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THE BLUE POND THRUST STACK – NEW MAPPING, RE-EVALUATION OF STRUCTURAL RELATIONSHIPS AND IMPLICATIONS FOR ALLOCHTHONOUS LOWER PALEOZOIC CARBONATE SHELF ROCKS

I. Knight

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St. John’s, Newfoundland
June, 2006

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ABSTRACT

The Blue Pond Thrust Stack (BPTS) is a large northeast-trending and plunging antiformal stack occupying an area, of at least 375 km^2, southwest of Pinchgut Lake to southwest of Grand Lake in western Newfoundland. It is one of several stacks that deform Middle Cambrian to Middle Ordovician predominately shallow-marine carbonate rocks that were part of the lower Paleozoic shelf in western Newfoundland. The BPTS structurally overlies Middle Ordovician flysch and carbonate rocks of the Taconian foreland basin.

Although, three deformations affect the geologic terrain, the regional-scale geometry of the stack was fashioned by D_1 and D_2. D_1 is characterized by northwest- to west-verging thrusts, folds and associated fabrics, and D_2 by southeast-verging, northeast-plunging folds and cleavage. Northeast of Grand Lake, the stack is essentially a distorted butterfly shape, reflecting a two part geometry. In the northwest, the BPTS consists of a northwestern antiformal wing which includes northwestward dipping and facing, foreland-dipping duplexes. In the southeast, the stack is formed by southeast-dipping and facing, hinterland dipping duplexes. A tight syncline separates the two wings and projects southwest toward the hinge zone along which the two duplexes converge. A third terrain comprises the footwall to the stack. It consists of several thin imbricate thrust slices that are deformed by the D_2 folds.

Southwest of Grand Lake, north-trending thrusts, folds and cleavage (D_1) swing to east-trending in close proximity to the southwestern cut-out of the stack. In this complexly deformed area, early D_1 fabrics are overprinted by southeast-verging D_2 structures. The east–west D_1 trends are interpreted to reflect a lateral ramp in this area.

Small and large, closed and breached footwall windows can be traced beneath the stack to within a few kilometres of the inner domain of the Humber Zone. This suggests that the stack is far traveled (more than 10 km) and is possibly fully detached. This conclusion is supported by a very large, northeast-trending, negative regional magnetic anomaly that coincides with the stack in the southwest and the allochthonous Pinchgut Lake Group to the northeast. Regional magnetic maps also suggest that northeast-trending basement shallows below the northwest part of the BPTS. This basement high is postulated to have formed a structural buttress and ramp that controlled the location and internal architecture of the stack.

INTRODUCTION

The Blue Pond Thrust Stack (BPTS) is a folded imbricate stack that lies east of Georges Lake, about 30 km southwest of Corner Brook (Figure 1). The stack hosts Middle Cambrian to Middle Ordovician carbonate shelf and foreland basin rocks. The sequence is preserved in several thrust slices deformed about large northeast-trending and -plunging folds. The shelf rocks were included as a largely undivided belt on early maps of the area by Walthier (1949), Williams (1985) and Williams and Cawood (1989). Although all three maps indicate a large anticlinal structure for this belt of shelf rocks, Walthier (1949), in two cross sections (C and D), showed that the shelf rocks had been carried west on a shallow, low-angle thrust. On his map (Walthier *op. cit.*) shows rocks of the Middle Ordovician Table Head Series and deformed shale and sandstone of the Humber Arm Series in the core of the anticline surrounded by, and hence overlain by, older rocks of the St. George Series. This thrust terrain was named the Island Pond thrust block (*see* Plate III, Walthier *op. cit.*). Williams (1985) called the large fold, the Pinchgut anticline.

The BPTS was named, mapped and described in detail for the first time by Knight (1996a, b, 1997) in the area from Pinchgut Lake to Georges Lake; also, part of the stack was included in a mapping study near Pinchgut Lake by Ferguson (1998). The impressive stack was shown to be at least 30 km long, 9 km at its widest, and still open to the southwest. In 2002, and in the summers of 2004 and 2005, the areas north and south of the western end of Grand Lake were mapped and/or re-examined along a number of woods roads, streams ponds and the Trans Canada Highway (TCH, Figure 2). The BPTS was extended for an additional 13 km to the southwest where it is covered by Carboniferous and Quaternary deposits. During the latest mapping, several small and large, closed and breached structural windows of footwall strata were also mapped within the BPTS and the front of the BPTS was re-examined close to the TCH; consequently, the thrust stack is being re-evaluated to reflect this recent work. Hence, it is clear that further mapping is necessary to better define relationships before a final map of the stack is produced.

REGIONAL GEOLOGY

A sinuous belt of autochthonous and parautochthonous Cambro-Ordovician siliciclastic and carbonate shelf rocks and the overlying flysch of the external Humber Zone, of western Newfoundland, can be traced for about 450 km from the Port au Port Peninsula in the south to Cape Norman at the tip of the Great Northern Peninsula (Figure 1). The belt is sandwiched between a number of Taconian allochthons to the west and north and the Precambrian Long Range Massif to the east. The shelf sequence lies structurally beneath the Taconian allochthons.

The autochthon is subdivided into two subterranes, a western foreland and an eastern fold and thrust belt. In the western foreland, the autochthon rests unconformably upon Precambrian crystalline basement and ranges from undeformed to locally folded and faulted by thick-skinned structures. The eastern subterrane is characterized by a number of imbricate thrust stacks that deform the Cambro-Ordovician shelf rocks and Middle Ordovician foreland basin carbonate shelf and siliciclastic flysch rocks along the eastern part of the external Humber Zone. In the stacks, the shelf and flysch strata are detached from basement, are polydeformed, and also are weakly metamorphosed; the metamorphic grades increase toward the east.

Two of the thrust stacks, the BPTS (Figure 1) and the Goose Arm Thrust Stack (GATS, Figure 1) occur north and south of Corner Brook where they lie east of the Taconian Humber Arm Allochthon (HAA). The two stacks are similar in that they are detached from basement, and the floor thrust follows shaly units within the Middle Cambrian part of the shelf sequence. Both stacks coincide with significant, negative magnetic depressions that contrast with strongly magnetic, basement-cored, thick-skinned structures to the west and northwest.

The GATS includes an antiformal culmination exposed by erosion through the structurally overlying allochthon that had been elevated as a broad north-trending anticline during the formation of the stack (Knight, 1994). The Old Man Pond Allochthon (OMPA) is an erosional outlier of the larger HAA (Williams and Cawood, 1989). The frontal edge of GATS was emplaced above foreland-basin flysch and carbonate, as well as broken formation of both flyschoid and shaly allochthonous aspect, immediately east of the sole of the HAA. This relationship, which is best exposed at Goose Arm, Penguin Head and Penguin Arm in the northern part of the Bay of Islands, is complicated further by later folding of the stack's frontal edge, by east-verging recumbent folds (Knight and Boyce, 1991). Small structural windows of footwall flysch occur a few kilometres to the southeast of the frontal thrust, and may also occupy other, more complex, structural windows including shelf and flysch rocks, 6 to 9 km southeast of the front.

The BPTS is also emplaced above foreland basin carbonates, flysch and broken formation. Structural windows of these Middle Ordovician rocks (flysch - Goose Tickle Group, broken formation - Goose Tickle Group, and shale of allochthonous aspect and shelf to basinal carbonate and shale - Table Head Group) mark the footwall to the stack well to the east of its frontal edge (Knight, 1997).

In both the BPTS and the GATS, there are common stratigraphic and lithofacies patterns that can be traced west to east across the stacks; further, the deformational chronol-

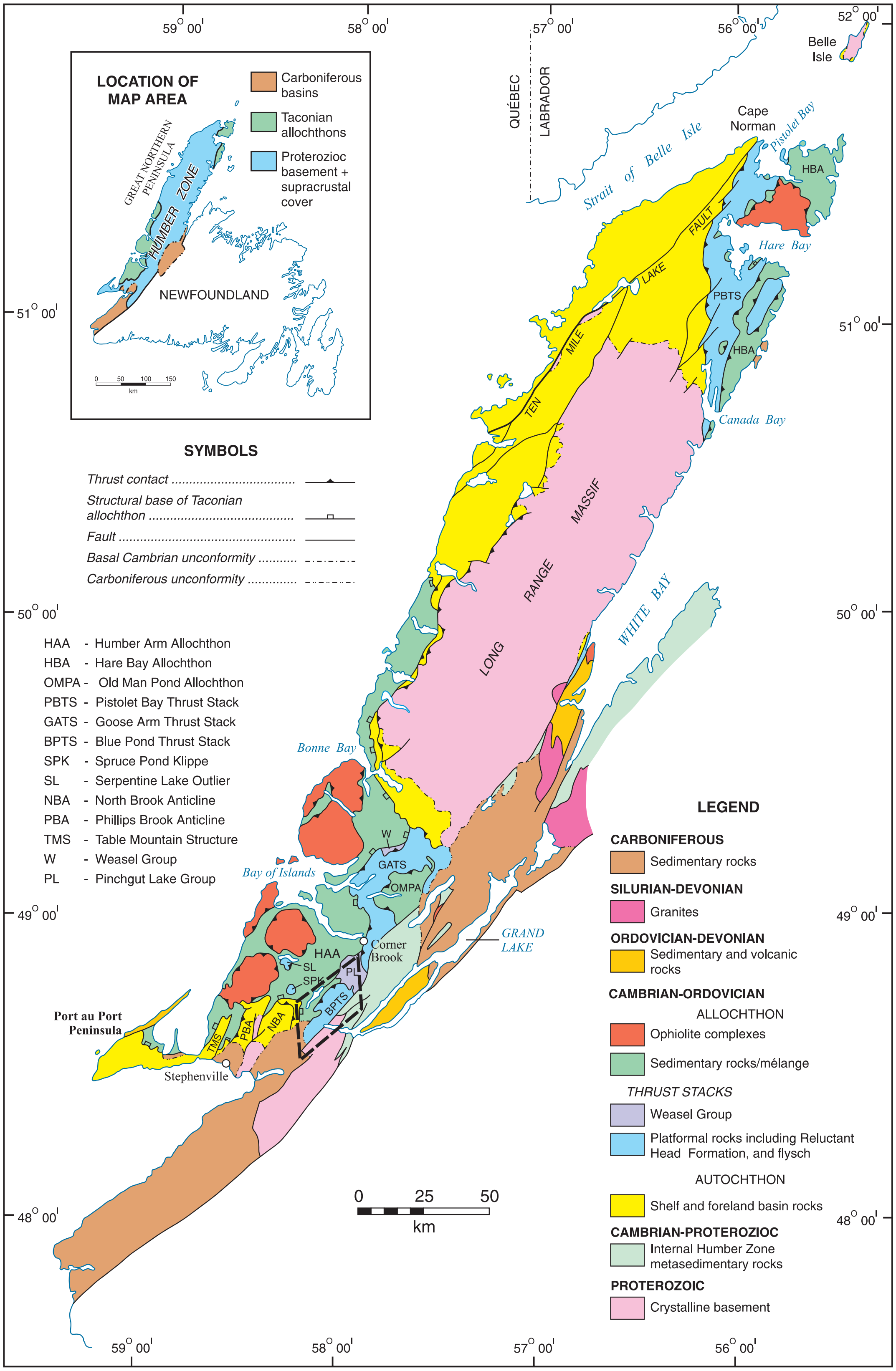

Figure 1. *Regional geology map of the outer domain of the Humber Zone, western Newfoundland, showing the location of the Blue Pond Thrust Stack.*

