbedded with alluvial fan deposits (Hamblin and Rust, 1989; Murphy and Rice, 1998).

The Horton Group exhibits considerable thickness variation both within and between sub-basins. Thickness estimates for the Horton Group in the type area along the Minas Basin range from 600 m (Martel and Gibling, 1996) to 1150 m (Bell, 1960). The Horton Group is reported to be approximately 2500-3500 m thick in the following basins: St Mary's Basin (Murphy and Rice, 1998), sub-basins along the west coast of Cape Breton Island (Hamblin and Rust, 1989), and half-grabens in the Gulf of St. Lawrence region (Durling and Marillier, 1993). Based on seismic data, Durling and Marillier (1993) interpret that 8000 m of Horton Group strata may be contained in the Malpequec sub-basin in the Gulf of St. Lawrence. However, this unusual thickness may reflect structural thickening or the possible inclusion of pre-Horton Group strata (Durling and Marillier, 1993).

Previous Work

The area covered by this report is bounded by the Glenroy Fault to the north, the Roman Valley Fault to the south, the Canso Strait in the east, and the Lochaber Lake Fault in the west (Fig. 2). The stratigraphy of the Horton Group in this area is difficult to model because the strata are complexly folded, have a well-developed cleavage, and are cut

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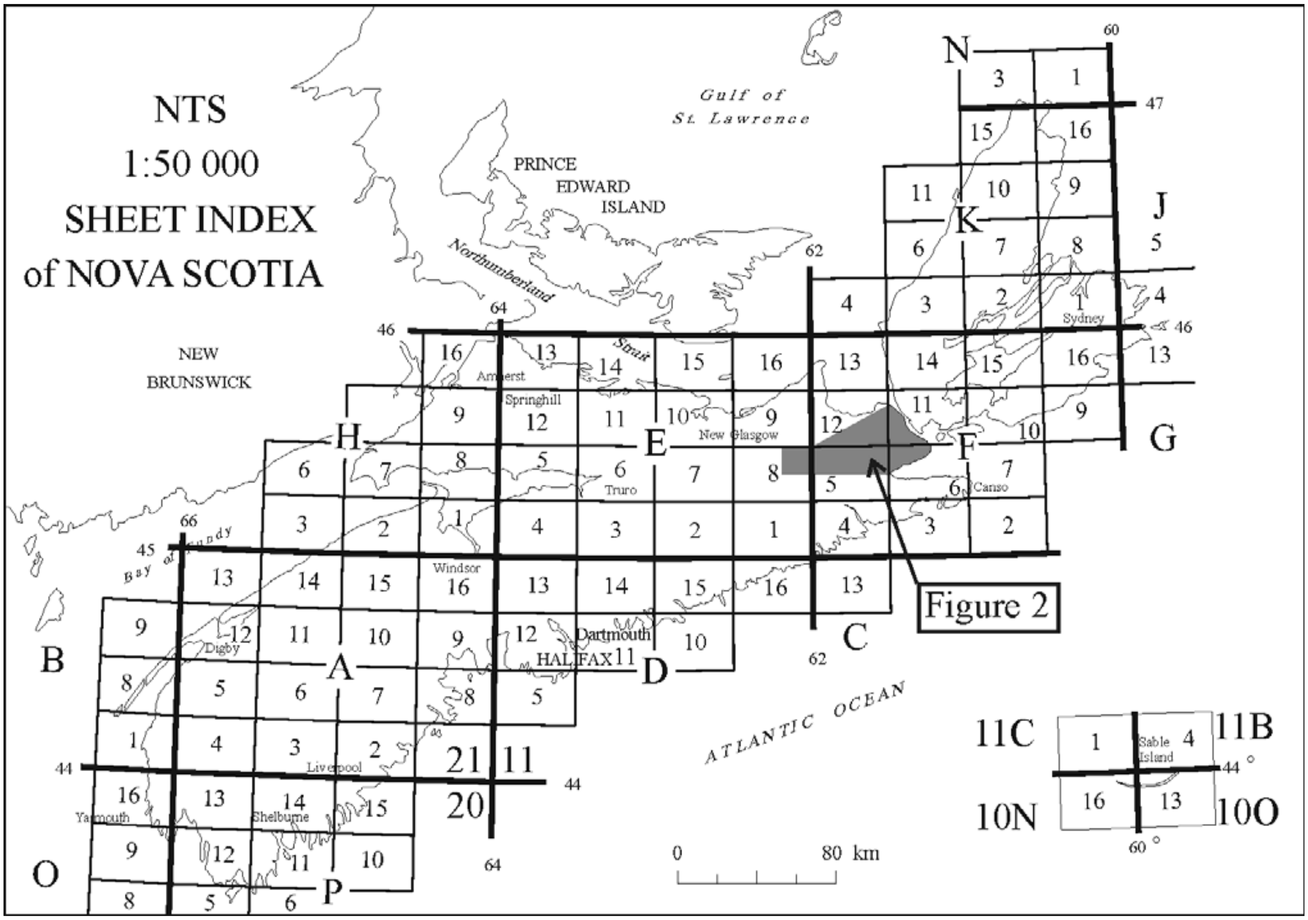

