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ORDOVICIAN CATCHERS POND GROUP AND ADJACENT SILURIAN ROCKS, INDIAN RIVER–SHOAL POND AREA (NTS 12H/8, 9), WEST-CENTRAL NEWFOUNDLAND

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ABSTRACT

Pillowed basalt and sheared metabasite located near the Southern Cross and Ursa Major massive sulphide prospects represent part of the oldest observed subdivision of the Ordovician Catchers Pond Group in the Indian River–Shoal Pond area. They occur structurally above younger subdivisions of intermediate and felsic pyroclastic strata. Southeast of Long Pond, flow-banded rhyolite and felsic breccia are well preserved within a thrust-bounded structural lens that overlies the youngest observed subdivision of the Catchers Pond Group within the map area. This folded horse contains the Pisces and Goldfish massive sulphide prospects.

High-level bodies of biotite microgranite and quartz-feldspar porphyry assigned to the Silurian Topsails intrusive suite are displaced by brittle transcurrent faults. In the Indian River appendage, the mineralized isotropic microgranite is intruded by a mafic dyke swarm that illustrates features of autokinematic deformation. Along the margin of this intrusion, the Ordovician country rocks are also crosscut by a carbonate-altered hydrothermal breccia. During a later stage of faulting and intrusion, cataclastite zones in brecciated syenite were intruded by hematitic granophyre and sheeted dykes of a pyritic felsic microporphyry, particularly in the area of Shoal Pond.

INTRODUCTION

The Indian River–Shoal Pond area is located in Green Bay District in west-central Newfoundland and straddles the topographic map boundary between the Springdale (NTS 12H/8) and King's Point (NTS 12H/9) map areas (Figure 1). Most of the area surveyed occurs north of the Trans-Canada Highway and west of the connecting road to the town of Springdale. Trails leading south from the vicinity of King's Point and east from the Baie Verte highway provide easy access to the area by truck and all-terrain vehicle.

PREVIOUS WORK

The most recent 1:50 000-scale bedrock maps of the Springdale–King's Point region released by the Geological Survey of Newfoundland and Labrador show the Early Ordovician Catchers Pond Group as an undivided lithostratigraphical unit. Mapping and compilation by Dean (1977) established the regional disposition of the Catchers Pond Group within the Springdale (NTS 12H/8) map area. Kean *et al.* (1995) provided the most current distribution of the eastern part of the unit and its possible correlatives in the King's Point (NTS 12H/9) map area. Although not publically available, a preliminary tripartite division of the Catchers Pond Group was originally depicted on an unpublished

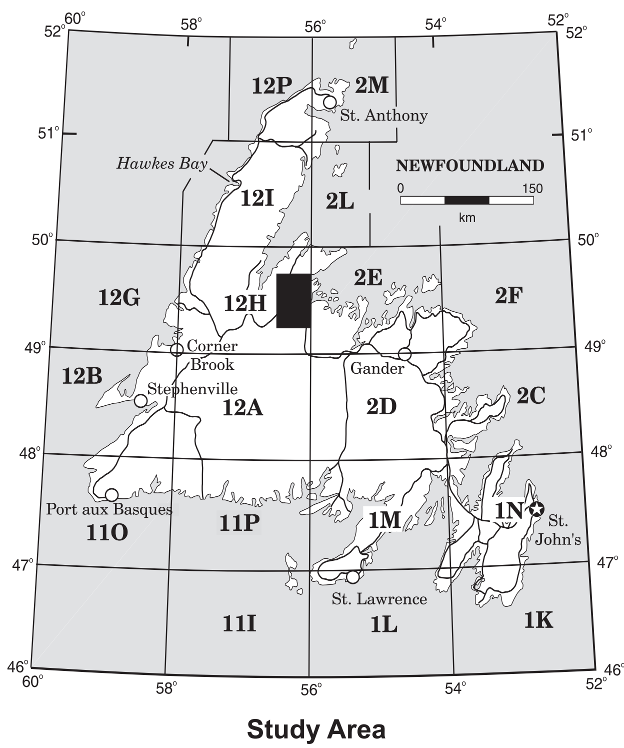

Figure 1. *Geographic location of the NTS 12H/8 and NTS 12H/9 map areas within the Island of Newfoundland.*

1:50 000-scale geological map of the area between King's Point and the Indian River in NTS 12H/8 (Jenner and Szybinski, 1987). Dominantly mafic, intermediate and felsic volcanic rock units were recognized and regionally mapped, although they were not necessarily listed in stratigraphical order on the accompanying legend. In the type area of the Catchers Pond Group, immediately northeast of the area reported on herein, Andrews (1991) produced a 1:20 000 scale geological map on which he illustrated a revised distribution of Jenner and Szybinski's (1987) lithological units. There, Andrews (*ibid*) showed areas where the primary geological and faulted boundaries of these mainly compositional units were interpreted to occur. Chronostratigraphic, structural, metamorphic and geochemical data gleaned from these volcanic rocks were subsequently developed into the tectonic synthesis given by Szybinski (1995).

Geological maps of the entire Catchers Pond Group, at 1:25 000 and more detailed scales, have since been produced as a result of systematic surveys by mineral exploration companies, and these have now become publicly available as non-confidential documents (Boisvert and Mouton, 1999; Moore *et al.*, 2002). In the case of the detailed geological maps of the latter workers, as many as ten lithological units of stratified and intrusive rocks are illustrated in the Catchers Pond Group in the Springdale–King's Point region. Moreover, it has been proposed that this Ordovician succession is made up of two, if not three, widely distributed lithostratigraphic units, each of which is extensively mineralized (Moore *et al.*, 2002). Different than the subdivisions portrayed by Jenner and Szybinski (1987) and Szybinski (1995), they have been informally named, from southeast to northwest, the Indian Brook, Batters Brook and Shoal Pond sequences of volcanic, hypabyssal and sedimentary rocks.

On the basis of detailed lithogeochemical sampling, Boisvert and Mouton (1999) suggested that felsic volcanic rocks in the Catchers Pond Group could be separated into an older tholeiitic rhyolite-bearing division in the southeast and a younger calc-alkaline-bearing rhyolite division in the northwest. However, the outcrop pattern of Boisvert and Mouton's (1999) felsic volcanic divisions in map areas NTS 12H/8 and 12H/9 is not coincident with the distribution of the disparate felsic volcanic rocks in Moore *et al.*'s (2002) Indian Brook and Batters Brook volcanosedimentary sequences.

