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GEOLOGICAL NOTES ON THE CAMBRO-ORDOVICIAN ROCKS OF THE PHILLIPS BROOK ANTICLINE, NORTH OF STEPHENVILLE

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ABSTRACT

Preliminary 1:50 000-scale mapping of parts of the Phillips Brook anticline north of Stephenville, western Newfoundland in adjoining parts of map areas 12B/9, 12B/10 and 12B/16, began in 1998 and 1999. The Phillips Brook anticline underlies a mountain upland comprising complex-faulted lower Paleozoic shallow-water carbonate and siliciclastic rocks of the Labrador, Port au Port, St. George and Table Head groups. The anticline predates the deposition of late Mississippian conglomerates and sandstones that unconformably onlap the southern end of the structure. A steep-angle thrust appears to mark the western edge of the anticline, emplacing Cambro-Ordovician shelf carbonates above footwall rocks that include Middle Ordovician shelf carbonates, overlying flysch and transported deep-water sedimentary rocks of the Taconian allochthon. The western part of the anticline is marked by numerous faults, some of which may be early thrusts that are folded about the structure. There is at least one bedding-parallel fault deformed by folds associated with one of the fault blocks. Cleavage penetrates the finer grained and shalier Cambrian shelf rocks in the core of the structure and also marks shales in footwall rocks of the western edge. The anticline is transected by long curvilinear and branching, northeast- to north-trending faults. Kinematic indicators and fold trends associated with the faults indicate both sinistral and dextral sense of displacement on the main faults. A suite of minor, northwest- and east–northeast-trending normal faults also cut the structure.

The Cambro-Ordovician shelf sequence is generally comparable to that elsewhere in Newfoundland. The important differences include:

a) the basal Bradore Formation (Labrador Group) is only 6 to 12 m thick in contrast to the 130 m in Port au Port #1 well, on Port au Port Peninsula;

b) the parts of the Port au Port Group, equivalent of the March Point and Petit Jardin formations, remain undivided and are dominated by shaly fine-grained ribbon carbonate having edgewise conglomerate more typical of the Reluctant Head Formation elsewhere in western Newfoundland; lesser cyclic peritidal carbonates occur in the tops of shoaling-upward decimetre-scale sequences; trilobite faunas recovered from the undivided March Point and Petit Jardin formations indicate that the unit is predominantly Dresbachian;

c) a relatively thin dolostone sequence marks the top of the Petit Jardin Formation;

d) the overlying Berry Head Formation compares to the succession at Goose Arm consisting of a basal cherty, thrombolitic sucrosic dolostone, a middle dolostone unit and an upper unit of intercalated peritidal limestone and dolostone;

e) Lower and Middle Ordovician open-shelf limestones of the Catoche and Table Point formations, respectively, are generally much finer grained and have a more distal shelf aspect, including abundant uneven nodular and lumpy stylo-bedding than the same units of adjacent Port au Port Peninsula;

f) sucrosic dolostones rarely replace limestones in the St. George Group; some sucrosic dolostones replace parts of the Watts Bight Formation, especially a sequence of basal cherty thrombolitic mounds;

g) the Costa Bay Member, Catoche Formation is absent in the area; however, white peloidal limestones similar to those of the Costa Bay Member are thinly intercalated with thick dololaminites at the base of the Aguathuna Formation in this area; and

h) the basal Spring Inlet Member, Table Point Formation, consisting of peritidal limestones and dolostones, is thinly developed and capped by a crossbedded grainstone; fenestral limestones underlying these peritidal carbonates occur only locally suggesting some irregular relief on the St. George Unconformity.

Mineralization is rare in the area. A millimetre-scale vein of calcite cutting the Petit Jardin Formation at the north end of the anticline is host to galena and pyrite. Pyrobitumen was noted in several calcite veins cutting Table Point Formation carbonate rocks along the western edge of the anticline.

INTRODUCTION

The Phillips Brook anticline underlies a 300- to 500-m-high, dissected, plateau-like upland comprising complex-faulted lower Paleozoic shallow-water carbonate and siliciclastic rocks of the Labrador, Port au Port, St. George and Table Head groups. To the west, the upland overlooks the broad valley of Fox Island River and Romaines Brook that is underlain by shaly and flyschoid rocks of the Goose Tickle Group, and basal sedimentary slices of the Humber Arm Allochthon. In the north, the valley is bounded by sedimentary rocks of the Humber Arm Allochthon and the Lewis Hills ophiolite. The eastern limit of current mapping lies mainly along the boundary with Grenvillian basement overlain by siliciclastic Cambrian rocks of the Labrador Group (Williams, 1985; Williams and Cawood, 1989). Most of the mapping involved carbonate rocks of the Port au Port, St. George and Table Head groups and also included some shales and sandstones of the Labrador Group. The area has been mapped, at a reconnaissance-level, by Williams (1985) and Williams and Cawood (1989), and is also included in a more detailed but unpublished study by Palmer (1995).

Access to the area is good via the road to the community of Cold Brook. To date, the mapping has concentrated along much, but not all, of the network of woods-roads and skidder trails that indiscriminately cross the ridge (Figure 1). Much of the wooded area in the valleys and around the fringes of the upland and the marshy area that caps the eastern part of the plateau remains unmapped. Entrenched stream valleys, which cross the Phillips Brook anticline and should provide understanding of its deeper levels, have yet to be mapped. Consequently no cross sections are shown across the upland.

GEOLOGICAL SETTING

The Phillips Brook anticline is one of a number of northeast-trending structures that expose the Cambro-Ordovician shelf sequence at the southwestern end of the external domain of the Humber Tectonostratigraphic Zone, and which includes the North Brook and Table Mountain anticlines (Figure 2; *see* Williams, 1985; Williams and Cawood, 1989). The Phillips Brook anticline (Figure 3) is unconformably truncated at its southwestern end by Carboniferous sedimentary rocks that unconformably onlap over an elevation of at least 60 m. The anticline is probably one of the post to late Middle Devonian-pre-Visean, thick-skinned, basement-cored structures that include the Round Head Thrust on the Port au Port Peninsula (Stockmal *et al.*, 1998; Waldron *et al.*, 1998).

LITHOSTRATIGRAPHY

The lithostratigraphy of the Cambro-Ordovician shelf in the Phillips Brook anticline is illustrated in Figure 4. The succession is generally similar to the shelf sequence described throughout western Newfoundland, the succession includes rocks of four groups, which are, in ascending order, the Labrador, Port au Port, St. George and Table Head groups. Flyschoid rocks of the Goose Tickle Group overlie the shelf rocks and are in turn overlain structurally by shale-dominated, often broken formations of the Humber Arm Allochthon, including rocks very similar to those of the Green Point Formation of the Cow Head Group (James and Stevens, 1986). Continuous sections have as yet not been logged through the shelf succession, but short sections, coupled with detailed systematic lithological mapping and fossil collection combine to highlight the area's important characteristics.

CAMBRIAN LITHOSTRATIGRAPHY

Labrador Group

The Labrador Group, which rests unconformably upon Grenvillian basement, is a mixed siliciclastic and carbonate sequence that marks the base of the Cambrian shelf, and is known from elsewhere in western Newfoundland to range between late Early Cambrian to early Middle Cambrian (James *et al.*, 1989; Knight, 1991; Knight and Cawood, 1991). In the map area, it has been examined, so far, only in the upper tributary valleys of Romaines Brook; it consists of the Bradore, Forteau and Hawke Bay formations.

The Labrador Group rests unconformably upon Grenvillian basement rocks that show little evidence of paleo-weathering below the unconformity. The basement consists of salmon pink to green mega- and medium-crystalline granite, slightly foliated granite containing amphibolite bands, all cut by quartz-feldspar-mica pegmatites and white quartz veins. The basement is chloritized along fractures and joints.

Bradore Formation

The basal Bradore Formation consists of brown-red to purple conglomerate, pebbly and granular, very coarse-grained sandstone and conglomerate and well-sorted, pink arkosic sandstone and purple to dark-red quartz arenite. It ranges from 6 to 12 m in thickness over a distance of less than a kilometre where it has been mapped in the area. This thin expression of the formation is in marked contrast to the 130 m section encountered in the hanging-wall sequence of the Round Head Thrust in the Port au Port #1 well at the west end of Port au Port Peninsula (Newfoundland Hunt Oil Company Inc., 1996). The conglomerate and pebbly sandstone rocks of the Bradore Formation are commonly cross-bedded and comprise rounded to angular, small pebbles (between 1 and 2 cm diameter) of white, blue-grey and pur-