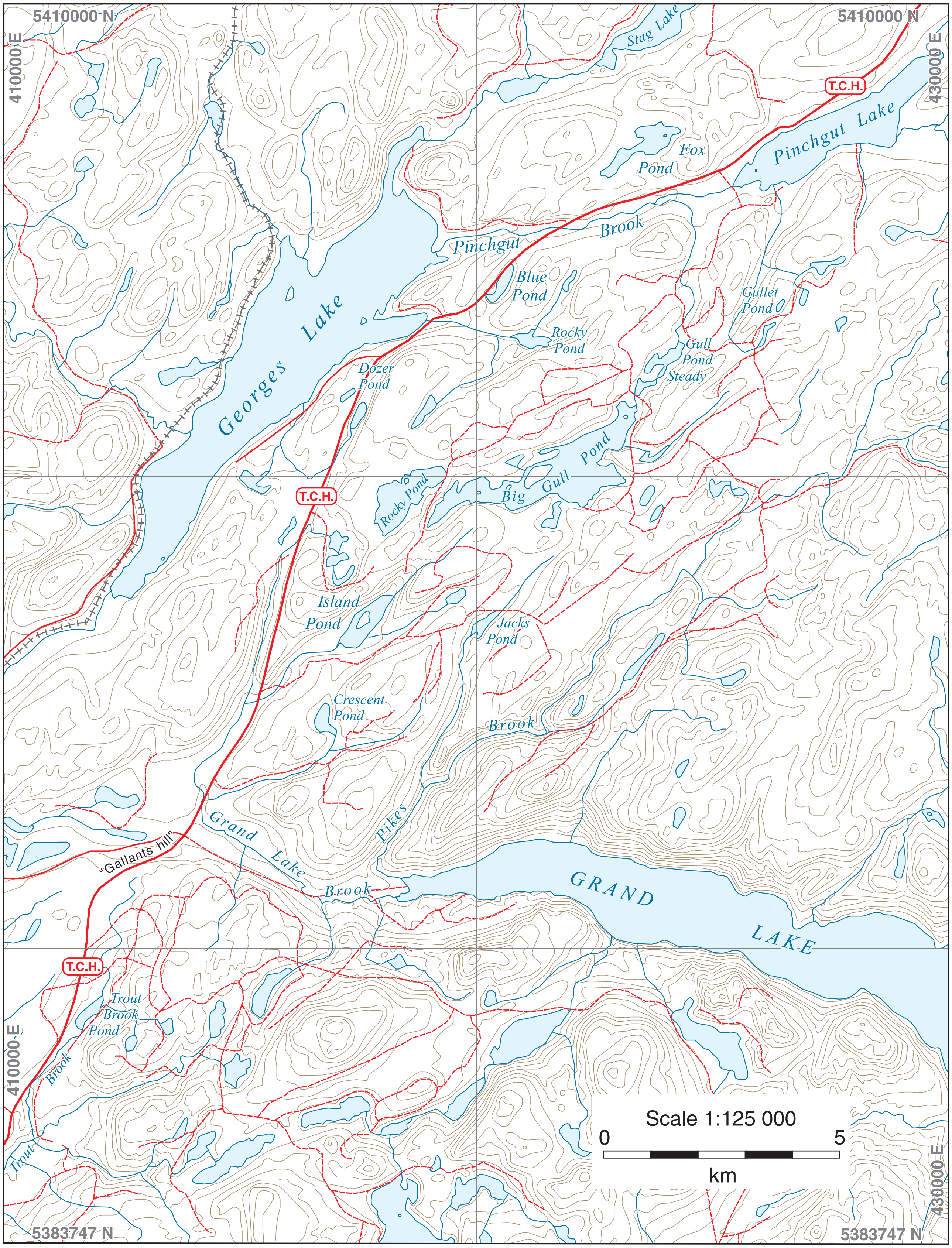

Figure 2. *Location map of the area host to the Blue Pond Thrust Stack showing new and disused woods roads and trails.*

ogy and style is similar. Metamorphism is generally low in the northwest but increases southeastward to low greenschist facies; macrofossils date some units in both areas.

Outliers of shelf carbonate lie 10 to 16 km northwest of the BPTS where they are surrounded by sedimentary rocks placed in the HAA and where, locally, they are structurally associated with narrow slivers of ophiolitic rocks (Williams, 1985; Williams and Cawood, 1986, 1989). A cluster of small shelf-carbonate outliers occur immediately north of the North Brook Anticline (NBA) which is one of several, large, thick-skinned structures in the region (Figure 1). Recent mapping indicates that these disparate carbonate pieces are erosional outliers of a carbonate klippe, named the Spruce Pond klippe (SPK) by Knight and Boyce (2002). The mapping showed that at least two thrust panels deformed about a north-northeast-trending anticline. The klippe lies structurally upon a footwall of flysch, broken formation and foreland-basin, carbonate shelf rocks. Follow-up mapping in 2004 and 2005 of the klippe by A. Meade and T. Calon (personal communication, Memorial University, 2005) suggests that these rocks are an imbricate stack that has a complex footwall of thin thrust slices of foreland-basin carbonate and flysch.

North of the SPK, the Serpentine Lake outlier (SLO) places a full succession of carbonate shelf rocks structurally above Table Head Group (I. Knight, unpublished data, 1996). Whether the SLO is a klippe or not is unclear because nowhere can it be shown to overlie the allochthonous rocks that surround it to confirm complete detachment; that older carbonate shelf rocks are thrust over younger foreland-basin shelf rocks does, however, imply a possible stack. Irrespective, the two outliers indicate that lower Paleozoic shelf rocks were likely transported to the west and perhaps even detached to lie within the allochthonous terrane where shelf slope and foreland-basin sedimentary rocks, broken formation and sedimentary elements of the western part of the HAA are complexly imbricated and broken (Godfrey, 1982; Burden *et al.*, 2001; Calon *et al.*, 2002; Young, 2002; Cocker, 2003).

The carbonate stacks contrast to a number of thick-skinned structures that deform the shelf sequence and Precambrian basement west of the BPTS and north of Stephenville (Knight and Boyce, 2000, 2002; Knight, 2003; Palmer *et al.*, 2002). These basement-cored structures are mostly southeast-verging, northeast-trending and -plunging anticlinal pop-ups that host well-preserved, well-dated shelf and foreland basin shelf rocks. However, a number of thrust faults cut the shelf sequence in both the Phillips Brook Anticline and the NBA and are deformed by the pop-up structures (Knight and Boyce, 2000, 2002; Knight, 2003). This suggests that blind thrusts propagated within the shelf sequence of the autochthonous foreland, possibly when the thrust stacks developed.

GEOLOGY OF THE BLUE POND THRUST STACK

INTRODUCTION/LOCAL SETTING

The rocks carried in the BPTS and forming part of its footwall were informally defined as geological domains[1] by Knight (1997). Domain 3A comprises the stack, and domain 2 is the footwall to the stack (Knight, 1997). The recent mapping extends both domains to the southwest where the footwall (domain 2) occupies a breached footwall window and the stack occurs in a number of outliers including a large area southwest of Grand Lake.

Northeast of Grand Lake, the stack in a simplistic sense has a map pattern that is shaped like a distorted butterfly whose two wings, one to the northwest and the other to the southeast are northeast-plunging antiforms (Figure 3). They

LEGEND (for Figure 3)

11 **Carboniferous and/or Quaternary deposits**

Allochthon

9 Sedimentary slices

10 Mount Musgrave Group

Offshelf carbonates (Middle Cambrian to Lower Ordovician)

8a / 8b Reluctant Head Formation (8a), Pinchgut Lake Group (8b): Shale, ribbon limestone, carbonate conglomerate

Taconian Foreland Basin (Middle Ordovician)

7 Mix of flysch and transported shale of Cambrian to Lower Ordovician age, includes broken formation

6 (6a, 6b) Goose Tickle Group: Flysch, sandstone and shale, includes Daniel Harbour Member (6a), 6b - psammite and phyllite below Pinchgut Lake Group

5 Table Head Group: Carbonate shelf and slope: limestone, shale and conglomerate

Lower Paleozoic shelf (Lower Cambrian to Lower Ordovician)

4 St. George Group: Carbonate

3 Port au Port Group: Carbonate, minor shale

2 Labrador Group: 2a - psammite, marble, 2b - phyllite, 2c - Penguin Cove Formation, thin-bedded sandstone, shale, carbonate

Grenvillian basement

1 Gneiss and granite

[1] In this and following parts of the discussion, "domain" as used by Knight (1997) will be loosely interchanged with geological "terrane".