OBJECTIVE

The main geological objective of this project is to attempt to establish the regional structure and internal stratigraphy of the Catchers Pond Group. Another outcome would possibly be to assign the known massive sulphide horizons to positions in a lithostratigraphic column or a chronostratigraphically controlled lithofacies assemblage. The ultimate aim would be to ascertain if the rocks of the Catchers Pond Group comprise a component of the base-metal-enriched Buchans-Roberts's Arm volcanic belt. At surface, the Catchers Pond and Buchans-Roberts's Arm volcanic units are separated by complexly faulted Silurian rocks that comprise the volcanosedimentary succession of the Springdale Group or later posttectonic plutonic rocks of the Topsails intrusive suite.

GEOLOGICAL SETTING

The Ordovician Catchers Pond Group is situated in the Notre Dame Subzone of the Dunnage Zone to the east of the ocean-continent boundary represented by the Baie Verte-Brompton Line (Colman-Sadd *et al.*, 1992). It occurs about 10 km northwest of the Early Ordovician (late Tremadocian) arc-plutonic and ophiolitic rocks of the peri-Laurentian Mansfield Cove and Hall Hill complexes (Dunning *et al.*, 1987; O'Brien, 2003).

The Ordovician Catchers Pond Group and adjacent Silurian rock units are bounded to the west by the Green Bay Fault, a large northeast-trending structure related to the Carboniferous and older Cabot Fault of White Bay. To the east, they are offset or truncated by both rectilinear and curviplanar fault structures lying within the Siluro-Devonian and older Lobster Cove fault zone of Notre Dame Bay. Along its northern boundary, the Catchers Pond Group is tectonically underplated beneath the Cambrian Lushs Bight Group along a 40-km-long, folded thrust fault of unknown age. The Catchers Pond Group is not known to extend any farther than 5–10 km south of the Trans-Canada Highway, where it is believed to be either juxtaposed against early Middle Ordovician metaplutonic rocks of the Hungry Mountain Complex, or posttectonically intruded by felsic and mafic plutons belonging, for the most part, to the Topsails intrusive suite (*cf.* Whalen and Currie, 1988).

Although the Catchers Pond Group is dominantly made up of submarine volcanic rocks, bioclastic limestones of Early Ordovician (early Arenig) age have also been recognized in a few localities (Dean, 1970; O'Brien and Szybinski, 1989). These carbonates are found in direct contact with both mafic flows and felsic pyroclastic strata. Szybinski (1995) established that Catchers Pond mafic volcanic rocks were mainly calc-alkaline basalt and andesite with the notable exception of a minor amount of pillowed oceanic island basalt. On lithogeochemical grounds, he postulated that the Catchers Pond volcanic arc basalts were correlative with basalts in the lower part of the Early to Middle Ordovician Western Arm Group.

Outcropping north of the Cambrian Lushs Bight Group in the NTS 12H/9 map area, the Western Arm Group contains a relatively small volume of felsic pyroclastic and sedimentary strata in comparison to the Catchers Pond Group (Kean *et al.*, 1995). However, Szybinski's (1995) hypothesis may be supported by a report of a preserved depositional contact between younger andesite and older felsic ash tuff in an upside-down, south-facing part of the Batters Brook sequence north of Catchers Pond (Mullen, 1994). This drilled section is located south of the structurally overlying Lushs Bight Group and a tectonically adjacent unit of dominantly tholeiitic basalts (Gaboury *et al.*, 1996) that have been variably included and excluded from the Catchers Pond Group. Moreover, the presence of a distinctive magnetic siliceous argillite in association with calc-alkaline basalt and mafic tuff in the Mistaken Pond panel, located east of Catchers Pond and southwest of the boundary with the Lushs Bight Group (Szybinski, 1995), has been taken to mean that complexly faulted felsic pyroclastic strata in the northeastern part of the Catchers Pond Group formed near the original stratigraphic transition zone between the Lushs Bight and Western Arm groups (Andrews, 1991; Kean *et al.*, 1995).

PROVISIONAL LITHOSTRATIGRAPHY OF THE CATCHERS POND GROUP IN THE INDIAN RIVER-SHOAL POND AREA

The oldest observed part of the Catchers Pond Group forms the most widely distributed map unit of stratified rocks in the area surveyed. Mainly composed of pillowed basalt, diabase dykes and interflow chert, it is referred to as Unit Cbc in Figure 2. In many places, primary rock textures and volcanological features are well preserved; whereas, in other locations, strata assigned to Unit Cbc are strongly altered and highly deformed. In the northwestern part of the Indian River–Shoal Pond area, a fault-bounded slice or tectonic panel of Unit Cbc basalt is apparently host to the Ursa Major and Southern Cross (Moore *et al.*, 2002) massive-sulphide prospects (Figure 2).

Very locally, in the upper part of Unit Cbc, minor grey-green interstitial chert within pillow lava sequences gives way to more laterally extensive interbeds of purple-red, parallel-laminated, ferruginous chert within silicified or jasperitized sequences of basalt breccia. Although bioclastic limestone has not been recorded in Unit Cbc, at or below the horizons where ribboned chert is present, pillowed chloritic basalt in the middle to upper part of the map unit has abundant matrix-disseminated carbonate and is highly reactive to a hydrochloric acid test in the field. Such rocks are intruded by pretectonic quartz–feldspar porphyry dykes that are similar to the quartz-phyric sill complexes observed in the overlying subdivisions of the Catchers Pond Group.

The succeeding lithological division, Unit Cmi in Figure 2, is internally well stratified and, despite being relatively thin in the Indian River–Shoal Pond area compared to areas farther east, is highly distinctive in its field appearance. It is found most extensively in the central part of the area surveyed where the map unit flanks a complex fault-bounded synclinorium present throughout the southwestern outcrop area of the Catchers Pond Group (Figure 2). Unit Cmi is mainly composed of intermediate pyroclastic strata that are intercalated with mafic extrusive and intrusive rocks and a subordinate amount of felsic lithic-crystal tuff.