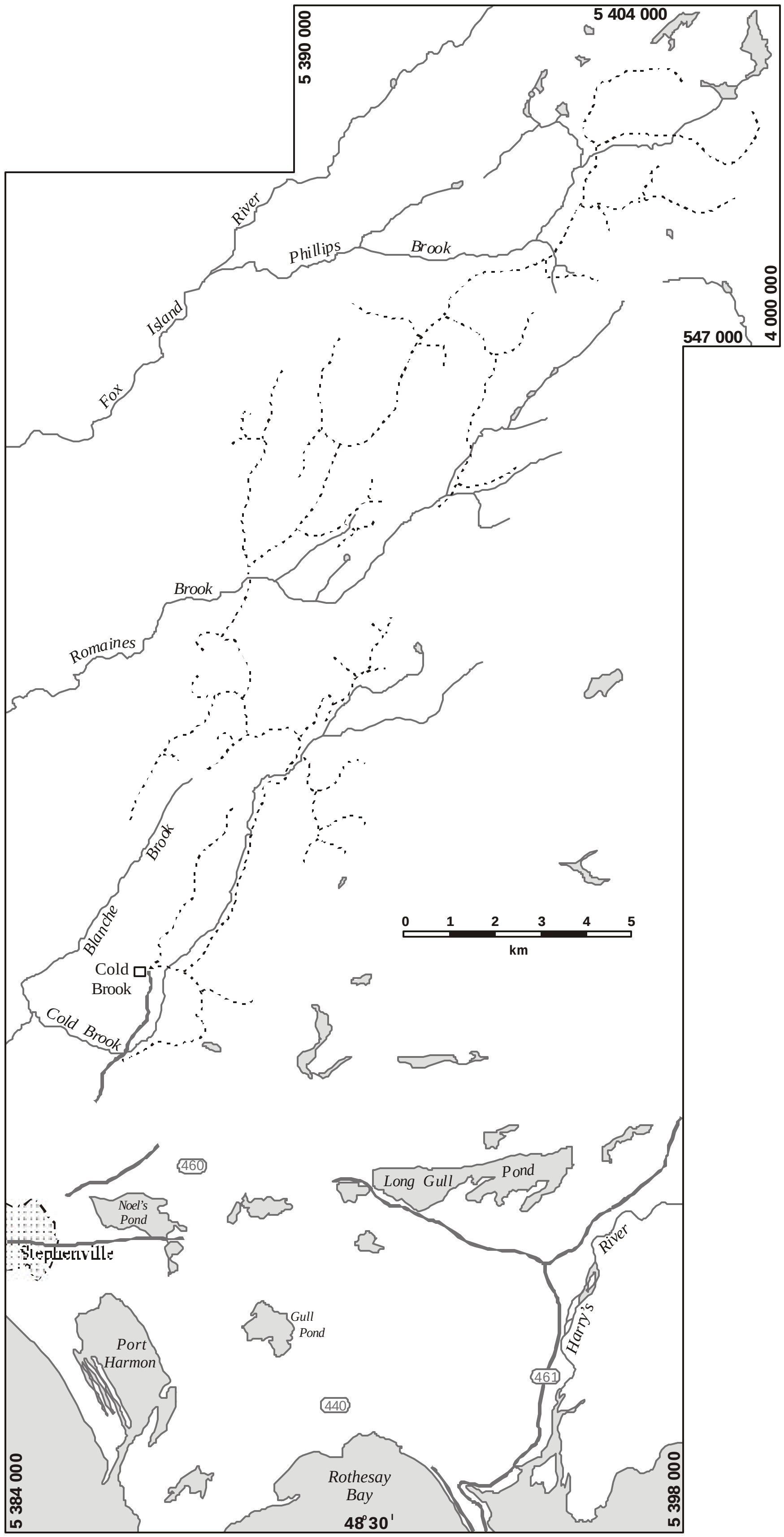

Figure 1. *Map showing the forest-access roads utilized during the mapping of the Phillips Brook anticline.*

ple vein and plutonic quartz mixed with granules of pink feldspar. The pebbly facies occupies the basal metre of the section and then occurs as 15 cm beds intercalated in an overlying well-bedded arkosic sandstone and quartz arenite that locally contains intraclasts of dark-red shale. The sandstone is generally fine grained and displays trough crossbeds, some of which may have planed-off tops, scoop-shaped scours ornamented by straight ripple marks and U-shaped and locally abundant *Skolithus* burrows. A few crossbeds indicate paleoflow between 260 and 340°.

The interlayered pebbly to well-sorted sand containing marine burrows and northwestward-directed paleocurrents suggest that the Bradore Formation was probably deposited along a shallow sandy shoreline. True, marine sand-dominated sedimentation is generally restricted to the upper 10 m of the formation elsewhere in southern Labrador and the Great Northern Peninsula (Hiscott *et al.*, 1984; Knight, 1991). The thinness of the formation in contrast to its equivalent below Port au Port Peninsula suggests that the basal Cambrian unconformity had significant relief over the 60 km separating the two locations, possibly reflecting fault-bounded rift basins separated by horst blocks.

Forteau Formation

The Forteau Formation consists of a thin, basal limestone, the Devils Cove Member, overlain by grey shales, nodular carbonate and siltstone.

The Devils Cove Member consists of 6.5 m of red and white, nodular and fossiliferous, argillaceous, fine-grained to crystalline carbonate that rests con-

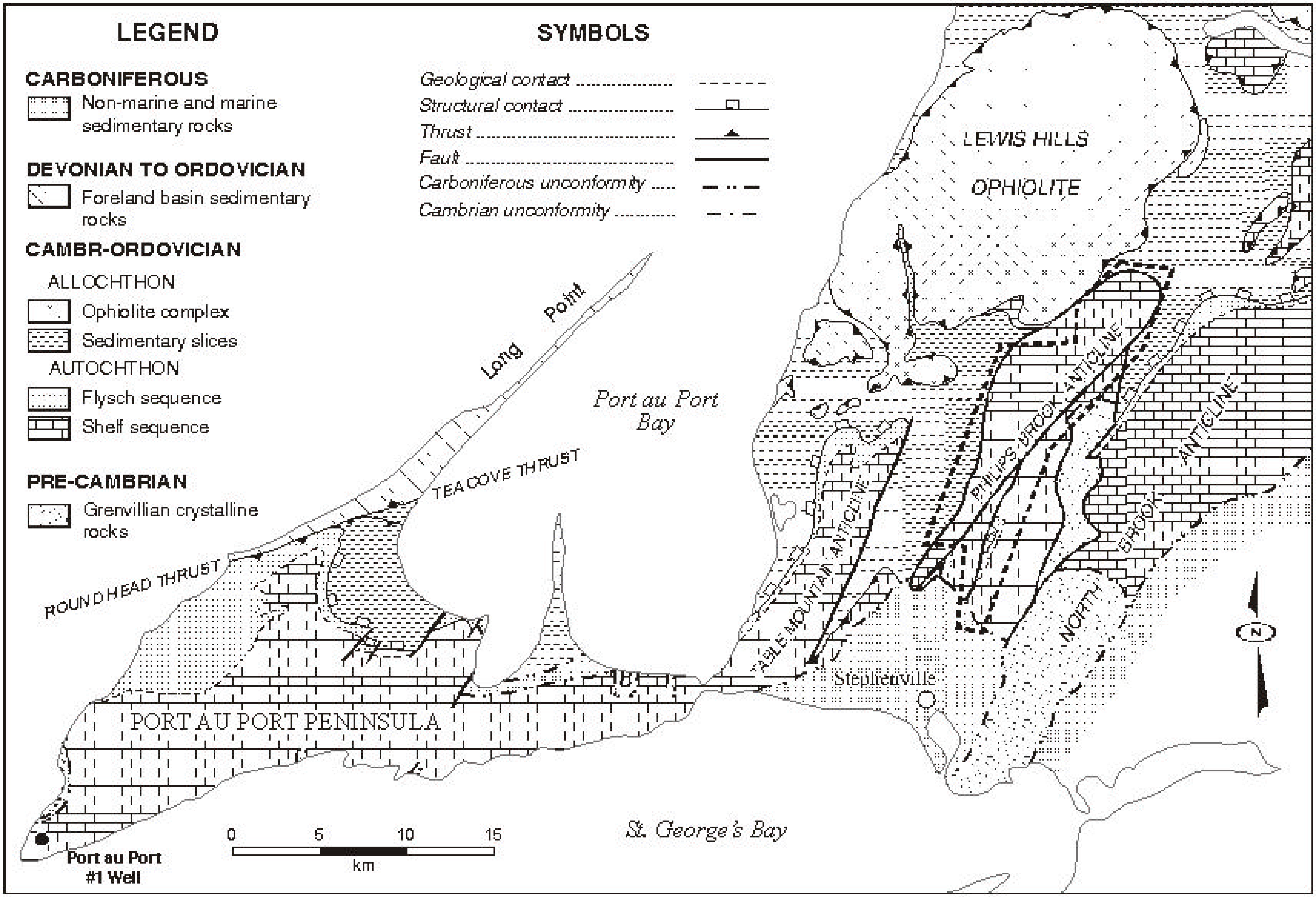

Figure 2. *Simplified regional geological map of the Port au Port and Stephenville areas showing the main geological terrains and outlining the map area of the Phillips Brook anticline (based on Williams and Cawood, 1989).*