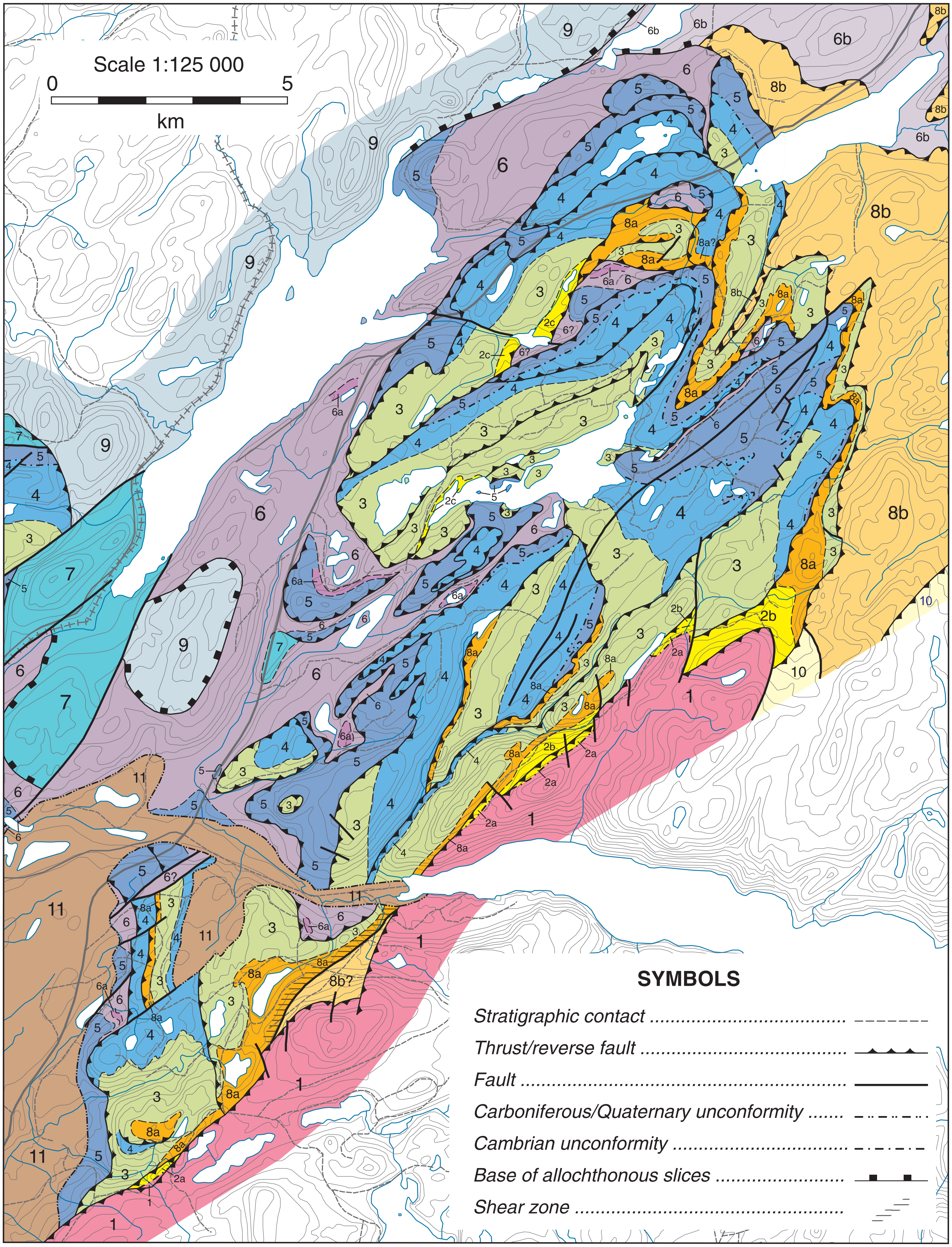

Figure 3. *Geology map of the Blue Pond Thrust Stack.*

are separated by a narrow northeast-plunging syncline. The antiforms were mapped as plunging below rocks of the Pinchgut Lake Group (domain 3B of Knight, 1997), a succession of phyllite, ribbon limestone, grainstone and carbonate conglomerate whose age spans the late Middle Cambrian to earliest Ordovician[2]. Pinchgut Lake Group rocks occupy the tight syncline between the two antiforms and overlie the truncated edge of the shelf rocks in the stack near Pinchgut Lake. Because the contact of the BPTS and the Pinchgut Lake Group is folded about the northeast closure of the two antiformal wings, and also because the Pinchgut Lake Group is polydeformed, with structural style and chronology in part matching that of the BPTS, it was interpreted to lie structurally above the stack and have an overlapping structural history with the stack (Knight, 1997).

Traced southward, the southeastern edge of the stack is in contact with a number of geological terranes. These are from northeast to southwest:

1) Metamorphic equivalents of the Pinchgut Lake Group (domain 4A of Knight, 1997).

The rocks of domain 4A are lithologically similar to the Pinchgut Lake Group. They are, however, metamorphosed to greenschist and mica grade in comparison to the sub-greenschist-grade rocks of domain 3B. A broad, shear zone of vertically dipping limestone mylonite marks the contact of the eastern edge of the stack with these metasediments. Domain 4A coincides with part of a large, low magnetic anomaly that also covers the Pinchgut Lake Group and the BPTS (*see* later discussion).

2) Precambrian crystalline basement and supracrustal rocks (domain 5 of Knight, 1997)

Domain 5 extends from about 7 km northeast of Grand Lake southwestward across the lake to the southwest end of the stack. There, Grenvillian basement is unconformably overlain by psammites, pelites and marble, equivalent of the Bradore and Forteau formations of the Labrador Group. Intrusive rocks of the Hare Hill Complex form part of the terrane which is carried by the Grand Lake Thrust of Williams and Cawood (1989). Southwest of Grand Lake, a 300-m-wide shear zone of vertically dipping, northeast-trending, isoclinally folded and polydeformed limestone mylonite marks the last carbonate rocks of the stack close to the thrust. Nonetheless, the mylonite is separated from granitic and crystalline basement by black to dark-grey, quartz-vein-rich pelites of uncertain stratigraphic affiliation. Metamorphic grade, lithological similarity to pelites of domain 4A, and low magnetic expression, outlined on regional aeromagnetic maps (GSC, 1968b, c), suggest that they may be metamorphosed Pinchgut Lake Group rocks.

To the southwest, the stack and its footwall sequence are unconformably overlain by Carboniferous and Quaternary deposits.

STRATIGRAPHY

The stratigraphy preserved in the stack, ranges through Middle Cambrian clastic and carbonate rocks to Middle Ordovician carbonate and flyschoid rocks as illustrated in Figure 4. Detailed descriptions of the various units are given in Knight (1997).

The oldest rocks seen in the thrust slices are early Middle Cambrian. Fossiliferous Penguin Cove Formation (a heterolithic sandstone/shale unit with minor interbedded thin limestone), mark the oldest and structurally lowest rocks in two thrust panels north of Big Gull Pond. Fossils in the Penguin Cove Formation, at Big Gull Pond, show it is the time equivalent of the upper part of the Hawke Bay Formation. This unit contrasts to early Late Cambrian Reluctant Head Formation rocks, a succession of phyllite, thin-bedded ribbon limestone and minor limestone conglomerate, that marks the lowest rocks in the southeastern thrust slices.

The significant age difference between the Penguin Cove Formation and the Reluctant Head Formation precludes any possibility that the two units interfinger as indicated by Ferguson (1998), who suggested that the thrust panels could possibly be linked across the hinge zone of the stack. The Penguin Cove Formation, however, clearly links the northwestern slices of the BPTS stratigraphically to the eastern part of the NBA, where the Penguin Cove Formation occurs at the top of the Labrador Group.

Above the Penguin Cove Formation in the BPTS, burrowed, oolitic and parted dolomitic limestone of the March Point Formation mark the base of the Middle to Late Cambrian Port au Port Group. They are followed by a tripartite succession of lower dolostone, middle limestone and upper dolostone of the Petit Jardin Formation. Oolitic, stromatolitic, parted and some ribbon-bedded dolomitic limestones in pale grey, white and yellowish colours are typical of the middle member which also includes interbedded dololaminites. The dolostone members are grey, thick-bedded and massive, and locally preserve mottled and microbial textures and some ghosts of grainstone. They are intercalated with argillaceous to laminated dolostone and dolomitic shale. Similar dolostone is joined by cherty dolostone in the overlying Berry Head Formation where they are succeeded by an

[2] Ages based on fossils collected in the correlative Weasel group (Boyce *et al.*, 1992) and recent unpublished conodont samples collected by author from both Weasel and Pinchgut Lake groups.