At the base of Unit Cmi, a highly vitric, jasperitized, plagioclase-porphyritic dacitic crystal tuff is commonly associated with a silicified, carbonaceous and sulphidic epidosite. Farther up section, mafic–felsic breccia displays hydrothermally-altered, vesicular basaltic bombs and hot-ejected lapillistone. Certain pyroclastic strata in Unit Cmi contain horizons of eutaxitically foliated welded tuff that was devitrified to form isolated spherulites and agate-bearing lithophysae. These deposits also contain outsized dacitic blocks (marked by chloritic amygdules and perlitic obsidian) and clast-rotated rhyolitic fragments (rich in shards and embayed quartz phenocrysts). Unit Cmi tuff is locally transitional to sericitic, chloritic or carbonaceous schist and is host to chlorite–quartz–pyrite–hematite veins.

A cyclically interstratified, relatively thick sequence of felsic pyroclastic rocks, rhyolite autobreccias and lutaceous sedimentary strata comprise the overlying lithological subdivision of the Catchers Pond Group. Widely developed in the northeastern part of the Indian River–Shoal Pond area, such rocks have been assigned to Unit Cfr on Figure 2. Felsic crystal-lithic tuffs at the base of this map unit are very fine grained and thinly bedded, have conspicuous reworked jasper clasts, and are intruded by copious quartz-feldspar porphyry sills and later diabase dykes. Typically, the immediately succeeding rocks are stratiform bodies of aphyric, quartz-phyric, banded feldspar-phyric and flow-folded rhyolite that pass gradationally into *in situ* hyaloclastite and autoclastic flow breccia.

Discontinuous lenticles of dominantly parallel-laminated argillite, replacement chert and phyllite commonly separate the underlying rhyolite flows from an overlying sequence of coarse polylithic felsic breccias. Subordinate felsic lithic tuffs within the breccia intervals are characterized by abundant rip-up clasts of the dark-grey background sedimentary material. At the top of Unit Cfr, a laterally extensive, very thick, stratified horizon of coarse-grained crystal tuff having centimetre-scale prisms of potassium feldspar and resorbed quartz grains is distinguished by large angular blocks of limestone and bedded tuff.

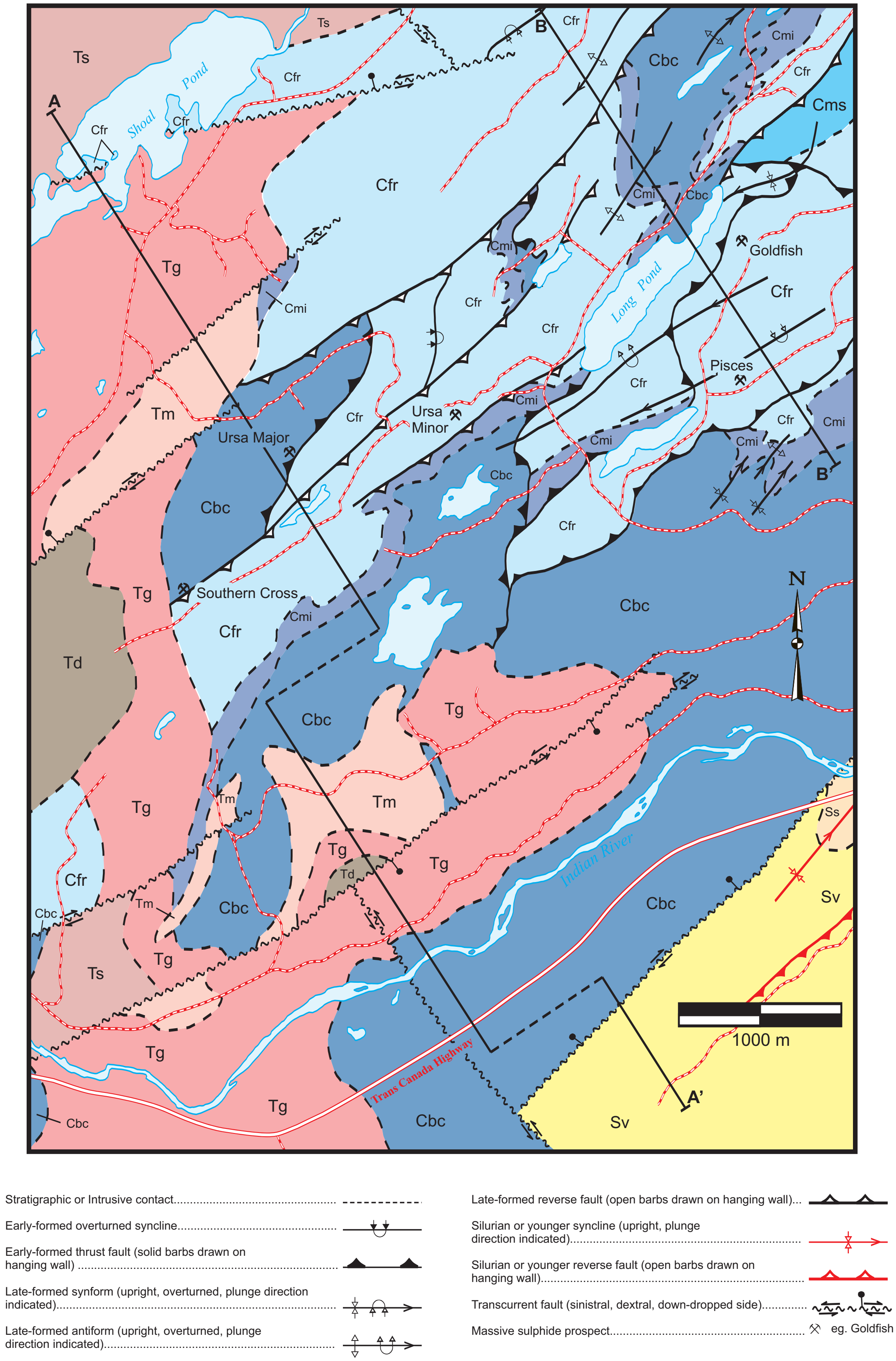

Figure 2. *Bedrock geological map of the Indian River–Shoal Pond area emphasizing the lithological subdivisions, rock structures and massive sulphide prospects found in the Ordovician Catchers Pond Group.*

LEGEND

Ordovician Catchers Pond Group and adjacent Silurian rocks, Indian River – Shoal Pond area [NTS 12H/8, 9], west-central Newfoundland

POSTTECTONIC INTRUSIVE ROCKS

Early to Late Silurian (?)

