Current Research (2007) Newfoundland and Labrador Department of Natural Resources
Geological Survey, Report 07-1, pages 45-54

GEOLOGICAL STUDIES IN THE LOMOND (NTS 12H/5) AND ADJACENT MAP AREAS OF THE EASTERN PART OF THE GOOSE ARM THRUST STACK, WESTERN NEWFOUNDLAND

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ABSTRACT

Deformed and low-grade metamorphosed, lower Paleozoic shelf rocks underlie the Lomond (NTS 12H/05), the northeast part of the Pasadena (NTS 12H/04), the westernmost part of the Deer lake (NTS 12H/3) and the Cormack (NTS 12/6) map areas. These areas were subject to detailed, 1:50 000-scale bedrock mapping and study for the first time, in 2006. The area is dominated by several large folded thrusts and shear zones as well as large map-scale folds. At least two deformations affected the rocks that were deposited on a more distal part of the ancient Paleozoic margin of Laurentia, through the Early Cambrian to the Middle Ordovician.

The deformed shelf rocks are recrystallized to marbles of different colours, compositions and textures. Carboniferous lacustrine rocks of the Visean Rocky Brook Formation unconformably onlap the eroded thrust stack along the northwest margin of the Deer Lake Basin.

INTRODUCTION

The Goose Arm thrust stack (GATS) is a large regional thrust stack, 75 by 20 km, and is one of three, thin-skinned thrust stacks that are an important but under-reported and under-appreciated part of the foreland fold and thrust belt in western Newfoundland (Figure 1). It is host to polydeformed, shallow-water siliciclastic and carbonate shelf rocks that were deposited along the lower Paleozoic margin of Laurentia. The western part of the stack, in the vicinity of Goose Arm and Corner Brook, was mapped in the early 1990s by Knight (1994), but the northeastern part of the stack, in the area north of Deer Lake to the southern boundary of Gros Morne National Park, was not mapped at that time. Although the northeastern unmapped area is included on 1:50 000- and 1:250 000-scale geological maps (Williams *et al.*, 1983, 1984; Williams and Cawood, 1989; Owen, 1991), the northeastern part of the stack remained unmapped, in the sense that the latest stratigraphic subdivisions of the lower Paleozoic shelf sequence, defined over the last thirty years elsewhere in the region, had not been applied until now, leaving the internal stratigraphic and structural architecture of the area largely unresolved.

This study summarizes in a very cursory manner, the commencement of the systematic mapping of this area by the Geological Survey of Newfoundland and Labrador (Figure 2), mindful that important areas within the Lomond map area and the northern edge of the Pasadena map area, have not been mapped even though mapping along a large number of woods roads has occurred nearby. These important gaps in the mapping and geological knowledge include, for example, Bonne Bay Big Pond (BBBP), a lake that has a meandering, rocky shoreline of close to 30 km in length, a multi-kilometre square area of woods that form an embayment into the southwest corner of the Long Range Massif, east of the pond and Route 430, and all the area from the pond, west to the contact with the Humber Arm Allochthon. Any conclusions raised here are, therefore, only preliminary.

A network of recent woods-roads and skidder trails provide access to this generally rugged, picturesque area and Bonne Bay Big Pond sits in the centre of the area. It, and several other ponds, remain to be mapped next year and will be critical to the geological understanding of the area. The rocks have been deeply incised, and truncated, by glacial erosion and overlain by glacial till and gravels. Long, linear valleys and ridges that have a north to northeast trend, in different parts of the map area, are superimposed on the underlying geological structure (Plate 1). Finger lakes surrounded by high limestone scarps are a common feature of the geographic terrain.