Figure 1. NTS index map of Nova Scotia, showing location of the study area.

by major faults. In addition, the thermal maturity is high, making it very difficult to recover palynomorphs that are suitable for rigorous biostratigraphic assessment. With the exception of a regional mapping project undertaken by White and Barr (1998a, b), previous workers have not examined the entire study area.

Ferguson (1946, 1950) provides detailed outcrop locations as well as useful structural and lithologic information on NTS area 11F/11. However, Ferguson did not suggest any formal lithostratigraphic subdivisons of the Horton Group. Schiller (1961) used colour as a basis to informally subdivide the Horton Group strata on the north half of NTS 11F/05 into three units. No formal nomenclature was proposed and the units were simply identified from the base to the top of the succession as Unit 7Ac (grey and grey-green), Unit 7Ab (maroon and grey) and Unit 7Aa (maroon). Benson (1970) proposed similar subdivisions for Horton Group strata on the west half of NTS 11F/12. Benson (1970) recognized a lower grey unit (Unit 5) and an upper redbed unit (Unit 6).

Based on mapping parts of NTS sheets 11F/05 and 11F/06 (Fig. 1), Smith (1980,1981, and Smith in Williams *et al.*, 1985) subdivided the Horton Group into five informal formations. In ascending order these include: the Glenkeen, St. Francis River, Clam Harbour River, Tracadie Road and Hadley Cove formations. The lower two formations, the Glenkeen and St Francis River, were considered by Smith (1980, 1981) to be lateral equivalents. These two units have a combined thickness of approximately 670 m and consist of grey conglomerate and sandstone with minor siltstone. The overlying Clam Harbour River Formation is approximately 1300 m thick and consists of greenish-grey siltstone with thin interbeds of dolomitic limestone. The Tracadie Road Formation is approximately 6000 m thick and