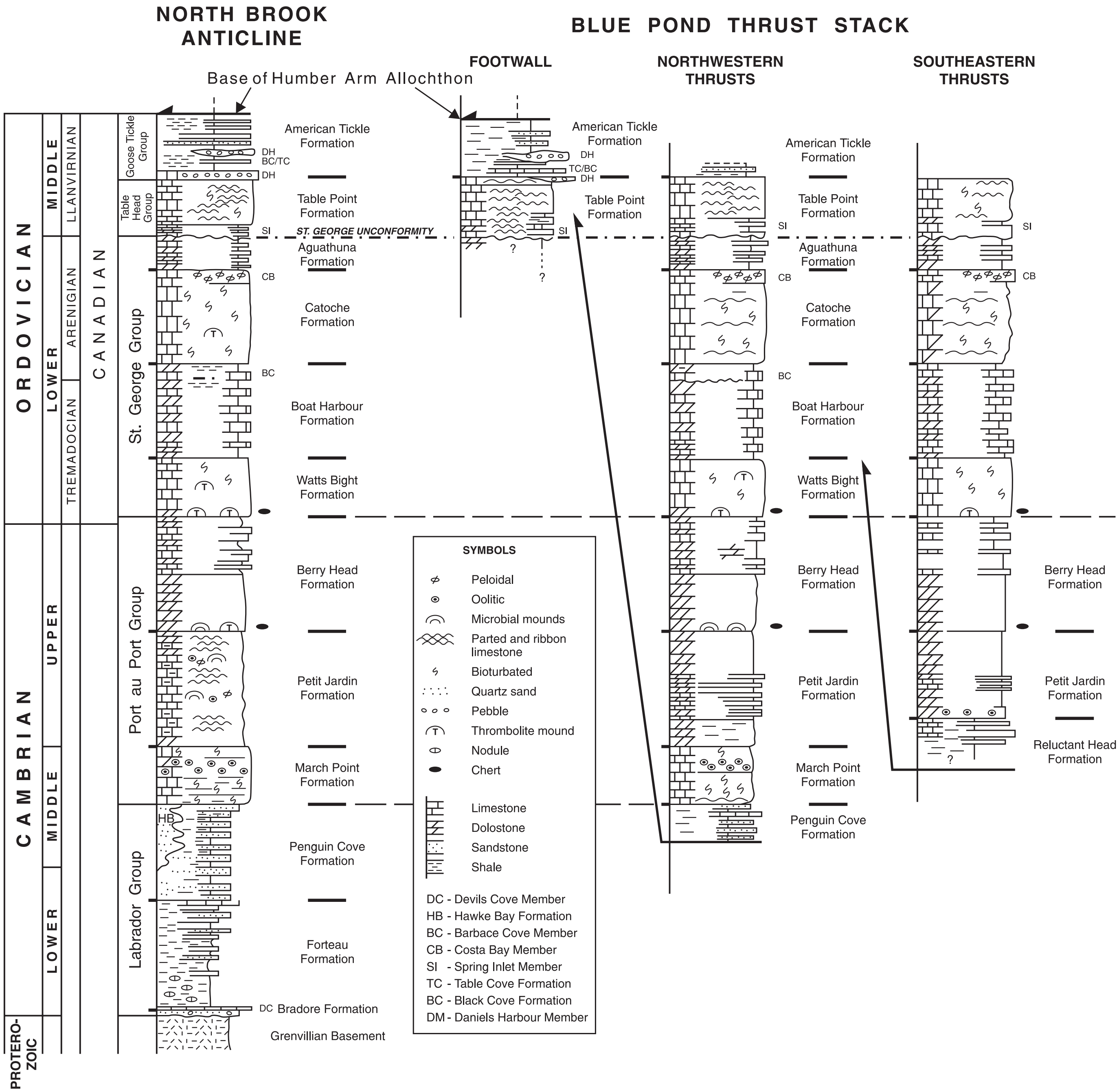

Figure 4. *Stratigraphy of the Blue Pond Thrust Stack and its footwall sequence along side a stratigraphic column showing the stratigraphy of the North Brook anticline. The arrows indicate the structural emplacement of the wings of the Blue Pond Thrust Stack.*

upper member of intercalated dark-grey, dolomitic, bioturbated, microbial, parted and laminated limestone and dololaminite beneath the base of the overlying Lower Ordovician St. George Group rocks. This succession mimics the succession in the northwestern thrust slices in the GATS (Knight and Boyce, 1991; Knight, 1994). However, although both the March Point and Berry Head formations in the BPTS compare, in part, lithologically with the same units in the NBA, the stratigraphy and lithofacies of the Petit Jardin Formation of the northwestern part of the BPTS do not resemble those in the NBA.

Dolostone dominates the Petit Jardin Formation above the Reluctant Head Formation in the southeast thrust slices. Limestone plays only a minor part in the middle of the thick succession; nevertheless the middle member is a mappable marker horizon in the thrust slices of the complexly deformed, shelf carbonates southwest of Grand Lake. Dolostones in the upper part of the lower Berry Head Formation include well-bedded, massive, off-white varieties. Metre-thick interbeds of white and pinkish marble occur in the upper member along with dark and light grey limestone and dolostone marbles and mimics the succession in the southeastern thrust slices in the GATS (Knight, 1991).

The succession in the St. George Group is generally consistent throughout the thrust stack and shows no discernable differences from its counterpart in the NBA, and elsewhere in southwest Newfoundland (*see* Knight, 1997 for details).

The Middle Ordovician Table Head Group rests unconformably upon the St. George Group in the thrust stack (Knight, 1997) and is also well developed in the footwall succession. Dark-grey, well-bedded, stylo-nodular, argillaceous and dolomitic limestone is the dominant lithology in the unit, and is associated with thin, ribbon beds, and beds and lenses of limestone conglomerate that show evidence of in situ disintegration and minor gravitational redeposition. The facies is similar to the lower part of the Table Cove Formation (Stenzel, 1992). In the core of the stack, these limestones rest upon a few metres of planar thin-bedded limestone that sit conformably upon intercalated limestone and dolostone of the Spring Inlet Member of the Table Point Formation. For this reason, and because the stylonodular facies is overlain by shaly nodular to ribbon limestones of the Table Cove Formation, they are placed in the Table Point Formation.

In the overlying flysch, grey to black, cleaved shales and thin beds of commonly brown-weathering, green-grey sandstone and siltstone mark the American Tickle Formation of the Goose Tickle Group. In this shaly flysch are found decametre-thick beds of cross-laminated limestone as well as limestone conglomerate beds of varying thickness of the Daniels Harbour Member (Stenzel *et al.*, 1990). The latter is critical to defining the stratigraphy and structure, where the shale is transformed into slate and shows little evidence for its stratigraphic origin. Stratigraphic, facies and thickness relationships of the carbonate units at the top of the Table Head Group and base of the Goose Tickle Group are so variable that caution is needed when interpreting structural relationships, particularly in the footwall units.

STRUCTURAL RELATIONSHIPS

The rocks of the BPTS and its footwall are characterized by at least 3 deformations. Deformations D_1 and D_2 are the principal architects of the geometry of the BPTS. Widespread broken formation, including flysch, in the Taconian foreland basin in front of the stack may be related to the earliest emplacement of the most westerly sedimentary slices of the Taconian allochthon during the early Late Ordovician, although it may possibly reflect footwall deformation during emplacement of the stack. A zone of flattening, containing kinematic indicators, locally affects the top of the Table Head Group limestone below the flysch. Since the sheared contact is locally deformed by D_1 folds (Plate 1) it is possible that detachment and shearing between the limestone and overlying foreland basin flysch occurred as the western sedimentary slices of the allochthon slid across the foreland basin. The kinematic indicators suggest northwestward overthrusting but whether or not this overthrusting is related to the emplacement of the allochthon or to emplacement of the stack during D_1 is not resolved.

Plate 1. *Recumbent fold of deformed Table Head Group limestone and Goose Tickle Group shale, TCH near Gallants junction. The fold plunges gently northeast (to left). The hangingwall of the BPTS occurs in the wooded hillside above the outcrop and in a gravel pit nearby, just south of the TCH.*

Episodes of Deformation

D_1 – The first deformation (D_1) consists of thrusts associated with northwest-verging, structures. Intense mylonitic and folded fabrics developed close to the sole of the thrusts (Plates 2, 3, and 4) and northwest-verging, northeast-trending folds, cleavage, shear fabrics and small scale duplexes are common within the thrust panels (Plate 5). Dynamic recrystallization is common in some limestone beds (Plate 6). Lineations associated with the thrusts trend from 310° to 325°. Recumbent folds of various sizes, in outcrops, are not uncommon in the immediate hangingwall to some of the thrusts (Plates 2 and 5). Northwestward dipping, foreland dipping thrusts mark the northwestern part of the stack. Thrust panels in the southeast of the stack dip and face toward the southeast and steepen as they are traced from west to east. S-folds in eastward facing thrust panels are common features of this deformation (Plate 7). Northwest-ward

Plate 2. *Recumbent, northwest-verging synformal anticline in thin bedded dolomitic limestone of the March Point Formation above a northwest-dipping thrust (arrow), base of BPTS near Big Gull Pond. A mylonitic fabric (Plate 3) occurs above the thrust which is underlain by Goose Tickle Group shale and Table Head Group limestone. Base of thrust carries a stretching lineation plunging into the hill.*

Plate 4. *Folded northwest-verging horses utilizing thin-bedded stylolitic limestone intercalated with dolostone (Boat Harbour Formation). Transposed foliated fabric in the limestone includes tight highly recumbent folds facing to the left. The main folds have a west-dipping cleavage indicative of D_3 structure. Core of the BPTS between Big Gull Pond and Pikes Brook.*

Plate 3. *Close up of mylonite in Plate 2. C-S fabrics and augen suggests left handed shear, i.e., down to the NW.*

Plate 5. *Culmination of a west-verging, recumbent anticline at base of the hangingwall of the BPTS, southwest of Grand Lake. The fold deforms Boat Harbour Formation. The sole thrust to the stack occurs in the trees below the cliff.*

emplacement of the thrust stack above the foreland-basin sequence mark this phase.

Southwest of Grand Lake, near the southwestern end of the stack, thrusts, folds and cleavage swing to a northerly trend before swinging to east-west. This trend is interpreted to reflect a lateral ramp.

D_2 – East- to southeast-verging folds associated with a northwest-dipping cleavage mark the second deformation (D_2). The D_2 structures deform the D_1 stack and its footwall (Plates 8, 9, 10 and 11). Chevron folds are common in the core of the southeastern anti-formal wing of the stack (Plates 9 and 12). The main folds in the terrain probably reflect this event.

D_3 – A crenulation cleavage that is variably developed and is associated with crenulation folds and lineations (D_3) affects earlier fabrics. The fabric is best seen in the slates of the footwall and in phyllites of the Reluctant Head Formation at the sole of eastern thrusts (Plate 13). Generally, the cleavage trends east-west and dips at a shallow angle to the south. Associated crenulation folds and lineations are virtually horizontal to gently plunging.

Late Faults

Northeast-trending high-angle faults – The leading edge of the thrust stack is cut by a series of northeast-trending nor-

Plate 6. *Barrel-shaped to fibrous-like calcite crystals indicating dynamic recrystallization of a dark grey limestone intercalated with dolostone (not shown) in the Boat Harbour Formation. Remnants of partings (arrows) and lack of dolomite suggest that the original limestone may have been a grainstone. Location between Big Gull Pond and Pikes Brooks.*

mal faults southwest of the Grand Lake Brook valley. Their downthrow is consistently to the southeast.

Sinistral strike-slip faults – The stack and footwall terrane is offset by east-southeast-trending, sinistral, strike-slip faults (Plate 14). These faults are best seen along the TCH southwest of the Gallants intersection. Narrow, centimetre-wide, paleo-solution features including fissures and small vertical tubes are developed along several of the faults. They display scalloped and fluted edges and are filled by red, fine-grained, calcareous, Carboniferous sediment.