Westfield Minerals conducted mineral exploration in the area in the 1980s. This work produced an unpublished regional map of the area by Keith Glover (Westfield Miner-

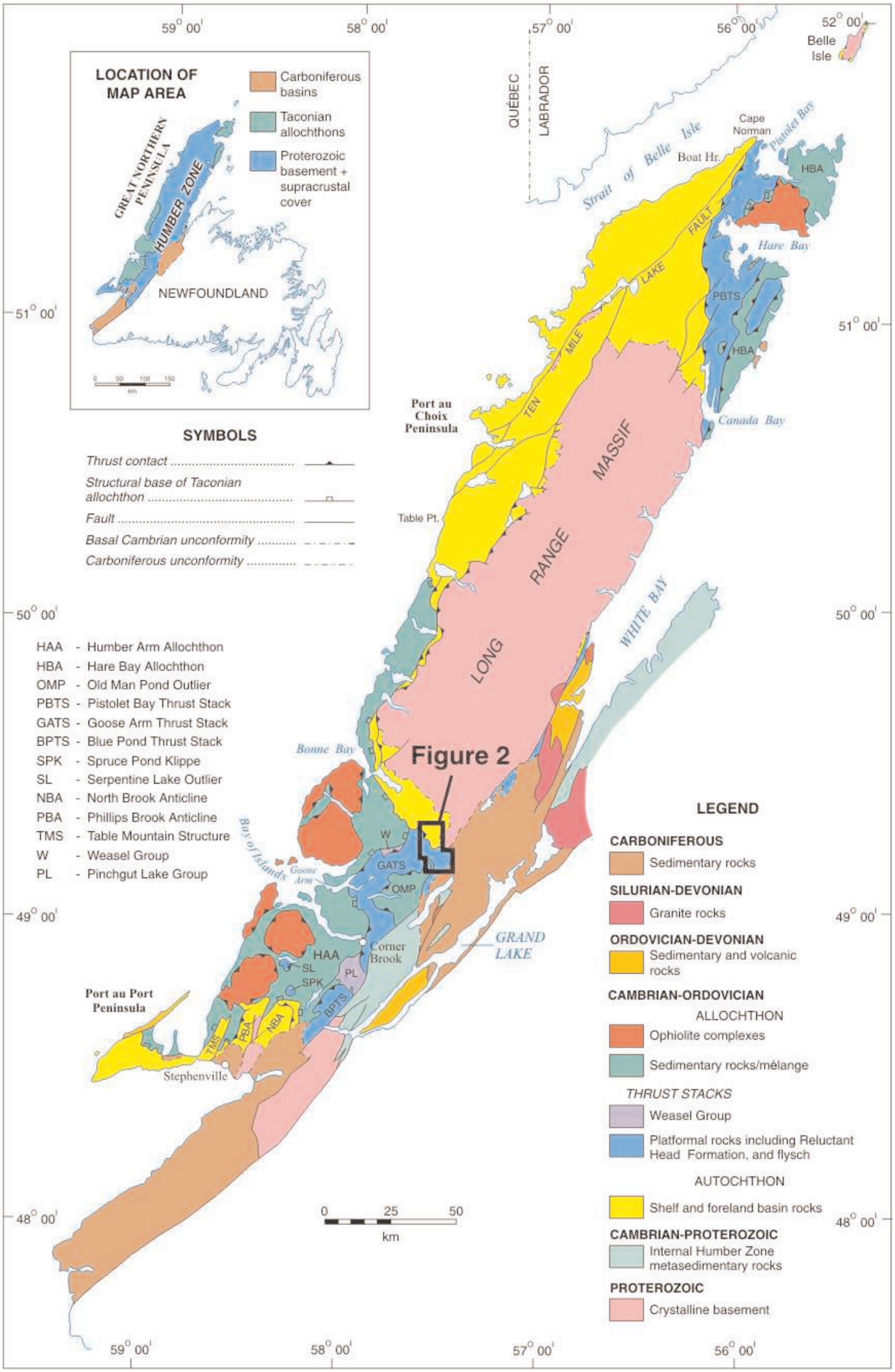

Figure 1. *Regional geology map of western Newfoundland showing study area.*

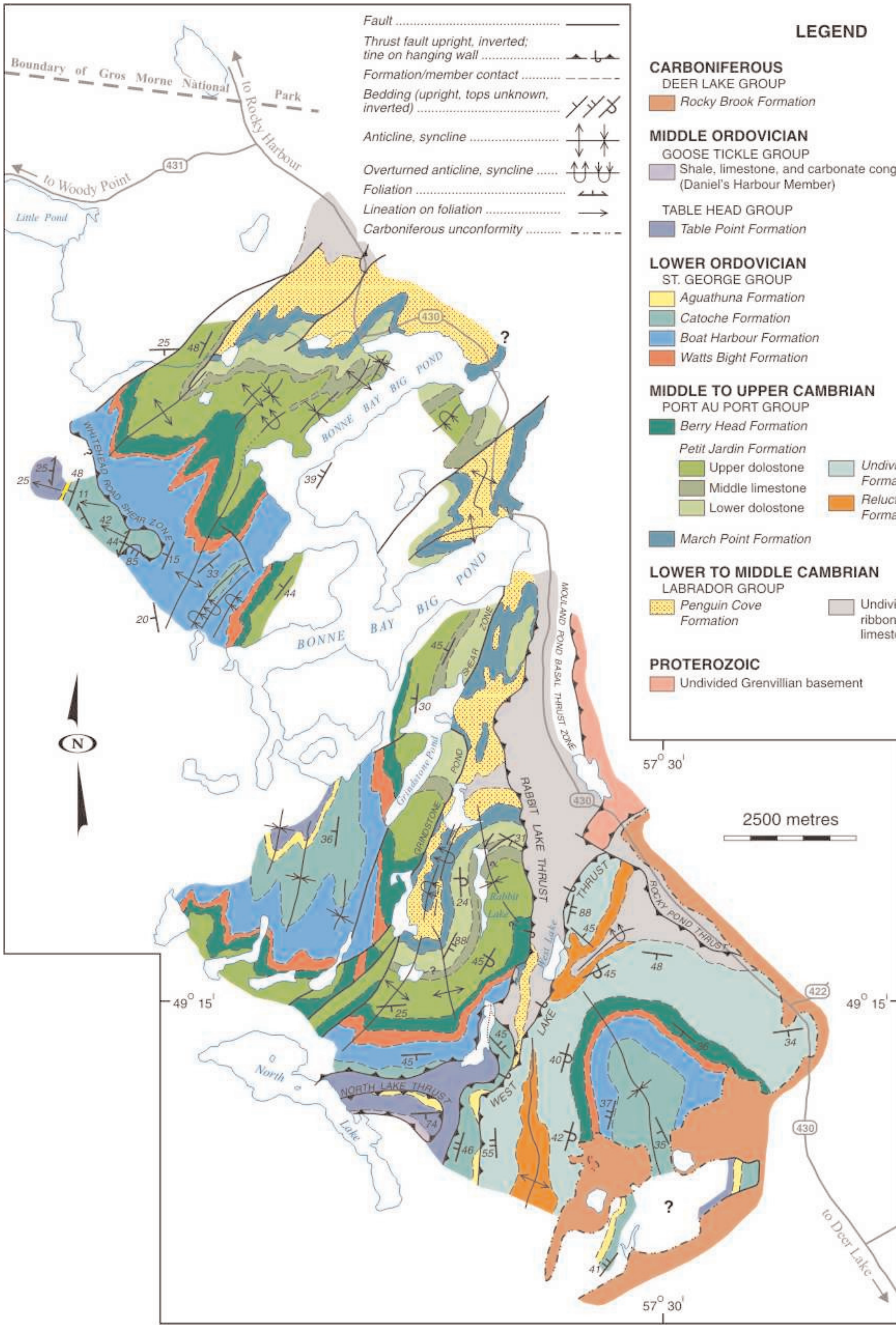

Figure 2. *Preliminary geology map of part of the Bonne Bay Big Pond area.*

Plate 1. *One of many long, unnamed finger lakes that point through forested hills of the Lomond map area.*

als Ltd., 1983) and located a number of small, base-metal showings.

STRATIGRAPHY

The Lower Paleozoic shelf rocks in the Lomond and northeast part of the Pasadena map area, as elsewhere in western Newfoundland, are divided into four main groups – in ascending order: Labrador, Port au Port, St. George and Table Head groups (Figure 3). The stratigraphy is slightly different in the two areas, west and east of the Rabbit Lake thrust. West of the thrust, the succession includes rocks of the Labrador Group to the Table Head Group, whilst east of the thrust, the succession begins with Cambrian grey phyllites and the Reluctant Head Formation and is overlain by carbonate rocks of the upper part of the Port au Port Group through to the Table Head Group.