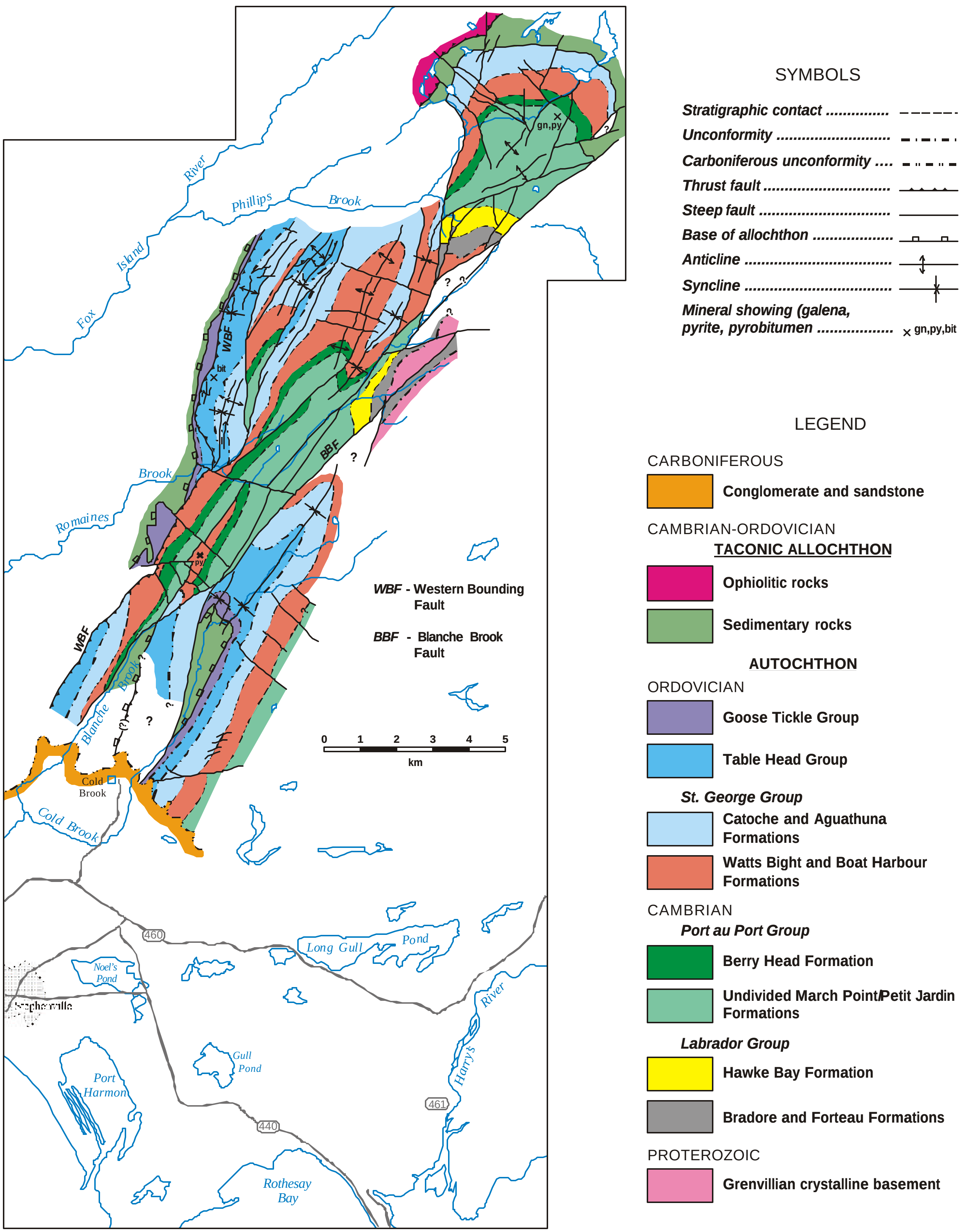

Figure 3. *Geological map of the Phillips Brook anticline.*

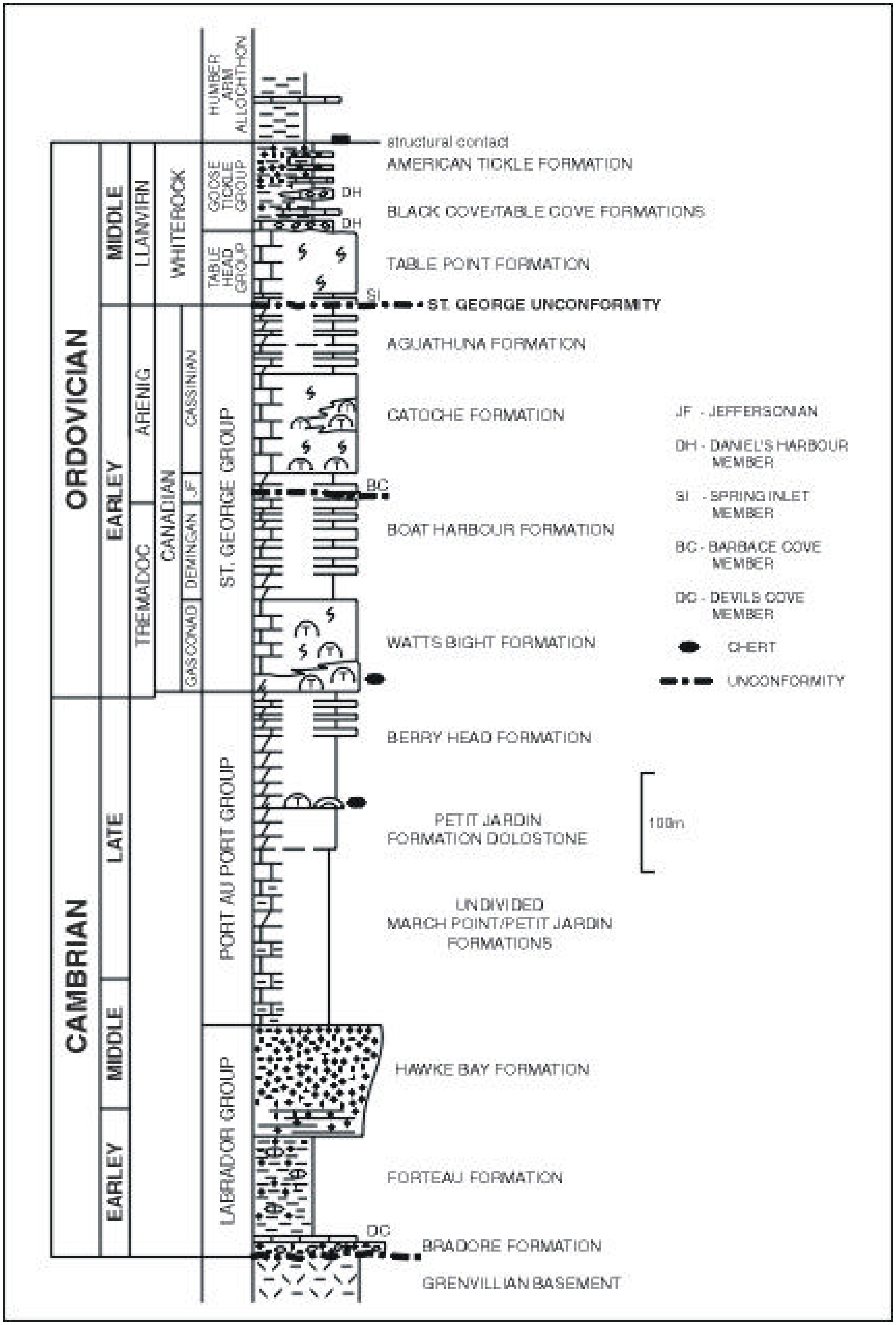

Figure 4. *Stratigraphy of the Cambro-Ordovician shelf rocks of the Phillips Brook anticline.*

formably upon the Bradore Formation. The limestone is locally rich in *Salterella* and trilobite debris. The latter, which includes *Wanneria ?logani* (Walcott, 1910), locally forms 2- to 5-cm coquina layers separated by shale partings.

The upper Forteau Formation is of unknown thickness. It generally weathers deeply and recessively to a purple and rusty colour. In the lower part of the unit, the succession is dominated by well-laminated grey shales and muddy siltstones that contain nodular carbonate and thin beds and lenses of laminated and crosslaminated siltstone, some having tubular burrows. The shales are fossiliferous and contain the trilobites *Wanneria ?logani* (Walcott, 1910)? and *Olenellus thompsoni* (Hall, 1859), inarticulate brachiopods and Salterella.

Upward the unit, which is exposed in the hills between upper Romaines Brook and Phillips Brook, appears to coarsen and comprises shales, 0.3 to 1.0 m thick, intercalated with rusty-weathered, 5 to 20 cm beds of extensively bioturbated, laminated and crosslaminated siltstone and stylonodular, fossiliferous, dark-grey limestone. Trilobites, hyolithids? and crinoids are common in both carbonates and shales. The shales have yielded the following fauna:

Agmata
- *Salterella* sp. Undet.

Arthropoda–Trilobita
- *?Antagmus* sp. undet.
- *Olenellus thompsoni* (Hall, 1859)
- *Wanneria ?logani* (Walcott, 1910)

Mollusca–Hyolithida
- Gen. et ap. undet.

Hawke Bay Formation

The Hawke Bay Formation, which is of unknown thickness in the area, includes a lower thin-bedded shale and siltstone–fine-grained sandstone member overlain by a cyclic member of bioturbated and fine-grained quartz arenite similar to that seen on Port au Port Peninsula (I. Knight and W.D. Boyce, unpublished data). The lower member is poorly exposed in the hills between upper Romaines Brook and Phillips Brook where it consists of shales interbedded with crosslaminated, very fine-grained sandstones containing shale partings. Shale clasts occur in some of the sandstone beds and beds are decorated by *Arenicolites, Diplocraterion, Planolites* and *Skolithus*. Rare beds of oncolitic limestone also occur.