THE BLUE POND THRUST STACK

Knight (1997) defined the Gullet Pond, Pikes Brook, Big Gull Pond and Rocky Pond thrust slices as the major panels of the BPTS. The base of the stack was defined as the Blue Pond Thrust. A duplex of several imbricates dominate the Big Gull Pond thrust slice and two, small, foreland-dipping thrust panels were defined in the north-eastward plunging core of the stack, near Island Pond. Interpretation of the map relationships suggest that the stack was carried by the Blue Pond Thrust, above a footwall of Middle Ordovician flysch and carbonate formations along with the broken formation that also included allochthonous shale. Thrust planes steepen to the vertical as the stack is traced toward the hin-

Plate 7. *North-plunging (20°) S-fold in a thin-bedded dolostone intercalated between sub-vertically dipping limestone beds in the Boat Harbour Formation. Southeastern wing of the BPTS north of Pikes Brook. Beds young to the right suggesting structures are D_1. Cleavage dips steeply to the left (i.e., northwest). Steepening of the thrust slice in this part of the stack reoriented the structures. An earlier structural fabric is folded by the folds.*

Plate 8. *Southeast-verging D_2 buckle folds (arrows) deforming an inverted limb of a west-verging recumbent fold which has folded mylonitic limestone and dolostone (arrow). D_1 cleavage (dashed line) is folded inside the dolostone bed. Woods road south of Big Gull Pond.*

Plate 9. *Southeast-verging irregular chevron D_2 folds deforming a strong D_1 dolostone mylonite above a thrust carrying Cambrian Port au Port Group within the core of the southeastern wing of the BPTS. Location between Big Gull Pond and Pikes Brook.*

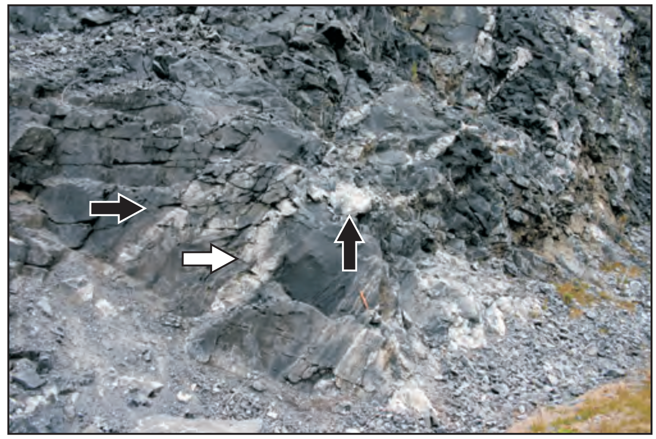

Plate 11. *Northwest-verging D_1 folds (white arrow) and southeast-verging D_2 folds (dark arrow) highlighted by thin, folded, white dolostone interbeds in dark limestones in a roadcut along the TCH near Pinchgut Lake. A D_1 shear fabric is deformed by D_2 cleavage in this outcrop.*

Plate 10. *Steeply-plunging D_2 fold deforming D_1 fold in Petit Jardin Formation dolostone, south of Grand Lake. Facing direction is unknown.*

Plate 12. *Quartz in accommodation structures developed in north-plunging chevron folds in Cambrian dolostone. Core of southeast wing of the BPTS between Big Gull Pond and Pikes Brook.*

terland. Although parts of this interpretation are still valid, the recent mapping has provided new evidence to re-interpret the stack and its footwall.

Two thrusts panels host the Penguin Cove Formation at their base just north of Big Gull Pond, and include the newly named Gull Pond Steady thrust and the Rocky Brook thrust slices; both panels dip and young to the northwest. Structural relationships with underlying footwall windows of Middle Ordovician strata indicate that both are foreland-dipping panels. Small, foreland dipping panels of Petit Jardin Formation lie below these two panels and above an antiformal footwall window along the shores of Big Gull Pond. Kinematic indicators in some of the thrust zones suggest northwestward overthrusting. This group of thrust panels forms the core of the northwest, antiformal wing of the stack. The structurally higher Gullet Pond thrust slice partially wraps around the lower thrust slices in the northeast of the antiform.

Mapping south and southwest of Big Gull Pond involves the southeast wing of the larger stack complex. In this wing, there are at least five thrust panels above the Blue Pond thrust. These include from west to east, the newly named Pelleys Brook thrust slice, the newly named Jack Pond thrust slice (previously considered to be the southern part of the Big Gull Pond thrust slice), the redefined Big Gull Pond thrust slice, the Pikes Brook thrust slice and the Gullet Pond thrust slice. The Pelleys Brook and Jack Pond thrust slices appear to converge to a branch point near Big Gull Pond and all the

Plate 13. *Gently northeast-plunging D_3, crenulation lineation and folds developed on D_2 cleavage in phyllites of the Reluctant Head Formation, base of Jacks Pond thrust, west of Jacks Pond.*

Plate 14. *Cross section through a cup-shaped paleo-karren partly filled by fine grained, red, Carboniferous, calcareous sandstone along a minor sinistral strike slip fault cutting Table Point Formation limestone. TCH at "Gallants hill". Arrow indicates slickensides.*

thrusts converge as they are traced southwestward toward Grand Lake. Recent mapping indicates that there may be a number of internal imbricates in the Jacks Pond thrust slice, which hopefully, will be clarified by future mapping.

Two outliers of the BPTS occur just northeast and southwest of Island Pond. The larger of the two outliers southwest of the pond juxtaposes the Port au Port Group (exposed in a large gravel pit near the access road to Crescent Pond) and Lower St. George Group rocks structurally above Middle Ordovician strata that are exposed along the TCH, and in a large breached footwall window near Island Pond. This outlier probably correlates with the Pelleys Brook thrust slice. The other outlier between Island Pond and Big Gull Pond consists of lower St. George Group rocks. This is probably an outlier of the Jacks Pond thrust slice.

Southwest of Grand Lake, the stack is intensely deformed and hosts at least three thrust panels, none of which can be linked, with any confidence, to those north of Grand Lake across the deep, glacial, west-trending valley of Grand Lake Brook. This southwest-narrowing triangular area is a broad plateau dissected by deeply incised, steep-sided stream valleys. Bedrock exposure is generally widespread except where the plateau overlooks Grand Lake Brook valley. There, a large, bog- and till-covered tableland obscures bedrock and adds to the difficulty of projecting geology both north and south.

A west-facing scarp marks the leading edge of the stack where resistant Cambrian and Lower Ordovician shelf rocks overlook lower ledges of Middle Ordovician footwall rocks. The footwall, in turn, overlooks the extensive lowland plain inland of the northeast end of St. Georges Bay, which is host to Carboniferous rocks of the Bay St. George Basin. In this area, the leading edge of the BPTS can be traced and projected south to intersect with the Grand Lake Thrust of Williams and Cawood (1989), 7 km southwest of Grand Lake.

Close to the leading edge of the stack, thrust panels trend north, and dip and face to the east with local evidence of rollover. Recumbent folds occur locally (Plate 5). To the southwest, however, the stack is marked by intersection of north and east-trending fold axes. There, Cambrian strata host strong early foliation fabrics that are deformed by the main southeast-verging, D_2 structures (Plate 10). To the east, beneath Hare Hill, the higher, most easterly thrust panel is host to northwestward-facing, slightly overturned Cambrian rocks that are broadly curved about a northwest-trending but southeast-plunging axis. A wide shear zone of limestone mylonite and a wedge of pelitic rocks, several hundred metres across, separates this panel from the Hare Hill terrane of granites and meta-sedimentary rocks that lie east of the Grand Lake Thrust.

An areally small, duplex that includes the Precambrian basement rocks and the immediately overlying cover of Labrador Group rocks, is found in the footwall to the Grand Lake Thrust along one of the tributaries of Trout Brook (Knight, 2004).

FOOTWALL TO THE BLUE POND THRUST STACK

The footwall to the BPTS is underlain predominantly by Middle Ordovician flysch of the Goose Tickle Group and broken formation that includes flysch and black, green and grey shales possibly derived from allochthonous formations lithologically similar to the Green Point and Northwest Arm formations. Limestones of the Table Head Group underlie the shales and are found in a number of structural windows and along the leading edge of the thrust stack within thin thrust slices (Figure 5). They include thick-bedded limestones of the Table Point Formation and thick sequences of thin-bedded and ribbon limestone of the Table Cove Formation. Much of the latter is argillaceous and resembles ribbon rocks of the Reluctant Head Formation and the Pinchgut Lake Group. However, fossils in these ribbon rocks, although not plentiful, include gastropods and poorly preserved trilobites, typical of the Ordovician carbonates. A decametre-thick unit of carbonate conglomerate, the Daniels Harbour Member (Goose Tickle Group) is found either capping the Table Point Formation, or overlying a thin black shale (Black Cove Formation) above Table Point Formation or intercalated within Goose Tickle Group shaly flysch.

FRONTAL EDGE OF THE STACK

The northwestern edge of the stack can be traced from the far southwest of the stack, northeast to Georges Lake and beyond to the area of Fox Pond. Topographically, the terrain immediately northwest of the frontal edge of the stack is characterized by steep, north to northeast-trending and locally, quite linear rock scarps coupled in parallel to the northwest by narrow, deep, linear valleys. The scarp-faced ridges are interrupted only where breached structural windows swing the frontal thrust inland as near Island Pond and Grand Lake Brook. The linear scarps consist mostly of Table Head Group limestone (footwall) and some Cambrian Port au Port Group dolostone of the hangingwall of the stack. The deep valleys and the terrain west of the TCH is underlain by the shaly flysch and broken formation, except for a few outcrops of Daniels Harbour Member.

For ease of description, the frontal zone is subdivided into three areas: 1) southwest of Grand Lake Brook; 2) between Grand Lake Brook and Georges Lake and 3) northeast of Georges Lake.

1) Southwest of Grand Lake Brook

In the area southwest of Grand Lake Brook, the frontal thrust follows topography and generally trends north–south and is projected to intersect with the Grand Lake thrust about 7.5 km south of Grand Lake Brook; mapping of the footwall terrane is ongoing in the southern half of this zone. In the most southerly area, near Trout Brook Pond, the sequence consists of limestone and minor dolostone of the Table Point Formation overlain by thin shale, a few metres of Daniels Harbour Member limestone conglomerate and Goose Tickle Group shaly flysch. Northeast-trending and plunging, southeast-verging overfolds and upright folds associated with a west-dipping cleavage deform this sequence just 100 m from the sole of the stack.