Topsails intrusive suite

Ts Mainly light pink, porphyritic to equigranular, quartz syenite and hematized granophyre; where cataclastically brecciated, syenite and granite intruded by pyritized felsic microporphyry sheets and fractured aplite veins; in places, Unit D may include enclaves of Unit A granodiorite. Widespread conjugate dykes of porphyritic and aphanitic diabase intrude Unit D and older subdivisions of the Topsails intrusive suite

Td Mainly dark grey, medium-grained, equigranular diorite and diorite porphyry; subordinate, coarse-grained, quartz-bearing gabbro

Tm Mainly buff-weathered, porphyritic to equigranular, carbonate-altered biotite-hornblende microgranite; saussuritized quartz-feldspar porphyry; cataclastite zones in microgranite intruded by swarm of sigmoidally-foliated diabase dykes; hydrothermal breccia having variably altered fragments of microgranite and basalt

Tg Mainly light grey, medium- to coarse-grained, isotropic, hornblende-biotite granodiorite (locally displaying cognate xenoliths); locally, green or light pink, epidotized, chloritized or sericitized granodiorite intruded by quartz-pyrite-chalcopyrite veins

STRATIFIED ROCKS

Early to Late Silurian

Springdale Group

Sedimentary rocks

Ss Red, clast-supported conglomerate containing well-rounded cobbles and boulders of variably hematized basalt, less common grey ignimbrite and spherulitic rhyolite, and minor mafic and felsic plutonic rocks; massive sedimentary breccia displaying concentric leached zones around mafic volcanic clasts; medium-bedded red sandstone and pebbly sandstone having a hematite-rich matrix; in places, yellowish-grey interbeds of parallel-laminated sandstone

Volcanic rocks

Sv Mainly light pink, K-spar porphyritic, massive and flow-banded rhyolite; light grey, felsic lithic crystal tuff having rare mafic lapilli; subordinate purplish-red, fine grained, plagioclase porphyritic, amygdaloidal basalt having flow top crevasses filled by red sandstone; vesicular grey and red basalt passing into basaltic breccia or mafic tuff and succeeded by coarse red sedimentary breccia

Early Ordovician

Catchers Pond Group

Cms Mainly mafic extrusive, epiclastic sedimentary and felsic tuffaceous strata; at the base of Unit Cms, dark to light green, fine grained, seriate porphyritic, vesicular flows including coarse-grained epidotized basaltic breccia, minor pillow breccia grading to mafic tuff, and rare pillow lava; basaltic breccia containing numerous small inclusions of quartz-phyric, chloritic, intermediate volcanic rocks; minor, dark grey chloritic basalt displaying calcite veins and matrix-disseminated carbonate; minor, partially-reddened amygdaloidal basalt having vesicles filled by a chlorite-carbonate-hematite-jasper assemblage; minor, ribboned ferruginous chert and green interpillow chert; light grey, graded feldspathic wacke having outsized detrital clasts of basalt and rare rhyolite; planar-bedded sandstone turbidite and parallel-laminated sandstone; banded to laminated, grey-green siliceous argillite; at the top of Unit Cms, light grey, poorly-stratified, coarse-grained rhyolite agglomerate and polylithic felsic breccia succeeded by massive to thick-bedded, medium-grained, quartz-feldspar crystal tuff displaying rare clasts of felsic lithic tuff

Cfr Mainly felsic pyroclastic rocks, rhyolite autobreccias and lutaceous sedimentary strata; at the base of Unit Cfr, light grey, fine-grained, thin-bedded to laminated crystal-lithic tuff locally displaying outsized jasper clasts; buff-weathered, very fine-grained, quartz-feldspar crystal tuff interstratified with dark grey, finely laminated ash tuff (intruded pretectonically by pyritic gabbro sills and multiple diabase dykes); localized stratiform bodies of grey aphyric or quartz-phyric rhyolite and associated feldspar-phyric crystal tuff; coherent rhyolite lava showing flow folds intruded by dykes and sills of massive or layered quartz-feldspar porphyry; autobrecciated lobes of flow-banded rhyolite gradational with in situ hyaloclastite illustrating monomictic jigsaw-fit texture; autoclastic flow breccia made up of porphyritic, aphyric and spherulitic rhyolite clasts augened by a eutaxitic foliation; discontinuous lenticles of greenish-grey to dark grey, thin-bedded sedimentary rocks interlayered with felsic tuff, including pebbly tuffaceous wacke and graded sandstone turbidite, siliceous argillite and banded chert, sericitic phyllite and laminated slate; very coarse-grained, polylithic felsic breccia having blocks of flow-banded rhyolite, vitric aphanitic rhyolite, and quartz-feldspar porphyry; an interstratified sequence of thin-bedded, felsic lithic tuff marked by abundant argillite rip-up clasts, massive size-graded rhyolite agglomerate, and upward-coarsening quartz-phyric crystal tuff, all intruded by pretectonic diabase dykes; at the top of Unit Cfr, a massive to thickly stratified, laterally extensive subdivision of very coarse-grained crystal tuff distinguished by centimetric scale prisms of K-spar and resorbed quartz grains together with decimetric scale angular blocks of limestone and bedded tuff; in some localities, silicified felsic tuff and quartz-veined volcanic breccia, ferroan carbonate-rich phyllite, and pyritic sericite schist hosting chlorite-quartz-feldspar-chalcopyrite stringers