Although the upper member is not well exposed, outcrops in cutovers and roadside ditches in the upper reaches of Romaines Brook valley suggest the member is similar to its counterpart on the Port au Port Peninsula. The vertical to inverted strata in this area comprises meter-scale, coarsening- and cleaning-upward sequences. Some sequences commence with up to 3 m of purple- and brown-weathering, grey shale intercalated with up to 40 cm intervals of very fine-grained sandstone and siltstone containing tubular burrows showing concentric layers (perhaps *Asterosoma* Form *Cylindrichnus*; cf. Frey and Howard, 1970). Thin-bedded, bioturbated and crosslaminated and laminated, very fine-grained, grey quartz arenite and shale also mark the bases of sequences. Beds, 10 cm thick, of poorly sorted, very coarse-grained quartz sandstone containing scattered glauconite grains also occur, as do phosphatic hyolithid cones and inarticulate brachiopods. The upper part of the sequences consists of several metres of crossbedded and stratified, fine- to very coarse-grained, white, red, pink and green-grey quartz arenites. Tops of sequences are sharp and planar and decorated by *Teichichnus*-like burrows. The general style of sedimentation in the upper part of the formation is very like the section exposed near Petit Jardin, Port au Port Peninsula (I. Knight and D. Boyce, unpublished data).

Port au Port Group

Carbonate rocks of the Port au Port Group are well exposed along various woods-roads in the centre and northern part of the study area. Even though the Phillips Brook anticline lies only 30 km east of the type section of the group on the Port au Port Peninsula, the succession in the anticline is not readily subdivided into the formations (March Point, Petit Jardin and Berry Head formations) and members (namely, Cape Ann, Campbells, Big Cove, Felix and Man O'War members of the Petit Jardin Formation) defined in the type area (Chow and James, 1987).

This is partly because of the lack of exposure in critical parts of the succession (e.g., rocks at the base of the group that may be later assigned to the March Point Formation have so far only been observed in one small outcrop in the upper waters of Romaines Brook). However, the significant difference appears to be lithological. Although much of the Port au Port Group succession in the map area is time equivalent of the Petit Jardin Formation, it is dominated by shaly fine-grained ribbon carbonate more typical of the Reluctant Head Formation (Knight and Boyce, 1991; Knight, 1994). Intercalated with the Reluctant Head lithofacies, however, are peritidal carbonates, typical of the Petit Jardin Formation. These peritidal lithofacies form the upper part of shoaling-upward decimetre-scale sequences that are dominated by the Reluctant Head lithofacies. This suggests that the area may mark a local transition from nearshore shelf such as the Port au Port Peninsula and more outer shelf ramp settings of the Reluctant Head facies. Nonetheless, for simplicity this unit is referred to on the geological map (Figure 2), as undivided March Point–Petit Jardin formations (to be used in future 1:50 000 maps) until further mapping clarifies the relationships.

In the study area, rocks of the Port au Port Group are divided into undivided March Point–Petit Jardin formations, upper Petit Jardin Formation dolostone and the Berry Head Formation.

March Point–Petit Jardin Formation

The undivided March Point–Petit Jardin formation is a unit of unknown thickness that consists of shale, laminated calcareous argillite containing quartz siltstones, red and green-grey silty mudstone, dolomitic, argillaceous and shaly ribbon and parted limestone, bedded and burrowed lime mudstone and wackestone, oolitic grainstone, intraclastic rudstones and floatstone, stromatolitic limestone and dolo-laminite and other dolostones. Unequivocal rocks of the March Point Formation have so far not been observed, although the lowest outcrop mapped along Romaines Brook likely belongs to the March Point Formation because it is located just above rocks of the Hawke Bay Formation and it consists of a dolomitic, possibly oolitic and skeletal, grainstone overlying thin-bedded, laminated and crosslaminated dolomitic limestone, which in turn overlies a bioturbated limestone.

The rest of the undivided unit is best seen in outcrops along skidder trails in the centre of the Phillips Brook anticline along a tributary valley of Romaines Brook and in the fault-bounded northern closure of the anticline east of Phillips Brook. The succession is dominated by the ribbon and parted limestones. These facies range from beds of essentially planar thin beds displaying lamination, to beds of stylonodular, thin bedding to beds of cleaner limestones containing shale and dolomite partings and isolated U-shaped burrows. In each case, the limestone is very fine grained although the cleaner limestones are generally microcrystalline. Inarticulate brachiopods, and less commonly trilobites, occur in the ribbon facies. The facies is commonly associated with shales but in some intervals, argillites and thin, laminated and locally crosslaminated siltstone beds and lenses that resemble rocks described in the Penguin Cove Formation at Goose Arm and west of Corner Brook (Knight and Boyce, 1991; Knight, 1997) are present.

A number of different lithofacies, generally as isolated beds, are intercalated with the ribbon-parted limestone facies. They include a number of rudstone types, grainstones, crosslaminated dolomitic limestones and boundstone. These rocks occur at the top of sequences (up to 10 m thick) of ribbon beds capped by grainstone, rudstone and/or boundstone that suggest repeated shoaling upward.

The crosslaminated, very fine-grained dolomitic limestones rarely exceed 20 cm in thickness and are present in some sequences and not others. The sheet-like beds have planar sharp bases overlain by crosslamination and locally undulose lamination that drapes over underlying ripple forms and scours. Convex-upward foresets (HCS?) associated with smooth ripple marks occur in some beds.

Intraformational edgewise to imbricated lime rudstone beds, which are 10 to 50 cm thick, are quite common and are interbedded at decametre- to metre-scale intervals within most of the ribbon and parted limestone units. The beds, which rest on sharp planar to scour bases, mostly lense out over several metres, and display a hummocky top. They consist mostly of locally derived, discoid ripup clasts, up to 15 cm in size, derived from the ribbon facies together with some clasts of crosslaminated limestone. The hummocky top is mostly the product of edgewise fans developed at spaced intervals within the beds.

A different rudstone type, ranging from grainy floatstone to graded rudstone to grainstone, occurs less commonly than the edgewise and imbricated rudstones and appears to be associated with ribbon beds that are intercalated with the crosslaminated limestone facies. Generally, the clasts include 2- to 5- cm, rounded pebbles of dolomitic oolitic grainstone as well as some platy fine-grained limestone clasts. The pebbles are set in a grainstone matrix that is commonly oolitic and intraclastic, and locally rich in trilobite debris. The beds, which are 10 to 30 cm thick, are either normally or inversely graded. Most beds are otherwise structureless, although the grainstones in the upper parts of some beds may be crossbedded.

Oolitic grainstone beds may occur at the top of the sequences. The beds, up to 30 cm thick, are coarse to fine grained, generally crossbedded, locally penetrated by vertical burrows, and frequently contain trilobite debris. The oolites display good concentric structure.

Rarely, a bed of boundstone caps an edgewise rudstone bed and marks the top of a shallowing-upward sequence. The boundstone mounds, which are up to 25 cm thick, are irregular in shape, and may drape over the irregularities of the underlying bed. Internally they show little structure suggesting that they may be thrombolites. However, in some sequences in the lower part of the formation near Phillips Brook, stromatolitic boundstones cap sequences. One such bed consists of long vertical columns up to 1 m in length consisting of cone-shaped, laminated stromatoid structures resembling *Conophyton*. The top of the mounds are enclosed by skeletal-rich oolitic grainstone. Trilobites, hyolithids and inarticulate brachiopods are found within these beds.

Metre-scale sequences, equally shared between the lower ribbon, stylonodular and parted limestone and argilllite-facies association and the upper grainstone- and boundstone-facies association, dominate major parts of the formation. In these sequences, the lower fine-grained association and the upper grainstone–boundstone association are each up to 2 m thick. The fine-grained association is similar to that described above although the argillites are locally cut by long, ptygmatically folded dolostone-filled fractures, many of which are linked to crosslaminated and HCS-laminated dolostone interbeds.

The upper association of the sequences is dominated by crossbedded, fine- to coarse-grained, oolitic grainstones. These host radial and concentric ooids, fossils, intraclasts of lime mudstone and grainstone, cracked lenses of dolostone and lime mudstone, and exhibit trough and herringbone crossbedding, as well as planar tabular units of crosslamination. Sharp planar truncation surfaces scour the grainstones and the paleoflow is polymodal. Intraclastic rudstone beds also occur. They display edgewise pebbles that are truncated by scours in some beds.

The stromatolitic boundstones are usually domal mounds comprising domal layers of LLH and SH structures as well as domal mats. Rare thrombolite mounds, some enclosing trilobites in the clotted microbial fabric and others with the microbialite *Renalcis* occur in some sequences. Intraclastic grainstones occur between, and above mounds, but in many sequences, the mounds are overlain by dolostones and dololaminites with lenses and thin beds of structureless, laminated and crosslaminated lime mudstone, and fine-grained lime grainstone. The dolostones range up to about a metre and exhibit mudcracks and tepee structures that are locally truncated by the basal scours of overlying grainstone interbeds. Some of the dolostone units are intercalated with red mudstone and mudcracked, brown-weathering, dolomitic argillite containing dolostone laminae and thin beds, and thin beds of grainstone and lime mudstone, the latter enclosing rolled dolostone mat intraclasts.

The undivided March Point–Petit Jardin formations has yielded two distinct Late Cambrian faunas. The lower fauna comprises:

Arthropoda–Trilobita
- *Arapahoia* sp(p). undet.
- *Blountia* sp. undet.
- Gen. et sp(p). undet.
- *Kingstonia* sp. undet.
- *?Lonchocephalus* sp. undet.
- *Talbotina / Welleraspis* sp. undet.