To the north by the TCH on “Gallants hill”, gently northeast-dipping, fossiliferous Table Point Formation limestone is apparently succeeded by a thick interval of complexly faulted, sub-vertical, north-striking, Table Cove Formation ribbon limestone and shale. A number of northeast-trending, high-angle faults displace the frontal thrust, and the footwall between Trout Brook Pond and “Gallants hill”. The appearance of a thick interval of Table Cove Formation rocks, not seen in a conformable and essentially co-eval succession 3 km to the south, implies rapid facies changes in the Middle Ordovician stratigraphy of the footwall succession. It also allows for the possible repetition of the sequence from south to north along a number of thrusts.

2) Grand Lake Brook to Georges Lake

The zone between Grand Lake Brook and Georges Lake is dominated by cleaved shales having thin interbeds of brown-weathering sandstone and siltstone and minor cross-laminated limestone. Much of this succession sequence is broken formation. Pyrobitumen is common in fractured strata in this zone. Daniels Harbour Member limestone conglomerate outcrops by Dozer Pond (*see* Figure 2 and Georges Lake map sheet, 12B/16) and locally along the TCH. Thrusts carry Table Head Group carbonates over the shaly flysch of the Goose Tickle Group west of Island Pond (Plate 15) and immediately south of the eastern arm of Georges Lake. The thrust near Island Pond is folded about a northeast-trending and plunging synclinal overfold which has a subvertical to slightly overturned west limb. This places the footwall flysch above the hangingwall Table Point Formation in outcrops along the TCH (Plate 16). Kinematic indicators and a stretch-

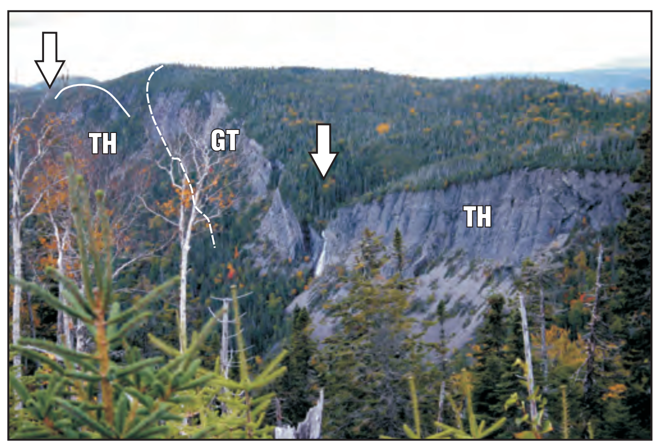

Plate 15. *View of cliff above Island Pond showing Middle Ordovician Table Head Group limestones (TH) thrust upon Goose Tickle Group flysch (GT). Right arrow indicates thrust. Dashed line is approximate stratigraphic contact of flysch with underlying Table Head Group. The lower limestone is folded in the west suggesting a rollover above a lower thrust (left arrow) that places the lower panel above broken flysch formation.*

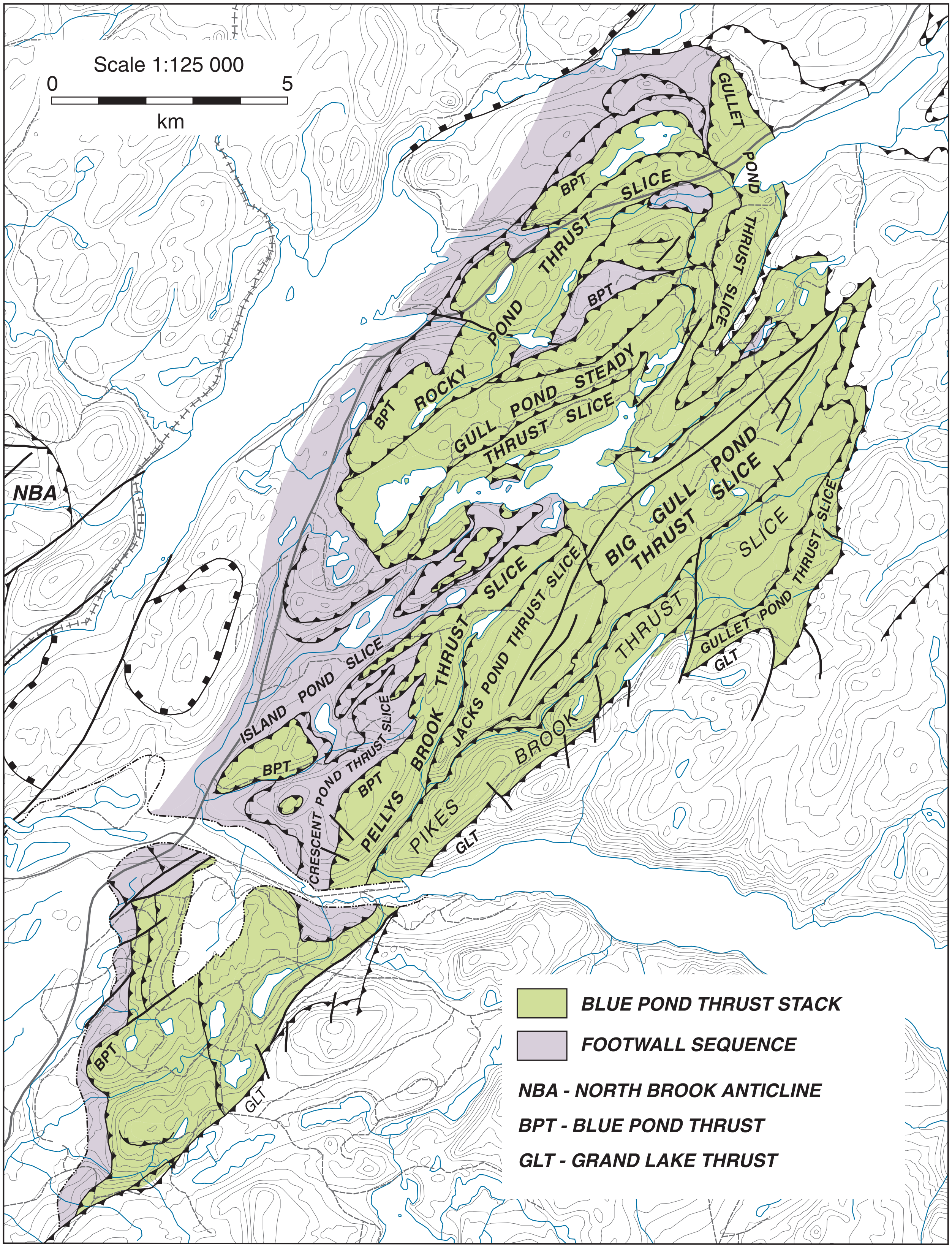

Figure 5. *Simplified map of the hangingwall and footwall of the Blue Pond Thrust Stack showing individual thrust slices named in the discussion.*

Plate 16. *A vertical stretching lineation associated with a steeply dipping strongly flattened and foliated Table Point Formation. The vertically dipping shear zone is part of a thrust exposed on the west limb of a southeast-verging, synclinal overfold. TCH southwest of Georges Lake.*

ing lineation suggest northwestward overthrusting along the fault. This thrust may link with the lower thrust of the Crescent Pond thrust slice mapped east of Island Pond.

Near the east arm of Georges Lake, the Table Head Group is juxtaposed with Goose Tickle Group along a subvertical fault. The Table Head Group sequence strikes northeast, is overturned to the southeast, and youngs to the northwest. This places the Table Point Formation structurally above the regionally conformably overlying Table Cove Formation. Followed southwestward, the overturned succession is gently warped about moderate to steeply south-plunging axes and swings through the vertical to become nearly upright close to the fault contact with Goose Tickle Group shales. The fault strikes 205° to 214° and dips 86° to 88° to the west. A near-vertical lineation is found in the limestone of the fault plane and a zone of flattening and transposition is present in the limestone close to the fault. These fabrics associated with the fault are consistent with those mapped close to thrusts in carbonate stacks elsewhere in the Humber Zone (Knight, 1994). This suggests that the fault is a thrust that is now inverted and whose hangingwall of limestone consisted of a downward-facing, overturned succession before it was folded. In both cases, the folding is believed to be D_2.

3) Northeast of Georges Lake

Previous mapping of the area northeast of Georges Lake (Knight, 1996a, b) showed that the thrust stack was folded about the northeast closure of the antiform. Although this remains likely, re-evaluation of the earlier mapping suggests that the Table Head and Goose Tickle groups in this area, which were shown in the hangingwall of the stack, are more likely to fall into the footwall sequence. Additional mapping should, hopefully, clarify the relationships in this area.

STRUCTURAL WINDOWS

Several, small to large, closed and breached footwall windows have been mapped within the BPTS. Southeast of the TCH, between Pinchgut Lake and Blue Pond, footwall windows are exposed beneath the Rocky Pond and Gull Pond Steady thrust slices. Three kilometres southwest of Pinchgut Lake, uppermost Table Point Formation limestone, Goose Tickle Group slate and Daniel's Harbour Member conglomerate occupy the core of a small antiform, surrounded by Cambrian hangingwall carbonates. Wide shear zones, and repetition of the Cambrian stratigraphy in the hangingwall to this window, suggest that a hangingwall duplex is part of the Rocky Pond thrust slice.

Sheared Table Point Formation limestone occupies a small window beneath the Rocky Pond thrust in a large outcrop on the TCH, just east of Blue Pond. Northwest-facing and dipping limestone and dolostone (Boat Harbour Formation?) forms the hangingwall (Plate 17). This window may be a small closed structure or could form part of a larger breached window lying just southeast of the frontal edge of the stack. This implies that the window would be linked to the frontal thrust along the valley of Pinchgut Lake Brook (Figures 3 and 5).