Figure 2. *Legend.*

Cmi Mainly mafic extrusive and intermediate pyroclastic strata; at the base of Unit Cmi, thin sulphidic or jasperitized interbeds of dark to light green, fine-grained, highly vitric, plagioclase-phyric dacitic crystal tuff and light grey, size-graded, felsic lithic-crystal tuff distinguished by rounded quartz eyes set in a lapilli-rich chloritic matrix; amygdaloidal dykes and sills of porphyritic diabase and equigranular gabbro; dark-green, carbonate-altered basalt and epidotized pillow breccia (having conspicuous fragments of red chert and orange jasper) interstratified with buff-weathered, plagioclase- and/or quartz-phyric crystal tuff; light green, silicified, mafic-felsic breccia marked by plagioclase-porphyritic mafic bombs (displaying vesicular chloritic cores and leached sericitized rims) and minor outsized blocks of felsic lapillistone (illustrating notched or hot-indented margins adjacent to mafic clasts and preserving a eutaxitically-foliated or spherulitic matrix); well-stratified, quench-textured polylithic tuff having fragments of light-green dacitic vitroclasts (perlitically-fractured, obsidian-rich pumice and ejecta characterized by compacted chilled selvages and minute chloritic amygdules) together with fragments of light-pink rhyolitic glass (porphyritic ash composed of embayed quartz phenocrysts set in a matrix of contorted dark-grey shards); minor, flow-layered welded tuff passing gradationally into devitrified zones made up of isolated spherulites and agate-bearing lithophysae; light-grey, coarse-grained, clast-rotated felsic breccias displaying sharp boundaries with interstratified horizons of fine-grained, medium-bedded mafic tuff, both affected by discontinuous stratabound and crosscutting zones of massive jasper or hematite-bearing quartz veinlets; at the top of Unit Cmi, extensively carbonate-altered and highly silicified basalt flows capping glassy intermediate tuff and jasperitized felsic tuff; Unit Cmi tuff is locally transitional to sericitic, chloritic or carbonaceous schist; in places, the subdivision is host to zones of disseminated chalcopyrite and sphalerite, arrays of chlorite-quartz-pyrite-hematite veins, stringers of jasper, hematite, sericite and feldspar, and spotted aggregates composed of ferroan carbonate and pyrite grains

Cbc Mainly pillowed basalt, diabase dykes and interflow chert; throughout most of Unit Cbc, dark green, well-stratified, medium- to fine-grained pillowed basalt and pillow breccia intercalated with massive, medium-to coarse-grained flows of plagioclase-porphyritic basalt; locally, pillow lava intervals displaying pipe vesicles, glassy selvages, interstitial grey-green chert, monomictic mafic breccia and jig-saw fit hyaloclastite; abundant gabbroic sills and multiple diabase dykes having variolitic or chilled margins; widespread chloritic basalt illustrating chlorite pseudomorphs after clinopyroxene, being crosscut by folded epidote stringers, and having ubiquitous quartz- and chlorite-filled amygdules; in places, deformed pyrite-sericite-quartz veinlets in silicified basalt; polylithic basaltic breccia and mafic tuff made up of relatively pristine and silicified volcanic fragments; minor pyrite-chalcopyrite mineralization in gossans developed along mafic breccia - massive flow contacts; very locally, in the upper part of Unit Cbc, and especially near its boundary with Unit Cmi, silicified or jasperitized basalt having purplish-red interbeds of parallel-laminated chert, crosscutting quartz-feldspar porphyry dykes, and abundant matrix-disseminated carbonate; near its faulted contact with the Springdale Group, sucrose basalt from Unit Cbc hosting open-spaced, fibred and slickenlined veins of quartz, calcite, hematite, ferroan carbonate, chlorite, clinozoisite, epidote, chalcopyrite and pyrite

Figure 2. Continued. *Legend.*

Thin sulphide lenses reported at the Ursa Minor and Pisces prospects (Moore *et al.*, 2002) and the Goldfish prospect (Thurlow, 1997) appear to be hosted by felsic volcanic strata assigned to Unit Cfr (Figure 2). The Pisces and Goldfish prospects occur in the same fault-bounded, northwest-dipping tectonic panel and are situated near the folded boundary between an aphyric rhyolite flow and a coarse felsic breccia.

At other localities within Unit Cfr, particularly south and east of the Ursa Minor prospect, silicified felsic tuff and ferroan carbonate-rich phyllite are observed to be crosscut by multiple generations of thick quartz veins. Folded veins deformed by the regional foliation were developed adjacent to several southeast-dipping faults that extend throughout most of the map area. Later northwest-trending veins locally contain pyrite and arsenopyrite and occur within quartz-cemented kink bands. Minor chalcopyrite is seen along with the gangue minerals that make up the gouge matrix of late-stage cohesive fault breccias.

The lithological subdivision identified as Unit Cms on Figure 2 crops out over a very limited tract of ground in the northeast corner of the Indian River–Shoal Pond area. It is thought to be the youngest mappable unit within this part of the Catchers Pond Group, as it occupies the faulted core of the regional synclinorium.

The base of Unit Cms is marked by a seriate porphyritic basalt breccia displaying numerous inclusions or xenocrystic aggregates of a quartz-phyric dacitic rock. In a few localities, partially hematized pillowed basalts have vesicles filled by a chlorite–carbonate–hematite–jasper assemblage. Associated with these mafic volcanic rocks are well-bedded intervals of sandstone turbidite and ribboned chert, each capped by discontinuous horizons of size-graded tuffaceous wacke and poorly stratified debrite. Based on its outsized clast population, it seems that the re-sedimented debris flow deposits contained lithified volcanic rocks eroded from a source area within, or near, the Catchers Pond Group and that basalt, rhyolite and quartz-feldspar porphyry were present in this region. The epiclastic sedimentary strata within Unit Cms are commonly seen to be sharply overlain by a probable vent-proximal rhyolitic agglomerate and a succeeding very coarse-grained, polylithic, felsic breccia. The stratigraphic top of Unit Cms is not preserved in the Indian Brook–Shoal Pond area.

SILURIAN SPRINGDALE GROUP NEAR THE INDIAN RIVER

The volcanosedimentary rocks of the Springdale Group have been historically interpreted to comprise a terrestrial Silurian cover sequence developed above the Ordovician marine strata located in this part of the Notre Dame Subzone of the Dunnage Zone (*see* Colman-Sadd *et al.*, 1992 and references therein). This notion is primarily based on a preserved sub-Springdale unconformity with the Ordovician rocks of the Roberts Arm Group, as seen farther east on the coast of Notre Dame Bay. Neither the primary stratigraphic boundary of the basal beds of the Springdale Group nor the postulated angular unconformity with the underlying Catchers Pond Group has been observed in the Indian River area. The postulated sub-Springdale unconformity has not been previously reported as being exposed anywhere along the northwest margin of the Springdale Group.