LABRADOR GROUP

The Labrador Group in the map area comprises a lower slate-phyllite formation equated with the Forteau Formation and an upper heterolithic unit of quartz arenite, sandstone, limestone and shale, correlated with the Penguin Cove Formation.

The lower phyllitic unit consists of rusty-weathering, dark-grey to silvery-grey phyllitic slates that have leaves and thin ribbons of very fine sandstone and limestone; the unit dominates the eastern terrane. The phyllites occur in one area beneath the Penguin Cove Formation in the western terrane along a valley floor close to Grindstone Pond. Highly deformed units of white quartz arenite also locally lie within the phyllites near West Lake. Both localities suggest that that the Penguin Cove Formation overlies the phyllites. The Penguin Cove Formation consists of intercalated metre-thick units of white quartz arenites and heterolithic, thin-bedded grey shale and brown-weathering grey ribbon sandstone; minor limestones also occur. The quartz arenites occur at the top of the sequences indicating that the formation is a succession of shallowing- and cleaning-upward siliciclastic rocks that were deposited in a distal setting on the Labrador Group shelf. This distal setting is supported by the feathering out of the quartz arenite and thin ribbon sandstone to the southeast into the slate–phyllite unit with only local thin ribbons of sandstone near West Lake. However, the phyllites are succeeded by the Reluctant Head Formation.

The succession has some similarity to that in Canada Bay and at Goose Arm (Knight, 1987; Knight and Boyce, 1991) where the Penguin Cove Formation is known to include both late Early Cambrian and Middle Cambrian fossils (Knight and Boyce, 1987, 1991).

PORT AU PORT GROUP

The Port au Port Group, when fully developed, consists of the March Point, Petit Jardin and Berry Head formations. In the map area, all three formations underlie the terrain west of the Rabbit Pond thrust. However, in the West Lake thrust (Figure 2), rocks of the Reluctant Head Formation underlie the Port au Port Group rocks, in particular the upper part of the Petit Jardin Formation suggesting that the March Point Formation and lower two members of the Petit Jardin Formation give way eastward to the Reluctant Head Formation. Although not strictly part of the group, the Reluctant Head Formation will be described in this section.

The late Middle Cambrian March Point Formation is characterized in the map area by dark-grey, oncolitic and oolitic limestone as well as lesser burrowed, ribbon and rare stromatolitic limestone and minor shale. In contrast, the Petit Jardin Formation is dominated by a lower and upper member of variable, grey, dolostone, and a middle member of metre-scale sequences of limestone, dolostone and shale. Variably grey-coloured dolostones also dominate a lower member in the Berry Head Formation below an upper member of limestone and dolostone. Facies in the dolostone are generally arranged in metre-scale sequences and range from subtidal, burrowed and microbial mounds to high-energy oolitic dolarenite, intraclastic dolarenites and dolrudstones to tidal flat dolostone/dololaminite, argillaceous dolostone and shale. It should be noted that no thick intervals of dolarenite have been identified.

The middle member of the Petit Jardin Formation consist of cyclic oolitic and intraclastic grainstone, stromatolitic (and rarely thrombolitic boundstone) mound beds, and parted and burrowed dolomitic limestone, overlain by dololaminite and dolomitic shales. The upper member of the Berry