A third window is exposed on the TCH, 1 km west of Pinchgut Lake (Knight, 1996a, b) where nodular limestone of the Table Point Formation and overlying shaly flysch of the Goose Tickle Group lie beneath a hangingwall of folded Berry Head and Watts Bight formations (Plate 18). Two fabrics, which are almost co-planar and two sets of folds with

Plate 17. *Blue Pond Thrust (arrow) structurally overlain by steeply dipping (towards left) Boat Harbour Formation that faces to the left (NW) and underlain by sheared Table Point Formation limestone. TCH just east of Blue Pond.*

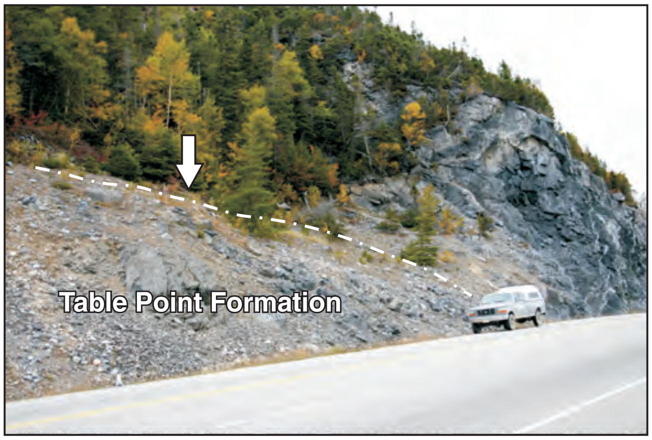

Plate 18. *A footwall window along the TCH near Pinchgut Lake. Dotted line marks approximate trace of thrust; mylonitic limestone (Plate 18) indicated by small arrow. Details of hangingwall are shown in Plate 11. Footwall of upper Table Point Formation and Goose Tickle Group.*

opposite sense of vergence, are preserved in the hangingwall. An earlier shear fabric is associated with downward-facing D_1 folds. It is overprinted by a later D_2 cleavage associated with southeast-verging folds. Disrupted, but essentially in place, blocks of a strongly mylonitic limestone occur above the footwall window. The mylonite is deformed by east-verging D_2 folds (Plate 19).

A previously identified window outcrops along the shore and on small islands of Big Gull Pond (Knight, 1996a, b) where Table Point Formation limestone is enveloped by Cambrian carbonate rocks. This window lies close to the branch point of several thrusts in the stack.

The rocks in the Big Gull Pond window are probably part of the Crescent Pond thrust slice, which occupies a major part of a large breached footwall window southwest of

Plate 19. *D_2, southeast-verging buckle folds in the limestone mylonite indicated in Plate 18.*

Big Gull Pond, near Island Pond. The breached window, which opens to the northwest into the footwall terrane of the leading edge of the stack, emerges from the core of the northeast-plunging antiformal stack. Limestone of the Table Point Formation, carried in the Crescent Pond thrust slice, are folded by an anticline close to the tip of the thrust slice. The limestone is thrust over shaly flyschoid rocks of the western part of the window that include strongly cleaved broken formation and units of the Daniel's Harbour Member. (This shaly terrane is informally named the "Island Pond slice" pending further mapping.) Black Cove Formation shales, Daniel's Harbour Member conglomerate and Goose Tickle Group flysch occupy a small breached antiformal window through the base of the Crescent Pond thrust slice near Crescent Pond. This window may indicate a blind thrust below the Island Pond slice. Outliers of the BPTS straddle the Crescent Pond thrust slice and its footwall west of Crescent Pond.

The Crescent Pond thrust slice can be mapped south to the Grand Lake Brook valley where it is obscured by glacial outwash and till. However, a single outcrop of deformed Daniels Harbour Member conglomerate occurs 2 km west of Grand Lake on the southern side of the valley. The conglomerate is associated with dark-grey slates of the Goose Tickle Group. The outcrop sits immediately below structurally overlying Cambrian Port au Port Group dolostone which are part of the BPTS. This implies that, in this area, at least, the footwall to the BPTS can be traced beneath the stack to within a kilometre or so of the Grand Lake Fault. If the geology north of the Grand Lake Brook valley is projected southward it is reasonable to place this outcrop within the Island Pond thrust panel!

REGIONAL AEROMAGNETIC SETTING

The area of the BPTS and the domains (3B and 4A) underlain by Pinchgut Lake Group rocks coincide with a very large negative aeromagnetic anomaly (digitally remodelled maps of old series GSC maps; GSC, 1968a, b, c, d, 1969a, b). The anomaly (Figure 6) suggests that basement lies deep below the southeastern slices of the stack, where Reluctant Head Formation occurs at the soles of thrusts. However, depth to basement begins to shallow in the vicinity of Big Gull Pond below the thrusts with Penguin Cove Formation at their sole. It is possible that this aeromagnetic configuration is purely coincidental with the structural order and geometry of the stack. However, it is also possible that it reflects a fundamental, deep structure, such as fault-bounded basement, which may have formed a buttressing ramp and consequently controlled the formation of the stack as well as influenced the stack's internal thrust geometry. A broad, positive magnetic expression marks the eastern edge of the NBA and coincides with areas underlain by Penguin Cove Formation, implying shallow basement just northwest of the BPTS.

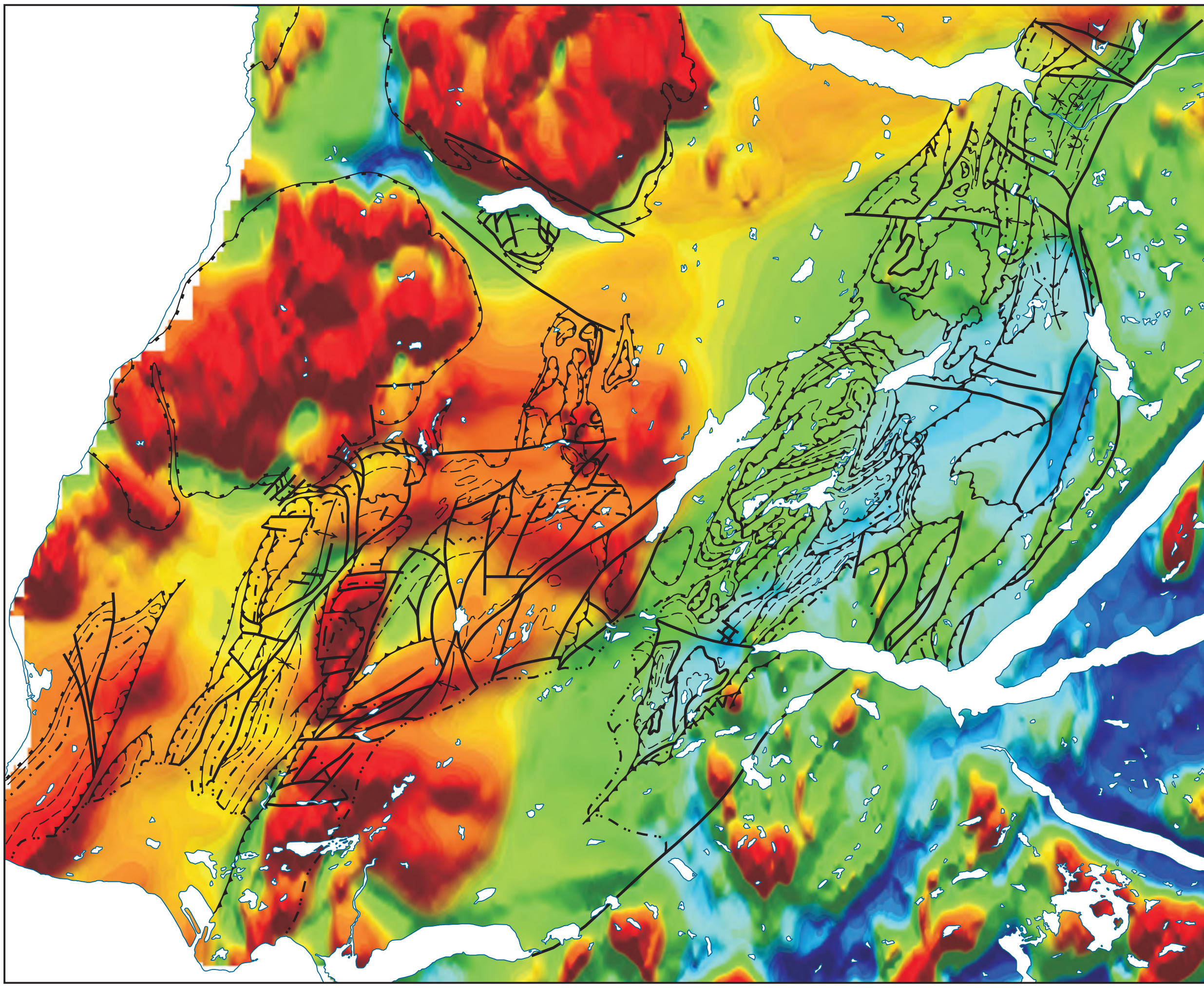

Figure 6. *Regional aeromagnetic map roughly superimposed with the regional geology showing the correlation of the Blue Pond Thrust Stack with a large negative anomaly. Structures such as the North Brook Anticline correlate with magnetic highs indicative of underlying Grenvillian basement.*

Therefore, it is reasonable to project Penguin Cove Formation rocks eastward to lie above the basement beneath the northwest part of the BPTS.

DISCUSSION

The BPTS is being re-evaluated in the light of recent mapping of the area near Grand Lake and re-examination of parts of the stack mapped in 1995. The BPTS was originally defined as an antiformal structure that consisted of a series of thrusts that carried Middle Cambrian through Middle Ordovician carbonate shelf rocks. The Blue Pond thrust was defined as the floor thrust to the complex. The complex was interpreted to structurally overlie an extensive footwall comprised of Middle Ordovician carbonate and flyschoid rocks.

The recent mapping shows that northeast of Grand Lake, the antiformal stack plunges to the northeast opening up its footwall toward the southwest. The geological shape of the northeastern part of the stack is that of a distorted butterfly, formed by two antiforms separated by a narrow pinched syncline. This syncline trends southwest essentially into the hinge zone of the complex which is centred on an area from Big Gull Pond to southwest of Island Pond. A large north-northeast-plunging, broadly arcuate antiform marks the northwest wing of the complex toward Pinchgut Lake; the second antiform is more northeasterly in trend and plunge. Knight (1997) interpreted this two-part form to reflect back-thrusting of the northwest antiform over the southeastern part of the stack.

Two groups of thrusts, a group to the northwest and the other to the southeast, form the two wings of the complex. The northwestern group comprises a number of thrust slices that face and dip northwest toward the foreland and are imbricated in the core of the northern part of the stack.