Near the Indian River, the Springdale Group has been generally separated into an older Unit Sv dominated by volcanic rocks and a younger Unit Ss dominated by sedimentary rocks (Figure 2).The lowest observed part of the lower volcanic division begins with conspicuous, highly vesicular, purple-grey basalt flows which are gradational to purple-red mafic tuff. They both have interbeds of parallel-laminated grey sandstone. An overlying sedimentary megabreccia is predominantly made up of angular and rounded fragments of argillite and basalt. A spatially associated sand-matrix conglomerate illustrates large intraclasts of amygdaloidal basalt, spherulitic rhyolite and banded ignimbrite together with less common dioritic and granitic extraclasts. Such strata are succeeded by a relatively thick sequence of felsic volcanic rocks that are mainly composed of potassium feldspar-porphyritic, massive and flow-banded rhyolite. Intercalated with the rhyolite flows are felsic lithic-crystal tuffs displaying mafic volcanic blocks and minor purple-red flows of plagioclase-porphyritic basalt illustrating crevassed flow tops.

The upper sedimentary division of the Springdale Group in the Indian Brook–Shoal Pond area (Figure 2) is characterized by medium-bedded red sandstone and subordinate pebbly sandstone having a hematite-rich matrix. Unlike the red beds farther southeast in the uppermost part of the Springdale Group, these rocks are not rich in detrital mica. A thin horizon of clast-supported red conglomerate and overlying cross-bedded red sandstone is found near the contact with a basalt flow located at the top of the underlying volcanic division. The conglomerate contains well-rounded basaltic boulders, many of which show variable degrees of hematization.

The terrestrial red beds in the Springdale Group outcropping near the Indian River are tectonically juxtaposed against the Catchers Pond Group. Based on the map pattern shown in Figure 2, they are not as old as the red beds situated below the rhyolite flows in the eastern part of Unit Sv. Immediately east of the area shown in Figure 2, Dean (1977) mapped the older red beds as being disposed in an anticlinal pericline and being overlain by Unit Sv felsic volcanic rocks. Of the minor sedimentary rocks present in this division, the megabreccias resemble talus, landslide or lahar deposits produced near volcanic cones and the polymict conglomerates are typical of the associated ring plain deposits. Their present proximity to the rocks of the Catchers Pond Group may imply an original stratigraphic position close to the base of the Springdale Group, at least in the area surveyed and in the region along strike to the northeast. Thus, the red beds of Unit Ss could not be correlatives of the Springdale Group red beds preserved above the inverted unconformity with the Roberts Arm Group unless there was Silurian overstep above the Catchers Pond Group along the western margin of the Springdale Group depositional basin.

POSTTECTONIC PLUTONIC ROCKS OF THE MAP AREA

The posttectonic intrusive rocks mapped in the Indian River–Shoal Pond area (Figure 2) comprise a series of small plutons, stocks and bosses emplaced into the complexly deformed country rocks of the Catchers Pond Group. They extend northeastward from the margin of the main Topsails intrusive suite, which is located in the Topsails Plateau region in the southwest part of the NTS 12H/8 map area. Some of the map units within the area surveyed, or their southwesterly extensions, were previously assigned to the Topsails granite (Dean, 1977), the Topsails complex (Coyle, 1992) and the Sheffield Lake complex (Coyle, 1992). Viewed regionally, plutonic rocks of the Topsails intrusive suite crosscut the entire Springdale Group and some members are also intruded along the northwest margin of the Buchans-Robert's Arm volcanic belt (Whalen and Currie, 1988).

Plutonic rocks assigned to the Topsails intrusive suite in the Indian River–Shoal Pond area comprise a broad range of rock types. They vary from coarsely megacrystic to microporphyritic in texture and from gabbroic to granitic in composition. Many of the major intrusions are strongly altered and primary minerals that form these intrusive rocks are partially replaced, especially near contacts with their country rocks. The plutonic rocks contain abundant minor intrusions.

Based on correlations with similar rocks in nearby mid Paleozoic batholiths, the intrusions are thought to range from the Early to Late Silurian, although some may possibly be even younger. Regardless of age differences between various bodies, plutonic rocks that are known to postdate the ductile deformation and dynamothermal metamorphism of their host rocks are all structurally isotropic, although several map units of intrusive rocks are extensively fractured.

Where the oldest intrusions in the Topsails intrusive suite trend northwestward across the regional grain of the country rocks and have a subvertical dip, they are assumed to be dykes (Figure 2). Where such intrusions turn northeastward, they are interpreted as sills. Younger constituent plutons are typically emplaced into earlier bodies. However, within the map area, locations exist where each unit of posttectonic plutonic rocks is believed to have directly intruded the Catchers Pond Group. Nested plutons are particularly evident along the faulted northeast-trending appendage of the Topsails intrusive suite near the Indian River (Figure 2).

PLUTONIC ROCK UNITS

In the area surveyed, the oldest plutonic rocks assigned to the Topsails intrusive suite have been grouped in Unit Tg (Figure 2). The intrusive margin of this medium- to coarse-grained, equigranular to megacrystic, hornblende–biotite granodiorite is exposed in localities north of the Indian River and south of the Trans-Canada Highway. However, Unit Tg is very poorly exposed in the area south of Shoal Pond and its outcrop pattern was mainly established by mapping large erratic boulders. Although the Unit Tg intrusive contact was not observed along the northwest bank of the Indian River (Figure 2), its boundary with the underlying Catchers Pond basalt seems to dip moderately or gently northwestward into the base of the high granitic cliffs above the river bank.

The generally light-grey granodiorite locally becomes green or light pink where it contains propylitic alteration minerals, such as epidote, chlorite, sericite or carbonate. In a few places, Unit Tg granodiorite is seen to be intruded by quartz–pyrite–chalcopyrite veinlets. The outline of certain granodiorite bodies are well expressed on detailed aeromagnetic maps of the map area, especially where they were affected by linear faults or intruded by mafic dykes and quartz veins.