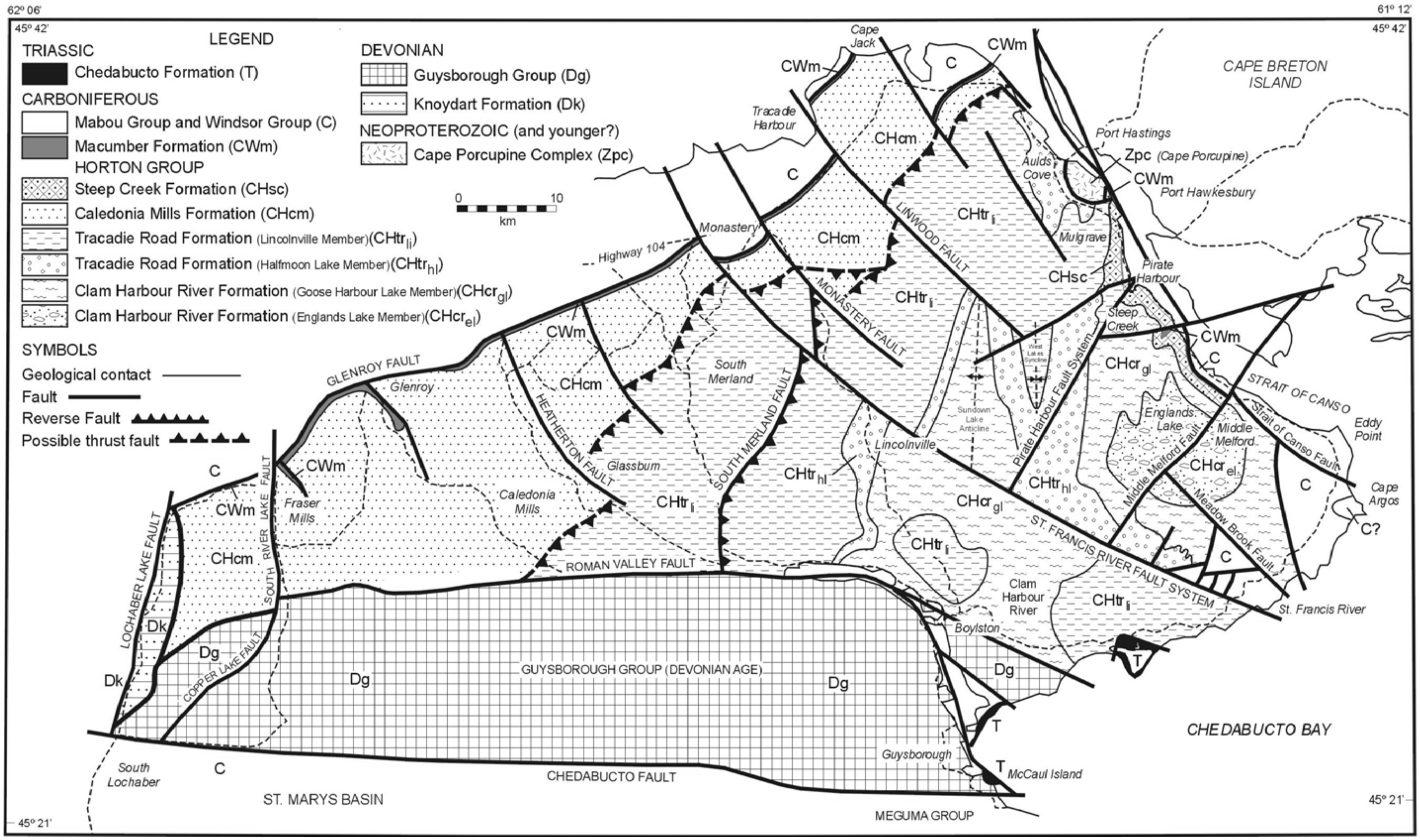

Figure 2. Simplified geological map of the Lochaber - Mulgrave area, northern mainland Nova Scotia.

is in gradational contact with the Clam Harbour River Formation. Smith described the Tracadie Road Formation as blue-grey thinly laminated siltstone with local sandstone and rare conglomerate interbeds. Smith (in Williams *et al.,* 1985) gives a minimum thickness of 850 m for the Hadley Cove Formation. Brown sandstone interbedded with red and green mudrocks form the upper Hadley Cove Formation while the lower Hadley Cove consists of dark grey shale and siltstone interbedded with thin calcareous siltstone.

White and Barr (1998a, b) undertook a regional study of the Horton Group that included all of the current study area and parts of southern Cape Breton Island. Based on this work they re-assigned the Glenkeen Formation to the Middle Devonian Guysborough Group, retained the Clam Harbour River and Tracadie Road formations, and proposed the term Caledonia Mills Formation for the redbed succession at the top of the Horton Group. No thickness estimates were provided by White and Barr (1998a, b).

Stratigraphy of the Study Area

Within the study area the Horton Group occurs in faulted contact with Neoproterozoic metavolcanic, metasedimentary and granitoid rocks of the Cape Porcupine Complex (Fig. 2) (White *et al.*, 2001), Devonian metasediments and volcanics of the Guysborough Group (Cormier *et al.*, 1995) and Devonian siliciclastics of the Knoydart Formation. The Horton Group is disconformably overlain by the Carboniferous Macumber Formation (Windsor Group), in assumed faulted contact with the Triassic Chedabucto Formation.

Based on work carried out as part of this project we have informally subdivided the Horton Group in the study area into the Clam Harbour River, Tracadie Road, Caladonia Mills and Steep Creek formations (Figs. 2 and 3). We agree with White and Barr (1998a, b) and exclude the Glenkeen or Hadley Cove formations from the Horton Group. We have further subdivided the Clam Harbour River and Tracadie Road Formation into members.