Higher thrusts appear to wrap around the duplex accentuating the plunge of the fold. The few kinematic indicators in the thrust zones indicate that the sense of movement is toward the northwest.

The southeastern group comprise thrust slices stacked in piggy back fashion and their panels face and dip, for the most part, to the southeast, i.e., hinterland duplexes. Although the thrust panels are folded in the core of the antiform, they appear to pass southwest into simply structured southeast-dipping panels that can be traced southwest to Grand Lake. Stratigraphic relationships across thrusts, plus intense stratigraphic thinning, strong zones of flattening and well-defined vertical stretching lineations, close to the thrusts, provide evidence of northwestward overthrusting of panels. In the core of the stack, some of the thrusts in the second group have folded tips suggesting a characteristic horse duplex form. There is no hard evidence, however, to link thrusts from each group across the hinge of the stack in spite of the fact that both sets of thrusts converge toward the axial zone of the dual winged structure of the BPTS. Nonetheless, further mapping of the Big Gull Pond area may show that the small foreland-dipping duplexes near the pond may be the tip of the Jacks Pond thrust slice or higher thrust slices of the southeastern thrust group. Only the Gullet Pond thrust slice appears to fold around the two wings of the stack.

The statigraphy of the Cambrian succession in the two groups of thrust slices also differ. The Penguin Cove Formation forms the sole of the northwestern slices and is overlain by rocks of the March Point Formation and a 3-member Petit Jardin Formation. This is in contrast to the southeastern thrust group where the Reluctant Head Formation defines the sole of the thrust slices and is overlain by a thick, predominantly dolostone, succession in the overlying Port au Port Group. As noted in the description of the BPTS, the presence of the Penguin Cove Formation in the northern group of thrusts suggests a close tie with rocks now exposed in the North Brook Anticline, just 7 km to the northwest.

Southwest of Grand Lake, the southernmost rocks of the BPTS are hosted by a large outlier consisting of rocks ranging from the Reluctant Head Formation up into the St. George Group. Thrusts and structures in the outlier swing from north–south trending along the leading edge of the stack to east-trending in the most southwesterly part of the outlier, where, the succession is polydeformed. Reluctant Head Formation rocks at the sole of the thrusts may indicate that they are probably the southern extension of the south-eastern-facing imbricates of the stack. The east-trending structures of the southern area indicate that the outlier preserves the southwestern lateral ramp of the stack.

The recent mapping southwest of Big Gull Pond shows that the Middle Ordovician footwall succession is constructed of several imbricate thrust slices. Newly defined thrust slices include the Crescent Pond thrust slice and the Island Pond slice. Thrusts are readily mapped where Table Head Group carbonates structurally overlie Goose Tickle Group shaly flysch. Others may be hidden in the flysch itself (*see below*). Close to the leading edge of the stack, the footwall thrusts are deformed about northeast-plunging overfolds. The thrusts steepen and are locally inverted on the limbs of southeast-verging synclines to reverse or invert the structural order of stratigraphy across the thrusts. Thrust slices in the core of the stack, such as the Crescent Pond thrust slice, are folded about anticlines suggesting typical horse duplex structure. Breached antiformal windows through the Crescent Pond thrust slice may indicate that blind thrusts occur below the flysch-dominated Island Pond slice.

Northwest-verging folds associated with a southeast-dipping cleavage are correlated with the northwestward emplacement of the thrusts in the stack and assigned to the first deformational event. However, widespread southeast-verging folds and northwest-dipping cleavage, assigned to D_2 deformation, cut and reorient the earlier D_1 structures. How much the later deformation modified or created the antiformal stack is one of the questions that awaits further mapping and consideration. Nonetheless, outcrops in the area, southwest of Grand Lake, and the structures of the footwall sequence indicate that D_2 greatly influenced the final architecture of the stack, including its northeast plunge. In particular, Cambrian dolostones with strong D_1 fabrics are deformed into large and small D_2 folds. The D_2 deformation also affected the footwall sequence (*see below*). Together, this suggests that the large anticlinal folds that define the butterfly outline of the stack may be principally D_2 structures. It is worth noting, that the general trend and orientation of the southeast-verging and northeast-plunging D_2 structures mimics those of the NBA and other pop-up structures to the west of the stack; whether or not this implies a common cause is uncertain.

The new mapping coupled with the regional aeromagnetic data appears to confirm that the stack was carried over a foreland-basin footwall sequence and may be both detached from basement and far carried. This is indicated by the presence of several footwall windows beneath the stack north of Big Gull Pond and footwall rocks immediately below hangingwall Cambrian dolostone less than 2 km from the Grand Lake thrust, just southwest of Grand Lake. Without adding the internal shortening linked to the internal thrust panels, the leading edge of the BPTS lies nearly 10 km from the Grand Lake thrust, suggesting that the stack is a substantial overthrust.

The assembling of the stack was clearly complex, probably reflecting progressive shortening associated with northwest overthrusting and stacking of the shelf rocks during D_1 regional deformation. Foreland propagating thrust complexes are generally modelled to reflect a stacking order of early, rear thrusts carried by later forward thrusts to form hinterland-dipping piggy-back duplexes and imbricate fans or sack-of-flour-stacked imbricate antiforms (Ramsey and Huber, 1987). If this is applied simplistically to the BPTS, it would then imply that the imbricated antiformal southeast wing, soled by Reluctant Head Formation, preceded the formation of the northwest wing stack, soled by the Penguin Cove Formation. Subsequent ramping of the floor thrust, through the Middle Ordovician foreland basin sequence, lead to collapse of the footwall and propagation of new hinterland dipping-duplexes below the BPTS.

The highest thrust panel, the Gullet Pond thrust slice, is soled by Reluctant Head Formation and is deformed by both parts of the stack. This supports the simple foreland propagating, piggy-back model outlined above. However, in the core of the stack, it is not possible to map thrusts across the hinge zone from one wing of the stack to the other, and the facing direction of the two wings of the BPTS have opposing polarity and different internal stratigraphy in Cambrian age rocks. This begs the question, why does the northwest wing preserve foreland-dipping thrust panels and not hinterland-dipping duplexes as seen in the southeast wing of the stack as a whole? The presence of the many footwall windows under the northern part of the stack constrain the interpretation of this area as host to a stack of foreland dipping thrust panels. It is important to also recognize that there are no thrusts in the core or middle levels of the stack that link across the hinge zone of the stack as a whole. Ferguson (1998) tried to overcome this problem by interfingering the Penguin Cove and Reluctant Head formations as the common sole to the thrust slices. This is unlikely, however, because the older stratigraphic age of the Penguin Cove Formation (early Middle Cambrian) rules out correlation with the stratigraphically younger Reluctant Head Formation (early Late Cambrian). This suggests, therefore, that both the northwest antiformal wing of foreland dipping panels and the southeastern antiformal wing of hinterland dipping panels climbed and stacked above a common footwall ramp and flat(?) comprised of Middle Ordovician foreland basin shelf carbonate and flysch.

This interpretation would indicate that unless there was a pre-thrusting configuration that juxtaposed the Reluctant Head Formation below or against the Penguin Cove Formation (as might occur if there was for example earlier Taconian? extensional faulting) the floor thrust that carried and imbricated the southeast wing of the stack (soled by Reluctant Head Formation) should have originally propagated structurally higher than that carrying the northwest wing of the BPTS. These constraints would require, that in a progressive foreland propagating thrust stack that the floor thrust would have had to transfer to a lower stratigraphic level, below the northwest wing of the stack abandoning the higher level thrust located below the southeast wing.

Ramsey and Huber (1987) suggest that foreland-dipping duplexes form when 1) slip on individual horses exceeds the length of the horse, 2) excessive uplift of both horse and roof thrust leads to tilting of strata in the horses toward the foreland as succeeding thrusts propagate and 3) emplacement of the later horses occurs behind those formed earlier. This means, by its very nature, that the polarity of depositional belts or facies within stratigraphic units will be reversed and that the facies, etc., between each individual foreland-dipping panel will become mismatched.

If the floor thrust did, indeed, transfer to a lower stratigraphic level, beneath the northwest antiformal wing, then the constraints outlined by Ramsey and Huber (1987) may have been overcome if the shortening was accommodated by inversion along a basement ramp. The ramp, which is supported by regional aeromagnetic data, occurs below the northwest wing of the BPTS. During the inversion, the forward thrust slices would have climbed up the basement ramp. In so doing, excessive slip and uplift placed the slices above a footwall flat of Middle Ordovician foreland basin strata to form the foreland-dipping duplexes. In this model, the Rocky Pond thrust slice, which lies to the northwest and includes the thickest section of Penguin Cove Formation, formed before and moved ahead of the Big Gull Pond thrust slice which lies to the south. Penguin Cove Formation in the latter panel is only thin below the March Point Formation. In the smallest, most southerly, foreland-dipping panel just south of Big Gull Pond, only the Petit Jardin Formation occurs above thin units of the March Point Formation. In combination, these panels may indicate that the floor thrust to this part of the stack climbed, perhaps in step-like manner, upward through the succession as the shelf was shortened.

Whether or not this model fully explains why there is a common footwall to both parts of the stack, and why, when considering the structural geometry of the stack as a whole, that the two wings meet at a common hinge zone, located in the zone of Big Gull Pond southwest to Island Pond, is uncertain. It probably can be argued that both wings of the stack responded to the basement ramp and as a result the stacking order could have been different than that suggested earlier. Also, it is conceivable that the floor thrust to each group of thrust panels was different. If so, at some time in the propagation of the thrust stack, the locus of shortening transferred from a lower to a higher stratigraphic level by back stepping. In this model, the forward duplexes which had already climbed the ramp were abandoned in favour of activation and generation of the rear duplexes. Once the lower floor thrust in the Penguin Cove Formation was abandoned, shortening was then accommodated above the new floor thrust below the Reluctant Head Formation. The transfer served to shorten the more easterly succession which in turn climbed the basement ramp leading to tilting of the foreland dipping panels. Panels in the southeastern part of the stack were physically tightened and back limbs were rotated towards the vertical. Locally, the upper parts of the northwestern thrust slices may have been back thrust over the southeastern antiformal wing close to the hinge zone (Knight, 1997). Whether or not D_2 structures formed in this later stage of deformation or as part of a later and separate period of deformation, perhaps timed with regional Acadian events, is not resolved.

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