Unit Tm of the Topsails intrusive suite is mainly composed of biotite–hornblende microgranite and quartz-feldspar porphyry and is best exposed in the Indian River appendage. There, the map unit appears to form the cupola of a high-level boss. It is also seen to be emplaced in subvertical sheets which extend outward from Unit Tg granodiorite across its contact with the Catchers Pond Group.

In one locality, a chalcopyrite-bearing hydrothermal breccia is developed at the margin of Unit Tm. It contains both fresh and carbonate-altered fragments of microgranite along with entrapped fragments of the basaltic host rocks. Closer to a nearby sinistral transcurrent fault, there are also cataclastite zones present in Unit Tm and adjacent pillow lavas. These are host to a spectacular swarm of subvertical diabase dykes. The sigmoidal wall-to-wall foliation observed within these autokinematically deformed diabase intrusions implies lateral displacement of the microgranite during the vertical ascent of mafic magma.

Unit Td, locally the only unit of mafic plutonic rocks in the Topsails intrusive suite, outcrops in two locations in the Indian River–Shoal Pond area (Figure 2). Equigranular diorite, diorite porphyry and quartz-bearing gabbro are the predominant rock types. Although generally poorly exposed, the rocks of Unit Td have a very strong aeromagnetic signature.

Unit Td diorite is seen to intrude Unit Tg granodiorite but its primary relationship with the microgranite and porphyry of Unit Tm has not been directly observed. It is possible that the subvertical stocks of diorite and gabbro may however relate to the subvertical mafic dyke swarms in the microgranite. Where Unit Td diorite is faulted against Unit Tm microgranite and Unit Tg granodiorite, the quartz-veined diorite is locally saussuritized and silicified. Plagioclase is replaced by hematite, carbonate and sericite; pyroxene is altered to actinolite and magnetite.

The youngest division of the Topsails intrusive suite in the Indian River–Shoal Pond area is referred to as Unit Ts on Figure 2. Mainly composed of quartz syenite, quartz-phyric granite and hematized granophyre, it is best exposed north of Shoal Pond. Near the Trans-Canada Highway, syenitic and granitic dykes are abundant and are locally observed to crosscut Unit Tg granodiorite. In the southwestern corner of the map area, within the body of Unit Ts located north of the Indian River, quartz syenite is very poorly exposed. It is thus possible that large enclaves of the adjacent older granodiorite occur within the outcrop area of Unit Ts in this region.

In the northernmost part of the Indian River–Shoal Pond area, granophyre and fault-brecciated syenite host abundant high-level sheets of felsic microporphyry, and are intruded by heavily-fractured aplite veins. Numerous pyrite- and chalcopyrite-bearing gossans are developed in some of the felsic microporphyries of this region.

Conjugate dykes of porphyritic and aphanitic diabase intrude Unit Ts and older map units of the Topsails intrusive suite. They represent the youngest and most widespread suite of mafic minor intrusions in the Indian River–Shoal Pond area.

REGIONAL STRUCTURE OF THE ORDOVICIAN AND SILURIAN ROCKS IN THE INDIAN RIVER–SHOAL POND AREA

The regional structure of the map area is illustrated in two cross sections labelled AA' and BB' (Figure 3). The northwest-southeast trending lines of section are shown on Figure 2.

Strata of the Catchers Pond Group were initially disposed by a synmetamorphic group of early-formed thrust faults and allied folds distinguished by solid black symbols