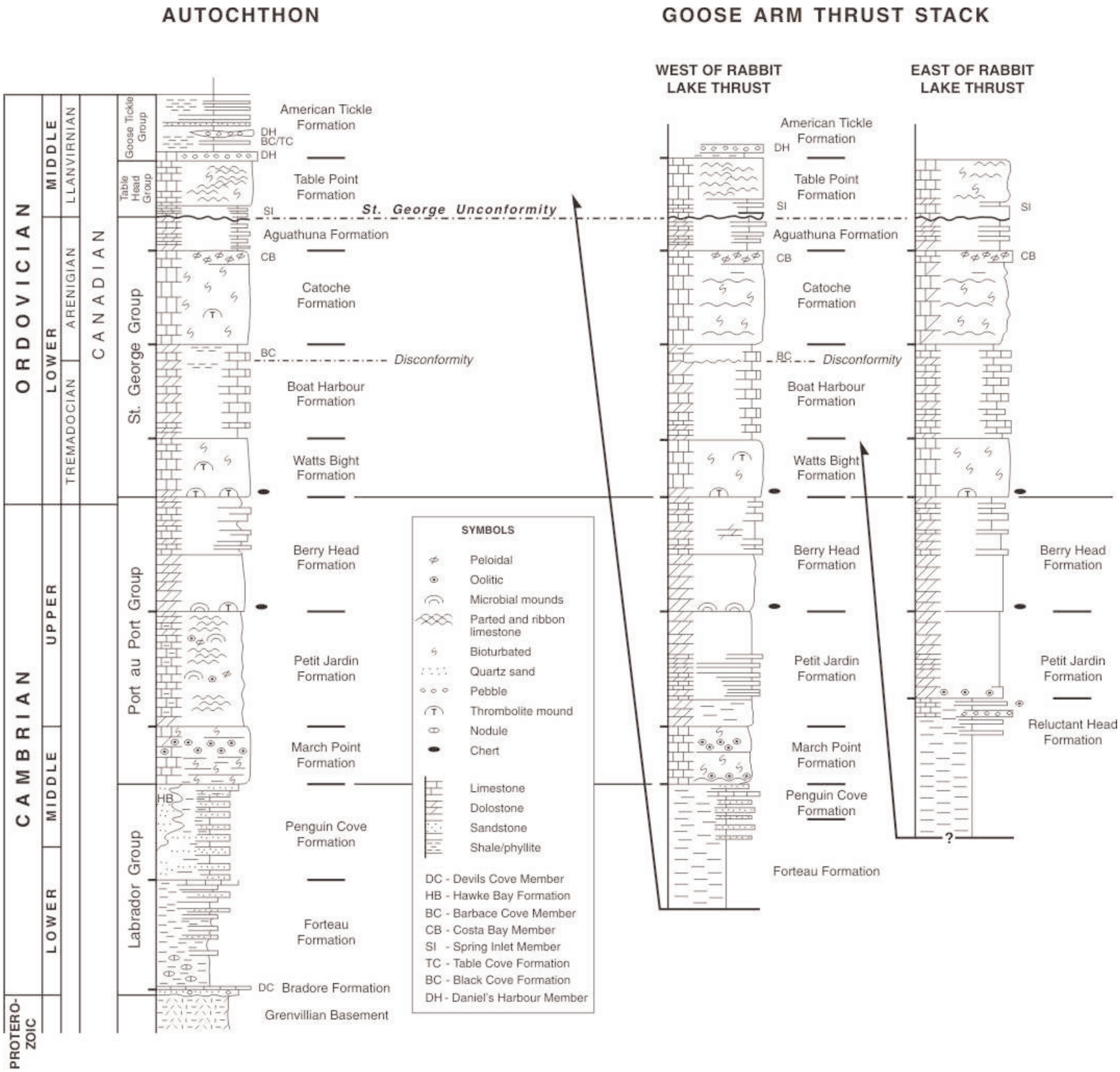

Figure 3. *Stratigraphy of the Cambro-Ordovician shelf rocks in the Goose Arm thrust stack, with comparison to the stratigraphy of the autochthon seen elsewhere in western Newfoundland.*

Head Formation consists of metre-scale limestone-dolostone cycles of parted, burrowed, stromatolitic and laminated and mud-cracked limestone and dololaminite.

The Reluctant Head Formation, which is known to span the late Middle Cambrian to early late Middle Cambrian near Goose Arm (Knight and Boyce, 1991; Boyce *et al.*, 1992), underlies dolostone in the West Lake thrust slice east of the Rabbit Lake thrust. The dolostone is correlated with the Upper dolostone of the Petit Jardin Formation. The Reluctant Head Formation comprises phyllite, dolomitic and argillaceous ribbon limestone, oolitic grainstone and limestone conglomerate, the latter consisting largely of clasts of intraformational origin.