Brachiopoda–Inarticulata
- Gen. et sp. undet.
- *?Lingulella* sp. undet.

Trilobites of this fauna occur predominantly in intraclastic, skeletal lime packstone/grainstone and the brachiopods mostly in ribbon limestone/dolostone and shale. This fauna correlates with that of the Big Cove Member (Chow and James, 1987) of the Petit Jardin Formation on the Port au Port Peninsula, described and illustrated by Lochman (1938), Kindle and Whittington (1965) and Westrop (1992).

The higher fauna mostly has been recovered from intraclastic, oolitic lime grainstone. It includes:

Arthropoda–Trilobita
- *Crepicephalus rivus* Kindle, 1948
- *Terranovella* sp. undet.

This fauna correlates with that of the Felix Member (Chow and James, 1987) of the Petit Jardin Formation on the Port au Port Peninsula, most recently described and illustrated by Westrop (1992).

Both trilobite faunas indicate that the unit is predominantly Dresbachian in age. Diligent searching for trilobites in the upper part of the succession immediately below the overlying Petit Jardin dolostone unit has so far been fruitless.

The succession described cannot be directly correlated with the well described succession on the Port au Port Peninsula (*see* Chow and James, 1987; Cowan and James, 1993). No Grand Cycle stratigraphy is definable in the map area although an attempt to compile a bed by bed stratigraphy has begun but is still in its preliminary stages. However, the general impression of the succession is that it combines lithological characteristic of facies from the Port au Port Peninsula with those from the Upper Cambrian Reluctant Head Formation, seen in thrust sheets to the east (Knight and Boyce, 1991; Knight, 1994). The fine-grained ribbon-facies association is probably a deeper ramp subtidal limestone deposited below wave-base, but influenced by storms that ripped up the seabed and redeposited debris as rudstones. Sequences divided equally between the fine-grained ribbon-facies association and the grainstone, boundstone associations indicate that with shallowing of the shelf, high-energy, tidally dominated barrier complexes repeatedly prograded over the shelf muds. Sheltered in the lee of the barriers, fine-grained dolostones containing a significant fine-grained terrigenous component accumulated in tidal flats.

Upper Petit Jardin Formation Dolostone

The upper dolostone unit of the Petit Jardin Formation consists of an unknown thickness of buff- to yellow-weathering, micro- to finely crystalline, light grey and grey dolostones and shales. The base of the unit is marked by an interval of mudcracked and fossiliferous shale interbedded with well-bedded dolostone. Inarticulate brachiopods occur in the shale that also includes thin beds of black shale, and thin laminated dolostone beds. Shale is ripped up and incorporated in the well-bedded dolostones, which display bioturbation and stromatolitic mounds that host large nodules of dolomite spar and calcite, possibly after evaporites. The remaining part of the dolostone unit consists of thick beds of dolostone, many of which display large metre-diameter domal stromatolite mounds. The domal structure is picked out by stylolitic and argillaceous seams, similar to mounds common in the Cambrian dolostones of the Great Northern Peninsula (Knight, 1977). Other mounds are mottled and some display long columnar structures. Mounds are frequently encased by crossbedded dolarenite. The unit also includes interbedded burrow-mottled dolostone, dololaminites and some patterned dolomite.

Berry Head Formation

The Berry Head Formation compares to the succession at Goose Arm (Knight and Boyce, 1991) and includes a basal marker of cherty, thrombolitic and stromatolitic, dark-grey dolostone overlain by a thick middle succession of thick-bedded dolostones. The formation is completed by an upper unit of intercalated limestone and dolostone. The basal member is characterized by very thick beds of large, predominantly thrombolitic, mounds that are extensively replaced by chert; crossbedded dolarenite and crinkly laminated dololaminite are also present in the member. The middle dolostone member comprises dark-grey to grey, burrow-mottled dolostone and crossbedded dolarenite intercalated with light-grey to grey dololaminite, some patterned dolomite, intraclastic dolrudstone and stromatolitic dolostone. Tepee structures, mudcracks and *in situ* brecciation typify the dololaminites. Very coarse-grained, rounded quartz sand is scattered in some of the dolarenites.

The upper member of the Berry Head Formation consists of metre-scale peritidal parasequences of dark-grey, bioturbated dolomitic limestone (lime mudstone to wackestone) intercalated with, or overlain by, peloidal, intraclastic-skeletal and rarely oolitic grainstone, which in turn is overlain by grey stromatolitic limestone capped by dololaminite; the grainstones may display cross stratification. The stromatolite mounds are characterized by domal form, LLH and domal mats, and locally are fenestral. Chert is also common in the mounds. Although cross sections of trilobites and brachiopods are visible in grainstones, the only fossil recognized so far from the formation is a *Sinuopea*, which was recovered from the formation in the centre of the anticline (*see* Rohr *et al., this volume*).

ORDOVICIAN LITHOSTRATIGRAPHY

St. George Group

The Early Ordovician St. George Group in the Phillips Brook anticline is divided into four formations; the Watts Bight, Boat Harbour, Catoche and Aguathuna formations. The lithological character of the group is similar to elsewhere in western Newfoundland, with a few notable exceptions. Secondary dolomitization of the thrombolitic mounds and burrowed carbonates by sucrosic dolomites in the Watts Bight and Catoche formations is minor or absent. The Early Ordovician open-shelf limestones of the Catoche Formation are generally much finer grained and have a more distal shelf aspect including abundant uneven nodular and lumpy stylobedding than the same unit of the adjacent Port au Port Peninsula. The Costa Bay Member, characterized by its white peloidal limestone, is absent or not divisible from strata at the top of the Catoche Formation as it is on Port au Port Peninsula (*see* Boyce *et al., this volume*). Rather, the lithologically characteristic white peloidal grainstones are found interbedded with dololaminite beds and are assigned to the base of the Aguathuna Formation.

Watts Bight Formation

The Watts Bight Formation consists of a succession of dark blue-grey to black, dolomitic and cherty, dolomitic limestone characterized by thick beds of thrombolite mounds and bioturbated carbonate. Also found, are stromatolitic limestone and dololaminite beds containing chert nodules; selective silica replacement of sedimentary fabrics is common throughout the unit. Some thrombolite mounds were extensively eroded before they were draped by dololaminite. Gastropods, straight, coiled, hook-shaped and cytoconic cephalopods and large sponges occur in the mound beds. Tan-grey sucrosic dolostone replaces some beds of the Watts Bight limestone including the lower 5 m of the formation.

Boat Harbour Formation

The Boat Harbour Formation consists of a lower interval of thick-bedded, burrow-mottled to massive, finely crystalline, grey dolostone and dololaminite containing local chert and dolostone matrix breccia. The breccia contains clasts of disoriented dolostone up to 10 cm in diameter. The main part of the formation is made up of metre-scale, shallowing-upward, peritidal sequences of limestone and dolostone. Rock types range from massive to thinly wavy bedded, bioturbated lime wackestones and packstones through thrombolitic and stromatolitic boundstone, intraclastic and skeletal grainstone and mud- and fissure-cracked, laminated dolomitic limestone and dololaminite. At least one of the mudcracked units forms a metre-thick marker in the northern part of the anticline.

A conglomerate bed, at least 1.5 m thick, which rests upon an irregular karst scour occurs locally near the very top of the formation in the west-central area of the anticline.

This unit probably marks the generally cryptic disconformity beneath the upper Barbace Cove Member seen at Isthmus Bay, Port au Port Peninsula and the Great Northern Peninsula (Knight, 1991; Knight and James, 1987, 1988; Boyce, 1989) The scour has relief of at least 25 to 50 cm with narrow, conglomerate-filled angular fractures penetrating 4 m below the surface into the underlying burrowed dolomitic limestone and interbedded dolostone. The conglomerate consists of small, 0.5 to 3 cm pebbles of dolostone, chert and white megaquartz and scattered, 10-cm-angular fragments of burrowed dolomitic limestone set in a dolostone matrix.

A mixed fauna of trilobites, gastropods, cephalopods and brachiopods occur in the limestones including some brachiopod coquina lenses in grainstone beds. The trilobite faunas confirm the presence of rocks of the upper Barbace Cove Member although its thickness is unknown and it is generally difficult to subdivide from the rest of the formation based on the outcrop so far mapped. The lower part of the Boat Harbour Formation has yielded:

Arthropoda–Trilobita
- Gen. nov. A sp. nov. A of Boyce (1989, page 45; Plate 20, figures 6-9)
- *Hystricurus oculilunatus* Ross, 1951
- *Hystricurus* sp. undet.
- *Randaynia saundersi* Boyce, 1989

Brachiopoda–Articulata
- clarkellid gen. et sp. undet
- *Diaphelasma* sp. undet.
- Gen. et sp. undet.

Brachiopoda–Inarticulata
- *Lingulella* sp. undet.

Mollusca–Cephalopoda
- *Bassleroceras* sp. undet.
- Gen. et sp. undet. – curved? form

Mollusca–Gastropoda
- *Ecculiomphalus* sp(p). undet.
- Gen. et sp. undet.
- *Lecanospira ?nerine* (Billings, 1865)
- *Lecanospira* sp(p). undet.

The fauna is indicative of the Middle Canadian (Demingian) *Hystricurus oculilunatus* to *Randaynia saundersi* zones of Boyce and Stouge (1997).