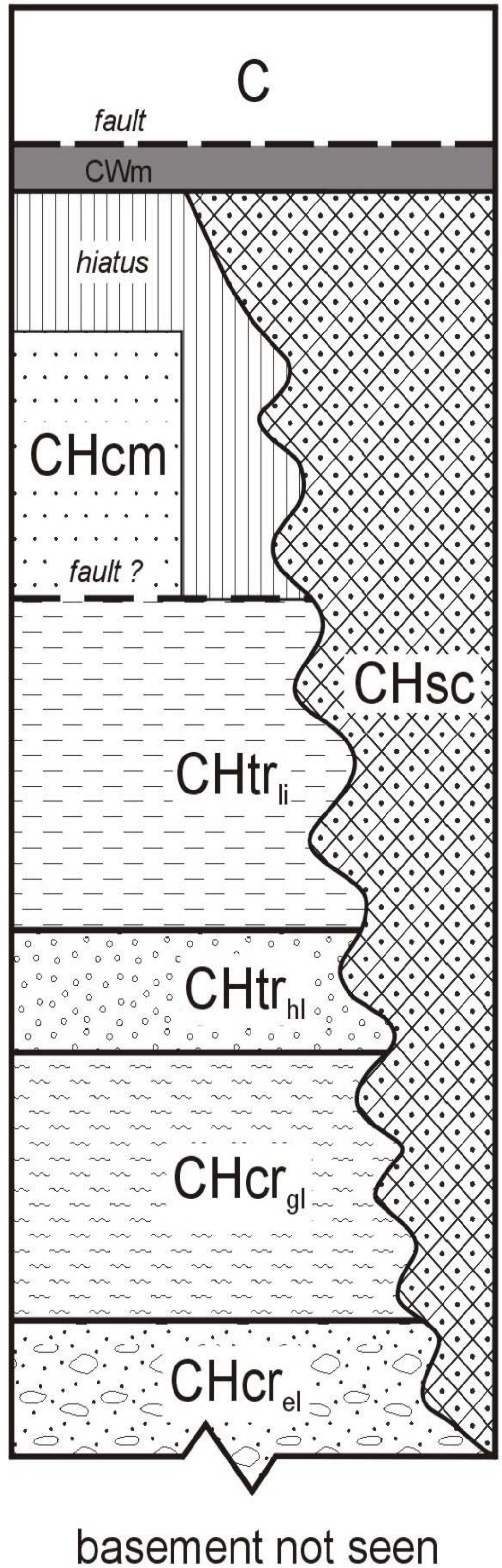

Figure 3. Simplified stratigraphic column for the Lochaber - Mulgrave area (refer to Legend in Fig. 2).

Clam Harbour River Formation

The base of the Clam Harbour River Formation occurs in faulted contact with other stratigraphic units. Therefore, it is possible to provide only a minimum thickness of 1500 m for the formation.

We have subdivided the Clam Harbour River Formation into the Englands Lake and Goose Harbour Lake members (Fig. 3). The Englands Lake Member forms the lower part of the Clam Harbour River Formation and is exposed on the east side of the map area near Englands Lake (Fig. 2). Equivalent strata may occur outside the map area on Isle Madame, but the correlation is tenuous. The Englands Lake Member consists of polymictic conglomerate and fine- to coarse-grained sandstone interbedded with red and green mudrock.

The Englands Lake Member is conformably overlain by the Goose Harbour Lake Member, which constitutes the upper 800 m of the Clam Harbour River Formation (Fig. 3). The Goose Harbour Lake Member consists of green mudrock with local thin (<1 m) fine-grained sandstone interbeds. The mudrock has a well-developed cleavage that makes recognition of bedding and sedimentary structures difficult. Bedding is generally tabular, less than 0.35 m thick, and distinguished on the basis of subtle grain size or colour variation. Beds often appear massive. However, millimetre-scale varve-like laminae or flaser to lenticular fine-grained sandstone laminae occur locally. Centimetre-scale graded bedding is common and usually occurs in fine-grained sandstone that grades upward through siltstone to claystone. Massive sandstone can also grade upward through ripple bedded sandstone to siltstone with lenticular sandstone laminae.