The eastward change from a shallow, high-energy succession of oolitic grainstones in the March Point Formation to the ribbon limestones, shales and limestone conglomerates of the Reluctant Head Formation reflect an eastward-deepening (possibly steeply) ramping carbonate shelf margin when the carbonate shelf was established in the late Middle Cambrian. The stratigraphic relationship of the upper Petit Jardin Formation overlying the Reluctant Head Formation in the most easterly thrust slices, compared to the lower member of the Petit Jardin Formation overlying the March Point Formation, in westerly thrust slices, implies that the carbonate shelf was diachronously prograding eastward during the late Middle to early Late Cambrian.

ST. GEORGE GROUP

The Lower Ordovician carbonate rocks of the St. George Group consist of the Watts Bight, Boat Harbour, Catoche and Aguathuna formations. Both, the Watts Bight and Catoche formations are dominated by burrowed and stylonodular dolomitic limestones that have thrombolitic mounds. Chert is common in the Watts Bight Formation as are intercalated thin dololaminites. The Boat Harbour Formation is a succession of metre-scale limestone–dolostone cycles of parted, burrowed, stromatolitic and laminated and mud-cracked limestone and dololaminite. White limestone and burrowed grey limestone intercalated with dololaminite make up the Aguathuna Formation. The variable and relatively thin thickness of the Aguathuna Formation suggests that it is probably eroded below the St. George Unconformity.

TABLE HEAD GROUP

To date, only the Table Point Formation of the Table Head Group has been mapped in this area. These Middle Ordovician limestones comprise burrowed, stylonodular and grainy limestones. Dolostone interbeds with the limestone in the lower part of the formation and a limestone conglomerate (Daniels Harbour Member) were noted at the top of the formation locally just north of North Lake.

STRUCTURE

The area is characterized by northeast- to northwest-trending folds and faults and by west-dipping cleavages. Most regional structures verge to the east and the structural complexity and metamorphic grade of the strata increases to sub-greenschist facies, east of the Grindstone Pond Shear Zone. The latter separates an eastern terrane of large thrust panels from a broad western terrane of large northeast-trending folds. In the vicinity of Bonne Bay Big Pond, west-trending folds also occur and locally interfere with the northeast folds. Most of the northeast-trending folds are D_2 structures. The D_1 structure is essentially linked to the emplacement of thrusts and includes strongly foliated shear fabrics, isoclinal folds, and extensional fabrics and lineations.

EASTERN TERRANE

The Eastern terrane includes the Grindstone Pond shear zone and the Rabbit Lake, West Lake, Rocky Pond and the Mouland Pond thrust slices (Plates 2 to 6). Sole rocks to the slices consist of Penguin Cove Formation, in the west, and phyllite with sandstone and limestone ribbons in more easterly slices. In each case, the thrusts are now steepened to vertical and in some cases they invert so that the younger rocks of the footwall now overlie older sole rocks of the hanging wall. Footwall thrust panels are also inverted as, for example, near Rabbit Pond (Plate 7). The contact of competent carbonate rocks (Port au Port Group) with the underlying finer grained rocks is generally sheared in each thrust panel, suggesting detachment occurred at the incompetent/competent stratigraphic transition. The Grindstone Pond shear zone is a strongly deformed zone with dextural shear. Whether it is a folded and steepened thrust or a shear zone will await further mapping and evaluation.

Plate 2. *The Grindstone Pond shear zone along a woods road just east of the pond. In the foreground, highly sheared, flattened and mylonitized siliciclastic rocks of the Penguin Cove Formation dip into the hill. The shear zone is in contact (dashed line) with flat-lying dolostones of the Petit Jardin Formation hidden in the woods higher on the hillside, in the background.*

The most easterly thrust faults include the Rocky Pond and the Mouland Pond thrusts. Both of these thrust zones trend about north, and dip at shallow to moderate angles to the west. Strong shear fabrics, foliation planes, isoclinal folds, folded and augened quartz veins are common with a lineation that trends to the northwest. The shear zones are overprinted by D_2 folds and cleavage, indicating they are D_1 structures. The large folds associated with the thrust panels generally change from north- to northwest-trending when traced from northwest to southeast in the terrane.