The Barbace Cove Member of the Boat Harbour Formation has yielded:

Arthropoda–Trilobita
- *Jeffersonia angustimarginata* Boyce, 1989

This species is indicative of the early Late Canadian (Jeffersonian) *Strigigenalis brevicaudata* Zone or the Late Canadian (Cassinnian) *Strigigenalis caudata* Zone (Boyce, 1989; Boyce and Stouge, 1997).

Catoche Formation

The Catoche Formation is a succession of dark-grey, dolomitic limestones that are characterized predominantly by thick to medium beds of bioturbated and stylonodular lime mudstone to wackestone. Intraclastic skeletal grainstone and rudstone is common as thin beds and lenses in the lower part of the formation. Thin beds of very fine-grained grainstone and laminated lime mudstone occur in the upper part of the formation. At the top of the formation, in the centre of the anticline, the succession consists of metre-thick parasequences of dark-grey, stylonodular fossiliferous dolomitic lime wackestone overlain by bioturbated limestone that hosts scattered small (1 cm) micritic oncolites and fossil debris that compares in style, but not colour, to the sequences in the Costa Bay Member at the west end of Port au Port Peninsula (*see* Boyce *et al.*, *this volume*).

The monotony of these stylonodular and bioturbated limestones is broken by a few beds of thrombolitic lime boundstone above the base of the formation. However, large, metre-scale thrombolitic boundstone mounds, rich in large sponges, gastropods and cephalopods and associated with crossbedded grainstones, form a member, a few ten's of metres thick in the middle part of the formation. In sections at the north end of the anticline, the mounds appear to form a continuous sequence. However, in the more westerly parts of the anticline the mound unit is divided by a middle interval of bioturbated limestone.

The lower part of the Catoche Formation including the mound beds has yielded:

Arthropoda–Trilobita
- *Bolbocephalus kindlei* Boyce, 1989
- Gen. et spp. undet.
- *Illaenus* sp. nov. of Boyce (1989, pages 33-34)
- *Ischyrotoma* sp. undet.
- *Jeffersonia angustimarginata* Boyce, 1989
- *Jeffersonia* sp. undet.
- *Petigurus nero* (Billings, 1865)
- *Uromystrum marginiatus* (Billings, 1865)
- *Uromystrum* sp. undet.

Mollusca–Cephalopoda
- *Cassinoceras?* sp. undet.
- *Cassinoceras wortheni* (Billings, 1865)
- *Eurystomites* sp. undet.
- Gen. et sp. undet. – straight form
- *Orthoceras explorator* Billings, 1865
- *Protocycloceras lamarcki* (Billings, 1859)

Mollusca–Gastropoda
- Billings' second operculum – see Yochelson (1990)
- *Maclurites affinis* (Billings, 1865)

Maclurites sp. undet.
Macluritid gen. et sp(p). undet. – cross-sections
Mollusca–Rostroconchia
Euchasma blumenbachii (Billings, 1859)

The above species suggest that the late Canadian (Cassinian) *Strigigenalis caudata* to *Benthamaspis gibberula* zones of Boyce and Stouge (1997) are represented.

The uppermost beds of the Catoche Formation at a quarry in the middle of the anticline has yielded:
Arthropoda–Ostracoda
Gen. et sp. undet.
Arthropoda–Trilobita
Gen. et sp. undet.
Brachiopoda–Articulata
Gen. et sp. undet.
?Pomatotrema sp. undet.
Echinodermata–Crinoidea
Gen. et sp(p). undet.
Porifera?
Gen. et sp. undet.
Mollusca–Gastropoda
Gen. et sp. undet.
This fauna likely correlates with that of the Costa Bay Member exposed along Route 463 on the Port au Port Peninsula (*see* Boyce *et al., this volume*).

Aguathuna Formation

The Aguathuna Formation is a succession of dololaminite and burrow-mottled dolostone intercalated with a variety of limestone. The latter include clean, light-grey, stromatolitic limestone that is dominated by LLH and SH structures but also includes fenestral, peloidal and lime mudstone mats, and locally mottled thrombolitic fabric. Other limestones range from off-white to light-grey stylolitic limestones to peloidal and oolitic grainstone–packstone to bioturbated packstone–wackestone to thin-bedded and laminated lime mudstone. Some beds of dark-grey, bioturbated, dolomitic limestone also occur. Chert is locally common and some beds contain nodules of white megaquartz. The limestones host a fauna dominated by the gastropods, silicified opercula and cephalopoda (*see* Rohr *et al., this volume*) including:
Mollusca–Cephalopoda
Gen. et sp(p). undet. – straight form
Mollusca–Gastropoda
Euchasma blumenbachii (Billings, 1958)
Ceratopea sp(p). undet.
Gen. et sp(p). undet. – high spired forms
macluritid gen. et sp(p). undet. – large (not collected)
Echinodermata–Crinoidea
Gen. et sp(p). undet. – abundant columnals

The formation is at least 100 m thick in one section measured in the northwest of the anticline.

Table Head Group

The Table Head Group consists of the Table Point and Table Cove formations and rests paraconformably upon the St. George Unconformity, which marks the top of the Aguathuna Formation. The surface of the unconformity is exposed in only one outcrop and shows no local discordance across the contact, which is apparently a planar surface.

Table Point Formation

The Table Point Formation includes a basal member, the Spring Inlet Member (Stenzel *et al.,* 1990; Ross and James, 1987). The member consists of dark-grey, burrowed and stylonodular, dolomitic lime mudstone and wackestone interbedded with laminated and mudcracked dolomitic limestone plus minor fenestral limestone and some dolostone. The member is only 9.3 m thick and is capped by a grainstone, 8.1 m thick. The nearshore trilobite *Bathyurus perplexus* occurs in the member, which also hosts the ostracod *Bivia bivia* (White, 1877) and an undetermined articulate brachiopod. The fauna is indicative of the *Bathyurus perplexus* Zone of Boyce (1997).

The grainstones range from very fine to very coarse grained in texture and consist of intraclastic, peloidal, skeletal, coated and possibly oolitic grains and include layers of small intraclastic pebbles of grainstone, lime mudstone, possible cryptalgal mat and dolostone. Brachiopod coquinas cap one bed of intraclastic floatstone to rudstone. The grainstones display herringbone crossbedding and trough crossbeds associated with festoon and planar–tabular crosslamination. Reactivation surfaces occur in some units and sharp planar truncation surfaces separate some units of crossbedding. Thin beds and lenses of dolomitic limestone in the grainstones are burrowed by *Chondrites*. Large, high-spired gastropods, *Murchisonia*, occur in the grainstones that also locally contain brachiopods, trilobites, sponges, planispiral gastropods and straight cephalopods. The only measured paleocurrent indicated some paleoflow to the south and southwest (192 and 252°).

Thick, light-grey, clean and massive, grainy to fine-grained, mollusc-rich, fenestral limestones, which are also typical of the Spring Inlet Member (Stenzel *et al.,* 1990; Knight, 1991; Stenzel, 1992), were noted only in one section in the faulted west limb of the anticline where they are locally interbedded with dolostone. The fenestral carbonates are 26 m thick and appear to underlie the cyclic limestone and dolostone previously described. Silicified opercula, straight cephalopods and the gastropod *Holopea* occur locally in the limestone.

The Middle Ordovician limestones of the Table Point Formation, like those of the Early Ordovician Catoche Formation, are generally fine grained, comprising predominantly lime mudstone and wackestone. The grey to dark-grey, fine-grained limestones range from clean limestone to limestones with argillaceous partings to dolomitic limestones. They occur in medium beds of bioturbation, uneven thin stratification and nodular and lumpy stylobedding. The mudstone–wackestone nodules and lumps, which may range in shape from rounded, to discoid to eye-shaped to jigsaw pieces, are mostly enclosed in yellow-weathering dolostone that, in many instances, gives the rock a pseudoconglomeratic look. Small slump folds occur locally. Many of the rounded lumps and nodules have a central dolomite-filled depression or tube that suggests they are sponges.

True, poorly sorted, intraformational breccia beds of the same rock types also occur in the succession. Angular and irregular, often platy clasts decorated by burrows, and clasts with shapes indicative of a nodular sediment protolith suggest both early partial lithification of the sea-floor muds as well as early shallow sea-floor diagenesis before shelf instability and/or less likely storms (mitigated against by angularity and poor sorting) reworked the shelf bottom.

Lenses and beds up to 10 cm thick of scour-based, intraclastic-skeletal rudstone and grainstone and gastropod packstone occur locally and may be crosslaminated with paleoflow to the east and south (120 and 175°). Thin beds of laminated lime mudstone, comparable with those of the Table Cove Formation (*see* Stenzel *et al.,* 1990; Knight, 1997), also occur, and locally form beds up to 60 cm thick of ribbon limestone with shaly partings. In one, metre-thick interval these thin-bedded limestones are intercalated with laminated, argillaceous dolostone and massive and bioturbated, dull-grey dolostone that is locally fossiliferous. Metre-thick units of crossbedded, intraclastic and peloidal grainstone occur in the lower part of the formation in the centre of the anticline.

Many nodular and lumpy beds are extremely fossiliferous and contain trilobites, which may be large and often partly articulated, several brachiopods, some of which are strongly ribbed and often articulated, gastropods, straight cephalopods, crinoids, ostracods, small sponges and rare bryozoa. The fauna includes:

Arthropoda–Ostracoda
- *Bivia bivia* (White, 1877)
- Gen. et spp. undet.