Siderite and dolomite layers up to 5 cm thick and finely disseminated pyrite are locally common within the mudrock. Thin (<0.15 m) beds of pale grey, massive or ripple-bedded, fine-grained sandstone are locally found interbedded with the green mudrock. Rare interbeds of massive medium- to coarse-grained sandstone, 5-10 cm thick, were also noted.

Near the contact with the Tracadie Road Formation the green mudrock of the Goose Harbour Lake Member is locally interbedded with pale red-grey sandstone and red mudrock. The sandstone is fine- or medium-grained and up to 2 m thick. Trough cross-stratification and ripple bedding are the most common bedforms. The red mudrock contains occasional flaser to lenticular sandstone laminae and green mottles.

Redbeds are not always present near the contact between the Tracadie Road Formation and the Goose Harbour Lake Member. In some locations redbeds are absent and the green mudrock of the Goose Harbour Lake Member is interbedded with black shale similar to that found in the Tracacdie Road Formation.

No plant, animal or trace fossils were observed in the Clam Harbour River Formation. We have not submitted samples of the Clam Harbour River Formation for palynological analysis.

Tracadie Road Formation

The Tracadie Road Formation outcrops throughout much of the central map area (Fig. 2). The formation is at least 1350 m thick and is in conformable contact with the Clam Harbour River Formation (Fig. 3). The nature of the contact with the overlying Caladonia Mills Formation is uncertain and is discussed under subsequent headings. We have subdivided the Tracadie Road Formation into the Halfmoon Lake and Lincolnville members.

The Halfmoon Lake Member forms the lower 600 m of the Tracadie Road Formation. Throughout much of the map area the Halfmoon Lake Member consists of a thick (>10 m) succession of pale grey sandstone and polymictic conglomerate, with thin (<3 m) interbeds of grey mudrock and black shale. The conglomerate can be clast- or matrix-supported, with pebble to cobble sized clasts. Individual conglomerate units have a maximum thickness of 6 m. Sandstone units are fine- to coarse-grained, locally appear arkosic, and are poorly sorted. Sandstone and conglomerate units can be planar and trough cross-stratified.

However, systematic vertical changes in grain size and the scale of bedforms were not recognized. The mudrock and black shale interbeds are not common and they often appear to be eroded laterally by coarser sediments.

Locally, black shale and grey mudrock are more common within the Halfmoon Lake Member. Conglomerate and sandstone are still the dominant rock type, although shale and mudrock units can be greater than 10 m thick.

The Halfmoon Lake Member is conformably overlain by the Lincolnville Member (Fig. 3). The Lincolnville Member is approximately 750 m thick and consists of black shale and grey mudrock with subordinate pale grey sandstone. The black shale is locally highly calcareous (e.g. near Mulgrave) and generally appears massive or has local pale grey sandy streaks. The grey mudrock can also be highly calcareous and typically has varve-like or lenticular laminae. Sandstone units are pale grey, fine-grained and 0.05 to 8.0 m thick. Thin (>1 m) sandstone units are commonly ripple bedded, and thicker sandstone units are typically cross-stratified.

The Lincolnville Member can be generally described as comprising three facies assemblages. Thick (10-40 m) shale- and mudrock-dominated successions with rare thin sandstone interbeds are the most common type of facies assemblage. Thinly interbedded sandstone, mudrock and shale successions, consisting of stacked 1-8 m thick coarsening-upward sequences, are increasingly common up section. The least common facies assemblage consists of 4-8 m thick fine- to medium-grained sandstone units that are typically well sorted, arenaceous and cross-stratified.

Plant fossils are rare and usually poorly preserved within the Lincolnville Member. Fossil roots were locally noted within thick sandstone units and near the top of coarsening-upward sequences. Well preserved fossil plant stems identified as late Devonian to Tournasian lepidodendropsis (Calder, personal communication, 2001) were found in association with coarsening-upward sequences on Monastry Brook near Monastary (Fig. 2). Similar fossil plants have been described in the Tracadie Road Formation north of Chedabucto Bay. No other macro-fossils or trace fossils have been recognized within the Tracadie Road Formation.