Plate 3. *Strong mylonitic fabric developed in an argillaceous siltstone with thin sandstone interbeds in the Grindstone Pond shear zone. Lens cap 6 cm wide.*

Plate 4. *Right-handed shear developed in intercalated thin-bedded sandstone and phyllite of the Penguin Cove Formation in the hanging wall of the Grindstone Pond shear zone. Woods-road just east of the Grindstone Pond. Late-stage, low-angle slip planes offset the foliation. Lens cap is 6 cm wide.*

Plate 5. *The inverted Rabbit Lake thrust (arrow) in a roadside outcrop, south of West Lake. Dolostone augen (left of arrow) set in mylonitic limestone developed in inverted Boat Harbour Formation is the inverted footwall, that now structurally overlies the inverted hanging wall of Lower Cambrian grey phyllites of the Forteau Formation. Hammer is 29 cm long.*

Plate 6. *Close-up of foliated limestone and dolostone augen in Plate 5. Lens cap is 6 cm wide.*

WESTERN TERRANE

Without the benefit of the shoreline geology of Bonne Bay Big Pond, where a hidden thrust may lie, this is a broad terrane of open to tightly cylindrical, northeast-trending overfolds and recumbent folds. Variable plunge occurs along the fold axes and strong extensional zones of lineated shear cleavage occur in the core of some of the tight folds. Most of the folds verge to the southeast and are associated with a steep to moderately northwest-dipping cleavage.

The terrane extends west to the Whitewash Road shear zone, a wide penetrative zone of strongly foliated carbonate rocks that dip, except locally, to the northwest, and carries a northwest-oriented stretching lineation. The carbonate rocks are dark-grey, burrowed and stylonodular limestones and porous diagenetic dolostones; remnant bedding dips moderately to the northwest. These rocks belong either to the Lower Ordovician Catoche Formation or the Middle Ordovician Table Point Formation. If the former, it represents either a zone of northwestward extension utilizing the >100-m-thick unit of Catoche Formation limestone or it forms the hanging wall to a hidden thrust. If it is the Table Head Formation, however, it likely forms the footwall to a thrust that subcrops beneath till in a tributary valley to the Lomond River, just east of the shear zone.

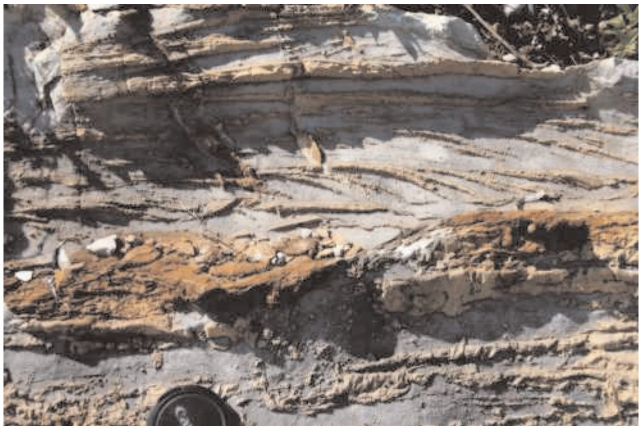

Plate 7. *Excellent inverted crossbedded oolitic grainstone in the middle member of the Petit Jardin Formation. Inverted footwall of the Rabbit Lake thrust, just west of Rabbit Lake. Lens cap is 6 cm wide.*

Plate 8. *Looking northeast along a Carboniferous paleo-cliff face formed of Ordovician limestone marble. Lacustrine green shale of the Visean Rocky Brook Formation abut the face. The Visean paleo-lake would have stretched out into the far distance more than 50 km to the south east,* i.e.*, to the right. Ridge a few kilometres east of route 430. Cliff is 5 m high.*