Arthropoda–Trilobita
- *Illaenus* sp. undet.
- *Ischyrophyma* sp. undet.
- *Pseudomera barrandei* (Billings, 1865)
- *?Stegnopsis* sp. undet.

Brachiopoda–Articulata
- *Aporthophyla aurora* (Billings, 1865)
- *?Aporthophyla* sp. undet.
- Gen. et spp. undet.

Echinodermata–Crinoidea
- Gen. et sp(p). undet. – fairly common stems

Mollusca–Gastropoda
- *Maclurites* sp(p). undet.

Porifera
- Gen. et sp. undet.

The fauna is indicative of the *Pseudomera barrandei* Zone of Boyce (1997).

Table Cove Formation

The Table Cove Formation is mapped only in the footwall sequence to the western bounding fault of the anticline near Romaines Brook. The formation, which is of unknown thickness, ranges from dark-grey shales having dolomitic siltstone laminae and some thin planar beds of lime mudstone to regularly intercalated shale and planar-thin-bedded lime mudstone. Graptolites, trilobites, ostracods and inarticulate brachiopods occur in the formation and include the following fauna:

Arthropoda–Ostracoda
- Gen. et sp(p). undet.

Arthropoda–Trilobita
- *Ampyxoides semicostatus* (Billings, 1865)
- *Cybelurus mirus* (Billings, 1865)
- Gen. et sp(p). undet.
- *Lonchodomas normalis* (Billings, 1865)
- *Nileus* sp(p). undet.
- Peraspis sp(p). undet.
- *Telephina americana* (Billings, 1865)
- *Triarthrus fischeri* (Billings, 1865)

Brachiopoda–Articulata
- *?Aporthophyla* sp. undet.

Brachiopoda–Inarticulata
- Gen. et sp(p). undet.
- *Lingula* sp. undet.

Echinodermata–Crinoidea
- Gen. et sp(p). undet.

The fauna correlates with the *Cybelurus mirus* Zone of Boyce (1997).

Goose Tickle Group

The Goose Tickle Group in the map area consists of dark-grey, silty shales of the Black Cove Formation, interbedded shale and sandstone of the American Tickle Formation and carbonate conglomerate and breccia of the Daniel's Harbour Member. The Black Cove Formation is noted in a quarry along Blanche Brook valley in the south-centre of the anticline and in quarry sections in the footwall to the western-bounding fault. The dark-grey to black silty shale is well laminated and is 6 to 10 m thick. Graptolites, the inarticulate brachiopod *?Lingula* sp. undet. and small pyrite nodules occur locally.

The American Tickle Formation is dominated by a succession of flysch, at least 185 m thick, and characterized by dark-grey to green-grey shales interbedded at intervals of up to 3 m with lenses and beds of green-grey, very fine- to fine-grained and uncommonly coarse-grained sandstones, a few centimetres to 40 cm thick. The sandstones, which are micaceous and normally graded, are generally characterized by sharp planar bases overlain by lamination and/or crosslamination. Pyrite laminae and calcareous nodules occur in some beds. The unit is rich in graptolites (at least 4 taxa) and inarticulate brachiopods.

The succession is not uniform but consists of decimetre-thick intervals of widely spaced sandstones in the shales to intervals made up of 90 percent shale and only very thin sandstone beds to intervals with thick sandstones equally interspersed with shale to intervals dominated by laminated siltstone reminiscent of a slightly coarser subfacies of the Black Cove silty shale. The formation becomes broken in the upper 20 m below broken strata of the structurally overlying allochthonous Green Point Formation.

The limestone conglomerate of the Daniel's Harbour Member consist of clasts of Table Point and, locally, Table Cove limestone, set in a calcareous and muddy fine-grained matrix. The member takes two forms. The first is a discrete, massive bed, up to 7 m thick, which is sandwiched between the Black Cove shale and the base of the American Tickle flysch. The first conglomerate consists of unsorted clasts, 1 to 5 cm and rarely 5 by 10 cm in size. The top of the bed is rusty-weathering, locally irregular, and is cut by narrow to wide fractures that are infilled by the overlying shales. The second conglomerate is also a poorly sorted deposit of variable thickness that appears to rest either gradationally or irregularly upon the top of the underlying Table Point limestone. Clasts of limestone 1 to 20 cm in size are set in a yellow-weathering dolomitic matrix.

The carbonates of the Table Point Formation and siliclastic and carbonate flysch of the Goose Tickle Group in the map area are part of a Middle Ordovician cycle of foreland basin fill that began with a carbonate shelf. The succession in the Table Point Formation follows the general regional pattern in western Newfoundland of drowning of an early, shallow peritidal shelf and the establishment of an open-shelf setting (Stenzel *et al.,* 1990; Stenzel, 1992). The local presence of a relatively thick interval of fenestral limestone below a thinner and more widespread section of peritidal cyclic carbonates in the Spring Inlet Member suggests that there was probably local relief on the underlying St. George Unconformity controlling facies distribution. This phase of nearshore deposition was probably bounded seaward by a complex of high-energy, tidally influenced carbonate sand shoals or barrier sands. However, the shoreline facies were rapidly drowned and the rest of the Table Point limestones were dominated by fine-grained, stylonodular to ribbon-bedded and locally brecciated carbonates having a diverse, normal marine shelly fauna. The facies and faunas of the upper Table Point Formation suggest a more distal open-shelf and possibly deeper water to shelf edge setting in this area. Seismic instability is suggested by the presence of the limestone breccia beds and locally slump folds.

The local presence of the Table Cove ribbon limestones and shales in the west indicate the presence of a shelf to deep-water slope setting, locally. The development of the limestone breccias and conglomerates (disconformably to gradationally) upon the Table Point limestones, and locally intercalated with the Black Cove shale and overlain by American Tickle shaly flysch, suggests this area of the foreland basin was also marked by active, fault-controlled uplift and subsidence with structural highs uplifting the Table Point limestone that was locally eroded and redeposited into the adjacent subbasin.

SEDIMENTARY ROCKS OF THE HUMBER ARM ALLOCHTHON

Sedimentary rocks of the Humber Arm Allochthon structurally overlie rocks of the Goose Tickle Group. They have been observed to date in the footwall succession of the western-bounding fault of the anticline and in a syncline in the valley of Cold Brook. The rocks are dominated by intact to broken formation of green and black shales with thin beds of siltstone, calcareous siltstone and grey limestone and nodular pyrite; the formation resembles the Green Point Formation of the Cow Head Group (James and Stevens, 1986). Some inarticulate brachiopods were recovered in the footwall succession to the western-bounding fault. Close to the base of the unit in Cold Brook valley, the unit is made up of dark-grey shales with broken laminated siltstone beds, some coarse-grained green-grey sandstone, and scattered pyrite nodules. A scaley polished, early cleavage augens the broken beds. A olistolith of vesicular pillowed basalt and breccia occurs in the unit 4 km north of Romaines Brook.

CARBONIFEROUS SEDIMENTARY ROCKS

Carboniferous strata outcrops along the forest-access road and stream beds in the south of the area. The strata unconformably overlies the folded Lower Paleozoic rocks of the Phillips Brook anticline. Based on limited mapping supported by air photo interpretation, the unconformity appears to be an irregular, but steep southward-facing paleo-hillside with many small indenting valleys. Two lithofacies occur in the Carboniferous sequence, a basal limestone–pebble conglomerate and a red-brown pebbly sandstone and small pebble conglomerate. The stratigraphic relationship between these two facies is obscured by Pleistocene glacial outwash gravels.

Limestone–Pebble Conglomerate Lithofacies

These coarse pebbly rocks form a marginal facies that was deposited upon the paleo-hillside that eroded the lower Paleozoic strata of the southern end of the Phillips Brook anticline. Many thin drapes and outlying pockets of the facies occur in several outcrops along the main forest-access road and its branches as the road climbs up onto the uplands just east of Cold Brook. Although generally lacking bedding, at least one outcrop at 165 m elevation and lying less than 50 m from the underlying lower Paleozoic basement has crude bedding that strikes 130° and dips southwest at 26 to 30°. The best outcrop of the facies, however, occurs at lower elevations of 120 m along the stream bed of Cold Brook just east of the community of the same name. Here strata striking 170° and dipping 12° to the west forms a sequence tens of metres thick.

The facies is characteristically grey consisting of loosely framed, angular pebbles of locally derived Ordovician limestone and dolostone supported in a reddish-grey matrix of silt- and sand-sized carbonate grains and calcareous mud or reddened quartz sand in a red calcareous mudstone matrix. Pebbles generally range up to 10 to 15 cm in size but some poorly sorted beds in Cold Brook contain boulders up to 30 cm in size. The conglomerates are crudely bedded and amalgamated with some south-dipping imbrication of pebbles.