Utting (2002) recovered palynomorphs from samples of the Linconville member that are comparable to those found in the Horton Bluff Formation at the Horton type section. This supports a Tournasian age for the Lincolnville Member.

Caledonia Mills Formation

The Caledonia Mills Formation is disconformably overlain by the Windsor Group and possibly the Steep Creek Formation (Fig. 2). The contact between the Caledonia Mills Formation and the underlying Tracadie Road Formation is enigmatic. Abrupt changes in bedding attitude commonly occur near the contact between these two formations, although we have not located any exposures of the actual contact.

Substantial changes in the total thickness of the Caledonia Mills Formation often occur very abruptly across a series of northwest-trending faults (e.g. Monastery Fault, see Fig. 2). It is very difficult to explain this thickness variation simply on the basis of lateral change in sediment accumulation. A possible explanation is that faulting and erosion of the Caledonia Mills Formation occurred prior to deposition of the Windsor Group. This could have resulted in less erosion of the Caledonia Mills Formation occurring in down-faulted blocks.

A second possibility is that within the map area the contact between the Tracadie Road and Caledonia Mills formations is actually a south-easterly dipping thrust fault. On average the contact between the Caledonia Mills and the Tracadie Road formation strikes roughly parallel to the South Merland Fault (Fig. 3). Bedding in the Caledonia Mills Formation typically strikes more to the east of this trend. Therefore, if the contact between the two formations is a thrust fault, it would explain the apparent tendency for the Caledonia Mills outcrop pattern to narrow to the northeast.

Subsequent movement along the northwest-trending faults would still be required to explain the abrupt variation in apparent thickness of the Caledonia Mills Formation. The fault contact between the two formations would dip to the southeast, and beds in the Caledonia Mills dip to the northwest. Therefore, normal movement of a block between two faults would produce an apparent narrowing of the Caledonia Mills Formation map pattern. Hence, a minimum thickness of 1500 m is assigned to the Caledonia Mills Formation.

The Caledonia Mills Formation consists of red mudrock with subordinate pale grey to red-grey sandstone and green grey mudrock. Rare occurrences of black shale and polymictic conglomerate have also been observed. Red mudrock with local thin (<1 m) red fine-grained sandstone and green-grey mudrock interbeds form successions up to 50 m thick. The red mudrock locally exhibits green mottling and poorly developed calcrete nodules. The pale grey fine-grained sandstone units are typically 5 to 15 m thick and usually multistoried. Each story is approximately 2 m thick and consists of a trough cross-stratified base overlain by 1-3 m of ripple bedding. The ripple bedding typically consists of linguoid ripples. Intervals 1 to 5 m thick, consisting exclusively of ripple-bedded fine-grained sandstone were also observed.

Polymictic conglomerate occurs in coastal exposures along the Strait of Canso near the base of the Caledonia Mills Formation. At this location the conglomerate appears to almost entirely consist of granitoid clasts from the Cape Porcupine Complex.

Plant fossils are very difficult to locate within the Caledonia Mills Formation. This is particularly true in the southwestern part of the map area. Rare, poorly preserved roots and green reduction zones around possible root traces are the only evidence of fossil plants that were observed. The Caledonia Mills Formation has not been sampled for palynomorphs.

Steep Creek Formation

The Steep Creek Formation occurs south of Cape Porcupine in the northwest part of the map area (Fig. 2). The Steep Creek Formation is approximately 500 m thick and rests unconformably on the Tracadie Road and Clam Harbour River formations (Fig. 3). We assume that the Steep Creek Formation unconformably overlies the Caledonia Mills Formation (Fig. 2). However, the contact relationship between the two formations is unclear. The Macumber Formation directly overlies the Steep Creek Formation with no apparent angular discordance. Based on tentative palynological evidence (Utting, 2002) the contact between the two formations is apparently a disconformity.

The Steep Creek Formation comprises black shale, red, green grey and grey mudrock, pale grey and green-grey, fine- to coarse-grained sandstone and polymictic conglomerate. The black shale units can be 1 to 10 m thick and commonly contain thin (<1 m) interbeds of grey mudrock and pale grey, fine-grained sandstone. Locally, black shale grades upward to green-grey mudrock with faint millimetre-scale dark grey colour banding and thin (<2 cm) carbonate layers. The green-grey mudrock commonly grades up-section into red mudrock with pedogenic carbonate nodules.