CARBONIFEROUS ROCKS – THE MARGINS OF AN ANCIENT VISEAN LAKE

Mapping shows that the Goose Arm Thrust Stack is truncated by an irregular Visean unconformity (Plates 8 and 9). The unconformity is onlapped by green shale and calcareous siltstone and by carbonate conglomerate, both belonging to the Rocky Brook Formation, Deer Lake Group. The shales abut against sloping to vertical to overhanging surfaces of Ordovician marble. A patchy to continuous millimetre- to centimetre-thick laminated and porous laminated, white limestone encrusts the unconformity surface below the shale (Plate 9). At the outcrop scale, the white

Plate 9. *A white microbial limestone encrusting the karst-sculpted unconformity along the rocky shoreline of the Visean lake in which the Rocky Brook Formation was deposited. The scalloped surface occurs in Ordovician limestone (Catoche Formation) now exposed by modern weathering along a woods-road a few kilometres east of Route 430. Lens cap is 6 cm wide.*

Plate 10. *Limestone marble pebbles derived from underlying lower Paleozoic carbonates mixed with white limestone clasts derived by erosion of the white microbial crust set in a green mudstone matrix, basal conglomerate, Visean Rocky Brook Formation. Woods-road a few kilometres east of Route 430. Lens cap is 6 cm wide.*

limestone also encrusts solution karst along joints and fractures as well as more delicate fabric-selective dissolution on the steep rock faces. It is likely that the limestone is, in part, microbial in origin.

The conglomerate, which was locally derived, lies topographically higher on the unconformity than the shale. There is at least one outcrop where pebbles are hosted by a shale matrix (Plate 10) and another where the pebbles are both encrusted and set in a matrix of white limestone sand, derived by erosion of the white-laminated crust limestone.

Pebbles of the white limestone are common in this conglomerate. Higher again, conglomerates are set in a calcareous siliciclastic sand matrix within narrow valleys in the unconformity.

The regional relationships suggest that the Rocky Brook palaeo-lake was characterized by a rocky shoreline of cliffs, islands and embayments. Shale abutting a marble cliff suggests, at times, the shoreline was permanently drowned. Conglomerates that have a sandy matrix in palaeo-valleys suggest that flash(?) floods fed pebbles into the lake along wadis. Pebbles in mud, in contrast to lime-sand matrix surrounding encrusted pebbles, suggest both local beach settings to pebbles dumped into lake muds.

ECONOMIC GEOLOGY

SULPHIDE MINERALIZATION

Base-metal showings are scarce in the area. A few veins of pyrite–galena and honey sphalerite occur in dolostones of the Petit Jardin Formation. Pyrite and malachite were noted in the Berry Head Formation. Pyrite occurs in the Rocky Pond and Moulands Pond shear zones associated with veins of white quartz and orange-weathering, Fe-rich calcite that cut the foliated phyllitic rocks. Magnetite (or ilmenite) is concentrated in calcareous, chloritic schist in the shear zones/thrusts of the eastern part of the area. The schist occurs where the shear zones cut the Penguin Cove and March Point formations.

DIMENSION STONE

Marbles are common in the eastern part of the area. Mottled, light-grey, to dark-grey, almost black, fine- to medium-crystalline, very hard limestone marble of Ordovician age occurs in the southeast of the area, where it is locally associated with a white marble. Creamy, off-white, to greenish to pink, red and purple dolostone marbles that are very fine grained, yet hard, occur in the Port au Port Group, particularly the Petit Jardin Formation.

HYDROCARBON INDICATORS

Porous and sucrosic, diagenetic dolostone in the Berry Head Formation and the Watts Bight Formation often exhale a sour gas smell when fractured. Sucrosic dolomite rich in vugs and intraclastic porosity replace large portions of many shear zones where they cut Ordovician limestones in the western structural terrane; no smell however is associated. Black pyrobitumen is common in fractures, joints, faults, and open spaces below the Carboniferous unconformity as well as on the unconformity below shales. The pyrobitumen is sourced by oil shale of the Rocky Brook Formation.

ACKNOWLEDGMENTS

Excellent field assistance and rowdy and entertaining discussion was provided by Daniel Brake (2005) and Matt MacInness (2006). Tony Paltanavage drafted maps and figures.

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