Locally, the conglomerates contain lenses of red siltstone and zones of caliche. The latter occur at the top of the siltstones but also forms deposits 15 to 20 cm thick and up to 20 m long in the conglomerate. They range from massive caliche to deposits that cement select beds of small-pebble conglomerate. Also common in conglomerates are zones dominated by small caliche clots and abundant hairline caliche veins cut by sparry calcite veins, the latter also penetrating into the matrix of underlying caliche-free conglomerate. Rhizoconcretions that display a concentric structure in cross section and form cylindrical rhizoliths up to 15 cm long occur at the top of one conglomerate layer. The rhizoliths resemble similar structures described just above the basal Carboniferous unconformity along the southern edge of "Pye's Ridge" north of Deer Lake (Knight, 1992) and discovered in a limestone–pebble conglomerate that fills a Carboniferous paleo-valley high on the slopes of the west end of the Port au Port Peninsula (I. Knight, unpublished data).

Red Pebbly Sandstone and Small Pebble Conglomerate Lithofacies

This facies is exposed in the floor of a gravel pit 1.9 km along the forest-access road near Cold Brook, where the beds strike 082° and dip south at 10°. The facies consists of friable dark red-brown sandstone, pebbly sandstones and small-pebble conglomerate. The sandstone and pebbly sandstone are generally poorly sorted, very coarse- to fine-grained, terrigenous clastics consisting of angular grains of quartz, feldspar and muscovite mica. The sandstones display crude stratification and crossbedding with paleocurrents to the southwest. The interbedded small-pebble conglomerate forms discrete layers and lenses and consists of an open framework of pebbles 1 to 8 cm in size set in a friable matrix of fine- to very-coarse-grained sandstone. Lenses of cross-bedded, medium-grained sandstone occur in the conglomerate. The pebbles in the conglomerate include white quartz, granite gneiss, quartz-mica gneiss and schist, green chloritic schist, green-grey phyllite, fine- to coarse-grained pink and grey granite, amphibolite (some cut by K-feldspar veins), coarse-grained grey anorthosite and green sandstone. Most pebbles are equant and moderately rounded but schist and phyllite pebbles are discoid to rod-shaped. Several pebbles in the conglomerates weather to soft textured, yellow-coloured limonite. Of particular interest is the complete lack of carbonate pebbles in the conglomerate even though the outcrop is less than 500 m from the south end of the outcrop of lower Paleozoic carbonate strata.

The Carboniferous strata exposed at the southern end of the Phillips Brook anticline appears to consist of a locally derived limestone–pebble conglomerate and a contrasting red-brown sandstone/conglomerate that was derived from a distant source area of crystalline Precambrian basement. The crudely stratified, poorly sorted, basal conglomerates with locally imbricated, angular clasts set in a fine-grained matrix suggest amalgamated debris-flow deposits deposited at the inner part of an alluvial fan. Lenses of siltstone probably indicate episodes of ephemeral stream flow between mass gravity deposition. Caliche horizons in the basal grey conglomerates also support episodic debris flows and suggest that the climate was probably semi-arid. Locally, steep dips adjacent to the basement hillside may reflect scree or mass-wastage deposition locally.

In contrast, the red-brown sandstones and conglomerates away from the margins of the Carboniferous basin are marked by crystalline basement detritus, discrete layers and lenses of small-pebble conglomerate and crossbedded but poorly sorted sandstones. These characteristics support fluvial deposition by probably braided streams possibly along the axis of the local basin or on the outer part of an alluvial fan. The lack of limestone detritus in these fluvial deposits suggests that the facies is possibly unconnected in time and space to the marginal conglomerate facies.

The Carboniferous rocks that truncate the Phillips Brook anticline are so far not dated. However, the presence of caliche may indicate that the basal conglomerates are correlative of deposits in the upper part of the Robinsons River Formation of the Codroy Group in the St. Georges Bay lowlands (Knight, 1983). There, caliche deposits are only well developed in the fluvial rocks of the Highlands and Mollichignick members of the Robinsons River Formation, i.e., post Windsor subzone C in age. Red-brown friable pebbly sandstones and conglomerates locally occur in the same part of the Codroy Group in the Flat Bay to St. Teresa area of the Carboniferous basin, again suggesting a mid to late Visean age for these deposits.

STRUCTURE

The Phillips Brook anticline is a complexly block-faulted terrain, which trends to the northeast, and plunges north of the Blanche Brook Fault and southwest to the south of the fault. The anticline predates the deposition of late Mississippian conglomerates and sandstones that unconformably truncate the southern end of the structure.

A steep east-dipping fault, the western-bounding fault, marks the western edge of the anticline. It emplaces Ordovician shelf carbonates above footwall rocks that include Middle Ordovician shelf carbonates, overlying flysch and transported deepwater sedimentary rocks of the Taconian allochthon. Rocks in the hanging wall of the steep thrust locally become overturned. The vertical displacement across this fault is probably no more than a few hundred metres. The throw, however, is at its maximum just south of the Romaines Brook fault where the Watts Bight Formation is emplaced above the flysch suggesting at least 500 m of vertical throw. Traced to the south, however, younger units of the St. George Group and the overlying Table Point Formation progressively cut out against the western-bounding fault. To the north of Romaines Brook, however, the Table Point Formation limestone in the hanging wall of the thrust overrides the footwall that comprises Table Point limestones, Goose Tickle flysch and allochthonous Humber Arm Group sedimentary rocks successively from south to north.

The main axis of the anticline occurs in the centre of the area mapped, north of Romaines Brook. South of the brook, the strata is for the most part a west-dipping homocline broken repeatedly by faults and locally folded by a late syncline south of the Blanche Brook fault.

At least one bedding-parallel fault, which maybe an early thrust, is deformed by folds associated with the fault. The best example occurs at the northwest end of the west limb of the anticline where a thrust separates fossiliferous carbonates of the middle part of the Table Point Formation. No major, early thrusts have so far been convincingly demonstrated, however. It is nonetheless possible that some of the faults that essentially strike parallel to the bedding in the west, north of Romaines Brook may be shown in future mapping to trace around the northern closure of the structure north of Phillips Brook to meet similar trending faults on the east limb of the anticline to indicate an early thrust phase.

The anticline is transected by long curvilinear and branching, northeast- to north-trending, steeply dipping faults, in particular the Blanche Brook fault. A steep cleavage penetrates the finer grained and shalier Cambrian shelf rocks in the core of the structure and also the shaly footwall rocks of the western edge. The anticline is marked by open upright folds. Zones of steep overturned bedding occur close to the major faults. Basement and cover are uplifted against the younger carbonate sequence in the east of the structure but the relationships in this area are as yet not mapped in detail to realistically interpret this area.

Exposed faults vary from sharp, planar surfaces having local breccias and a normal sense of displacement to metre-wide shear zones associated with brecciation, shear surfaces, augen structures, and rotation and extensional boudinage of broken beds. Both shears through the faults and exposed fault planes locally indicate that the faults generally strike between 025 and 042° and dip between 45 and 80° southeast. Both the normal and the shear faults are marked by steepening of adjacent bedding.

The steep faults that dissect the central zone of the structure have kinematic indicators and offset that suggest sinistral displacement through this central zone. Viewed at the large scale, this suggests much of the structure south of Romaines Brook is the western limb of a very large hanging-wall anticline that was later reorganized by sinistral displacement on the Blanche Brook and other faults. This would mean that in the south of the structure, the contact of the carbonates with the allochthonous rocks between the outer reaches of Blanche Brook and Cold Brook (shown by question mark (?) on the map) is the offset of the western-bounding fault. Resolution of this relationship, however, like the northern contract of the anticline must await future mapping especially along the stream courses. The history of fault movements and understanding of the structure is further complicated because the oblique orientation of many of the folds to the north of Romaines Brook, in particular, is characteristic of the transpressional geometry of dextral wrench faulting.

Suites of northwest-trending high-angle normal faults cross the anticline at various places; downthrow is to both the northeast and southwest. A few east–northeast-trending faults also occur in the south. Both of these fault suites apparently predate the Carboniferous, which truncates them at the southern end of the anticline. It is also noteworthy that paleo-solution opened up caves along fractures in the fault zones in the centre of the anticline. These open caves were infilled with locally derived, red calcareous siltstone to conglomerate and locally a hematite druse overlain by dog-tooth spar and mosaic calcite cements, all of which is supportive of the probable Late Devonian or Early Carboniferous age of the anticline and its attendant and late faulting.

Carbonate stratigraphy of the upper St. George Group and overlying Table Head Group are missing at the north end of the anticline. Rather here, limestones of the Catoche Formation are truncated by a fault that appears to be folded and abuts against hanging-wall rocks of the Humber Arm Allochthon and Lewis Hills Ophiolite (*cf.* Cawood, 1990). This relationship is not exposed so that a number of interpretations are possible as follows:

1) the allochthon structurally overlies the truncated platform carbonates, the truncation predating the folding and possibly related to the emplacement of the allochthon;
2) the platform was truncated by Ordovician erosion either at the St. George Unconformity or both at the St. George Unconformity and again later during the seismically unstable block faulting of the foreland basin phase in the area. This interpretation demands that the northern end of the Phillips Brook anticline was a structural high in the Middle Ordovician foreland basin and was later overlain by allochthonous sedimentary rocks and then folded; and
3) the northern edge of the anticline is a thrust that emplaced the carbonates above the allochthon sedimentary sequence, the thrust was then, but not necessarily, folded as the anticline developed.

MINERALIZATION

Mineralization is rare in the area. A millimetre-scale vein of calcite cutting the Petit Jardin Formation at the north end of the anticline is host to galena and pyrite. The joint trends 095° and dips 75°S. Pyrobitumen was noted in several calcite veins cutting Table Point Formation carbonates along the western edge of the anticline.

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