Black shale units also form the base of coarsening-upward successions that are 10 to 25 m thick. A typical coarsening upward succession consists of black shale interbedded with grey mudrock and ripple-bedded fine-grained sandstone, overlain by low-angle cross-stratified and ripple-bedded pale grey or green-grey fine-grained sandstone, which grades upward to fine- to medium-grained pale grey fine-grained cross-stratified sandstone. The sandstone is well sorted and arenaceous. Pebble conglomerate units up to 2 m thick were noted near the top of some of the coarsening-upward successions. Convolute bedding is locally common, particularly within thin sandstone beds near the base of coarsening-upward units.

Interbedded sandstone and conglomerate units up to 35 m thick are also common within the Steep Creek Formation. The base of these units typically consists of 1 to 6 m of pale grey, polymictic granule- to pebble-conglomerate with local to abundant red interformational mudrock clasts. Lithic clasts often appear to be subangular and poorly sorted. Up-section the polymictic conglomerate grades to poorly sorted and somewhat arkosic cross-stratified medium-grained sandstone with local pebbly layers. Ripple bedding is rare and systematic vertical changes of bedforms were not observed. The interbedded sandstone and conglomerate units are often abruptly overlain by black shale and are typically found in erosional contact with red sandstone or mudrock.

A few very poorly preserved plant fossils have been observed within sandstone beds of the Steep Creek Formation. However, the specimens were so degraded identification was not possible. Trace fossils are also very rare and were only observed in one green-grey sandstone unit near Pirates Harbour. Two types of trace fossils were observed in grey mudrock near the middle of a coarsening-upward succession, *Undichna sp.* (sinusoidal trail made by fish) and an unidentified arthropod trackway.

Basin Configuration and Depositional Environments

A detailed discussion of basin configuration and depositional environments is beyond the scope of this report. However, it is possible to make some general observations based on the data presented here.

It is difficult to estimate the size and configuration of the Horton Basin(s) within the study area. Lateral changes in the thickness of various stratigraphic units occur, but it is difficult to determine if this is a result of faulting, folding, erosional unconformities or the original sedimentation patterns. Therefore, sediment thickness does not currently provide a useful guide to basin configuration. Similarly, basin-fill patterns are not well enough understood to clearly define coarsening and fining trends. Locally derived conglomerate clasts (e.g. Cape Porcupine Complex granite clasts in the Caledonia Mills Formation) occur at various stratigraphic levels, indicating some of the sediment was locally derived. However, there are no clearly defined coarsening trends to indicate the proximity or direction of the paleo-basin margins. The Horton Group adjacent to the Guysborough Group Block (Fig. 2) exhibits no obvious lithostratigraphic change, suggesting this was not a paleo-basin boundary.

A variety of fluvial, alluvial and lacustrine deposits appear to constitute the Horton Group within the study area. To date we have undertaken only a preliminary examination of the sedimentology of these deposits. A preliminary discussion of the types of deposits that are interpreted to constitute each stratigraphic unit is provided below.

The sandstone- and conglomerate-dominated Englands Lake Member of the Clam Harbour River Formation is poorly exposed, which makes it difficult to study. Until further work is done we are limited to describing it as consisting of fluvial sandstone, mudrock and conglomerate.

The green mudrock and thin sandstone of the overlying Goose Harbour Lake Member appear to be lacustrine deposits. Supporting evidence for this interpretation includes the occurrence of distinctive varve-like laminae, and the absence of fossil roots, paleosols and fluvial sandstone. Massive sandstone beds that grade upward to lenticular-bedded siltstone appear to be waning flow deposits. Coupled with the common occurrence of normal graded beds, these facies have some broad similarities to lacustrine turbidites.

The occurrence of redbeds and thicker sandstone units at the top of the Clam Harbour River Formation appears to herald the deposition of thick channel sandstone and conglomerate successions at the base of the Tracadie Road Formation (i.e. Halfmoon Lake Member). The redbeds may represent lacustrine shoreline deposits or possibly floodplain deposits that accumulated in interfluve areas between the fluvial channels at the base of the Tracadie Road Formation.

The absence of clear, systematic vertical changes in bedforms, rare occurrence of mudrock interbeds, and the common occurrence of both planar and trough cross-stratification indicate that the thick sandstone and conglomerate units of the Halfmoon Lake Member are probably braided river deposits. Local occurrences of thick grey mudrock and black shale interbeds may indicate periodic development of lacustrine conditions.

Lacustrine conditions appear to have prevailed during deposition of the Lincolnville Member of the Tracadie Road Formation. Evidence for a predominately lacustrine origin include the generally fine-grained nature of the deposits, excellent preservation of sedimentary structures, and the lack of evidence for subaerial exposure or plaeosol development. Thick black shale and mudrock sequences with thin sandstone interbeds are interpreted as distal lacustrine/pro-delta deposits. Coarsening-upward shale to sandstone successions are interpreted to represent more proximal lacustrine delta-fill deposits. The occurrence of fossil roots at the top of some of the coarsening-upward successions suggests that as lakes were infilled, delta plains formed and were colonized by plants. The 4 to 8 m thick, fine– to medium-grained, cross-stratified sandstone units appear to be distributary channel deposits that may have fairly limited lateral extent. Fossil roots at the top of these deposits indicate that when these channels became infilled and abandoned they formed topographic highs that were favourable for plant growth.

Channel and overbank deposits appear to constitute the Caledonia Mills Formation. The cross-stratified multistoried sandstone units may be channel deposits of high sinuosity rivers. However, further work is required to more fully characterize these deposits. The red colour, close association with channel sandstone, and paleosol development indicate the thick mudrock-dominated units are overbank deposits. However, it is difficult to reconcile the rare occurrence of fossil roots within these strata.

The Steep Creek Formation appears to consist of both lacustrine and fluvial deposits. The coarsening-upward shale to sandstone successions are interpreted as lacustrine delta-fill deposits that are broadly similar to those found in the Linconville Member. Evidence for a lacustrine delta origin includes the excellent preservation of sedimentary structures, the absence of fossil roots, the presence of fish and arthropod trackways, and the gradual upward increase in grain size and scale of bedforms. Upward transitions from black shale through green murock to red mudrock with pedogenic carbonate are interpreted to represent a gradual regression of a lacustrine shoreline. The thick multistoried sandstone units with interbedded conglomerate are interpreted to be braided river deposits. The poorly sorted and immature nature of the sandstone and the angular lithic clasts in the conglomerate suggest rapid deposition under periodic flood conditions, possibly in distal areas of a braidplain.

Economic Geology

As part of the Targeted Geoscience Initiative project, other workers will carry out an evaluation of known mineral occurrences on map area 11F/11. These results will be provided in a future report. For the purposes of this report a few brief comments on resource potential are provided below.

There appears to be very little potential for hydrocrbon exploration in the study area. The thermal alteration index of spores is commonly very high (T.A.I. 4/5; Utting, 2002). This equates to a vitrinite reflectance value of Ro 3.5%, which is beyond the limit of dry gas preservation.

Martin Marietta Limited operates a large aggregate quarry in the Cape Porcupine Complex at Aulds Cove. Aggregate from this operation is supplied to clients throughout the Maritimes and from Texas to New England. No further mapping of the Cape Porcupine Complex was undertaken as part of this study. However, White *et al.* (2001) undertook detailed mapping of the Cape Porcupine Complex and this work provides useful information for future aggregate mining of the Cape Porcupine Complex.

An additional potential source of aggregate, identified in this study, is the highly calcareous black shale of the Linconville Member of the Tracadie Road Formation. We are currently evaluating its potential to act as a carbonate source for cement production.

Known metallic mineral occurrences are predominately galena and sphalerite associated with carbonate veins (DeMont, personal communication, 2001).

Future Work

During the 2002 field season, measurement and description of a reference or type section will be undertaken for each formation and member of the Horton Group. The contact relationship between the Caledonia Mills and Tracadie Road formations will also be the focus of further study.

Future work will also include comparing the stratigraphy and depositional history of the Horton Group in the study area to Horton Group strata in the St. Marys Graben and southeastern Cape Breton Island.

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