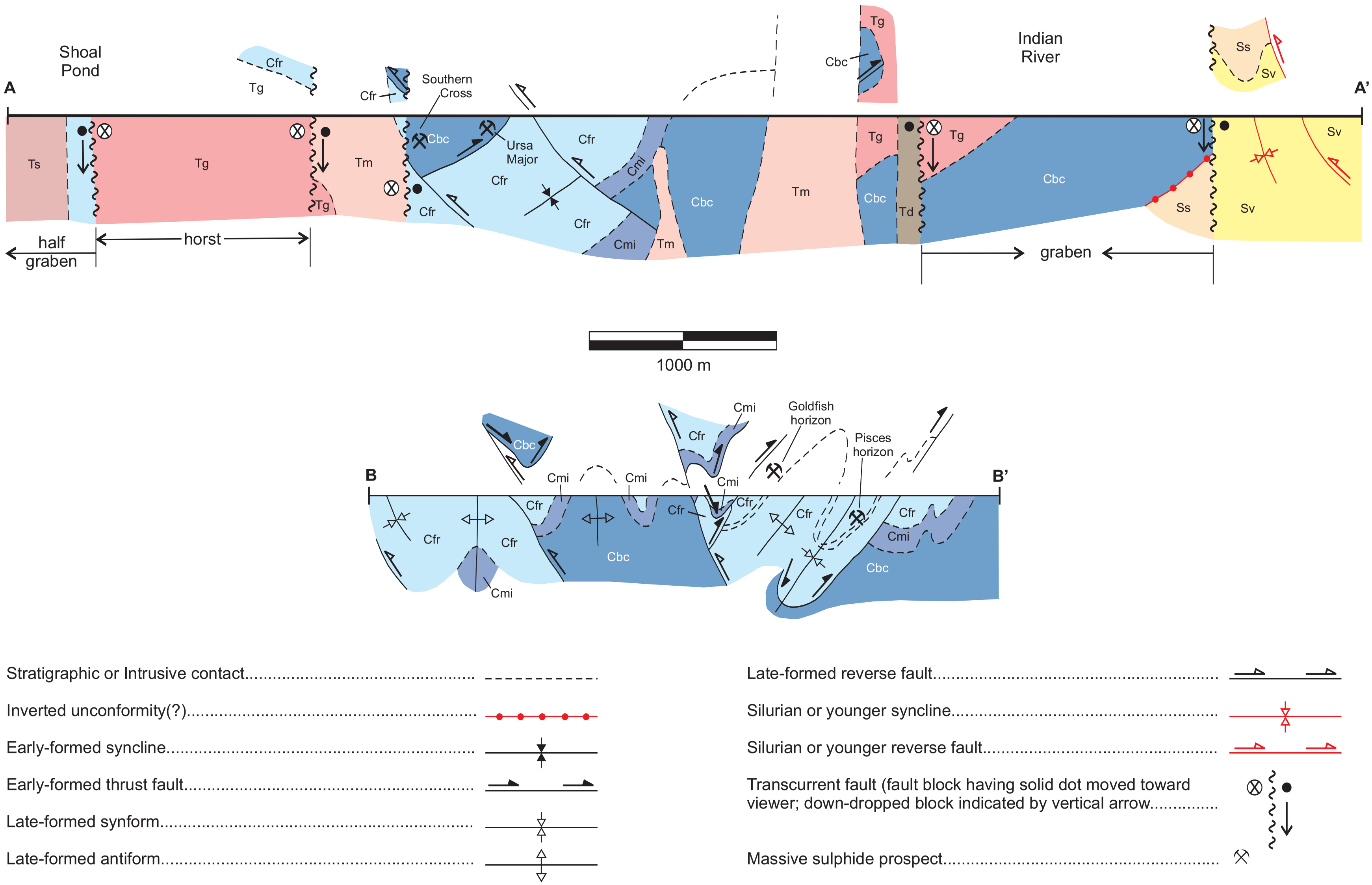

Figure 3. *Regional cross sections AA' and BB' illustrating the sequence of structures recognized in the Catchers Pond Group, the Springdale Group and the Topsails intrusive suite. Vertical scale is exaggerated. Lines of section for AA' and BB' are shown in Figure 2. Lithological units are described in the Legend for Figure 2.*

in the key for the Figure 3 cross sections. In plan view, they are marked by a slightly different solid black symbol set, as seen in the key for the Figure 2 geological map. In the area surveyed, the early-formed structures are generally inclined to the west or the northwest. This may not have been their original orientation however, as several thrust faults of this generation are mapped as being affected by regional folds (Figure 2). According to Szybinski (1995) and Gaboury *et al.* (1996), the pre-*ca.* 437 Ma structures (Ritcey *et al.*, 1995) observed in the footwall sequence of the northeast-dipping ductile thrust carrying the Lushs Bight Group were probably Taconian tectonic features that mainly predated deposition of the Silurian Springdale Group.

The tectonic panel disposing altered Unit Cbc basalts and the contained Ursa Major and Southern Cross massive-sulphide prospects is bounded at its structural base by an early-formed thrust fault lying parallel to the metabasite foliation (Figures 2 and 3). The axial surface of the underlying overturned fold in the bedded tuffs of Unit Cfr is inclined to the northwest and it is probably a footwall syncline allied to this fault structure. The regional structural repetition of Unit Cbc basalt and the southwestward excision of the Unit Cfr panel carrying the Goldfish and Pisces massive-sulphide prospects occurs in the area immediately northeast of the Indian River appendage of the Topsails intrusive suite. These features resulted from fault imbrication and the coalescence of early-formed thrust faults.

Near Long Pond, parts of Unit Cmi and Unit Cfr make up at least two early-formed thrust sheets that are complexly imbricated and tightly folded within a regional synclinorium situated structurally above the Goldfish horizon (Figure 3). Northeast of Long Pond, a folded south-dipping thrust forms the structural top of the youngest lithological subdivision in the map area (Unit Cms). It is also locally coincident with the fault structure responsible for the northward truncation of the panel containing the Pisces and Goldfish prospects and, ultimately, for the production of a tectonic horse occupied by this particular slice of Unit Cfr felsic volcanic rocks (Figure 2).

A widespread group of later-formed fold-and-fault structures is consistently northeast-trending within the outcrop area of the Catchers Pond Group in the Indian River–Shoal Pond area. The intermediate pyroclastic strata of Unit Cmi and the underlying basalts of Unit Cbc form open to tight, upright periclinal folds north of Long Pond; whereas, felsic tuffs and grey phyllites in Unit Cfr outline northwesterly-overturned and subrecumbent folds east of Shoal Pond (Figure 2). Ordovician strata in the northern and central part of the area surveyed are dominated by southeast-dipping, high-angle reverse faults that are generally associated with the regional northeast-trending folds and a strong axial planar foliation. They displace the early-formed thrust faults and allied folds and tectonically readjust the earlier-formed imbricate thrust stack (AA' and BB' in Figure 3).

Farther south, the southwest-plunging S-shaped secondary folds crossing the Pisces–Goldfish horse are overturned to the southeast (BB' in Figure 3). In contrast, the coeval W-shaped fold affecting the Cbc–Cmi–Cfr stratigraphic succession in the immediately underlying tectonic panel is upright. Locally, the temporal relationship of the southeasterly overturned folds (in the south) to the more commonly encountered northwesterly overturned folds is unknown. In this regard, Szybinski (1995) postulated that the Catchers Pond and Lushs Bight groups were structurally emplaced above the Springdale Group, along northwest-dipping reverse faults near the town of Springdale.

The late-formed antiforms, synforms and reverse faults affecting the Catchers Pond Group in the Indian River–Shoal Pond area are truncated by felsic and mafic plutonic rocks assigned to the Topsails intrusive suite (AA' in Figure 3). Strongly foliated volcanic and sedimentary rocks from the Catchers Pond Group are observed as accidental xenoliths in small exposures of these isotropic intrusive rocks. In the north, a northwesterly overturned fold is interpreted to have been crosscut by an east-northeast-trending transcurrent fault that also deforms Unit Ts and Unit Tg (Figure 2).

STRUCTURE OF SILURIAN ROCK UNITS

In the southeasternmost part of the Indian River–Shoal Pond area, several northeast-trending fold and fault structures are depicted by red symbols (Figure 2). These affect the dominantly volcanic (Unit Sv) or sedimentary (Unit Ss) subdivisions of the Silurian Springdale Group. A northeast-plunging upright syncline and a southeast-dipping high-angle reverse fault are shown as representative structural features in plan view and cross section (Figures 2 and 3). These are displaced by a northeast-trending dextral transcurrent fault and a later northwest-trending sinistral transcurrent fault. The intersection of such faults facilitates tectonic extrusion of the quartz-veined Ordovician stratified rocks and the faulted Silurian plutonic rocks that lie to the immediate north of the negligibly strained strata of the Springdale Group.

TECTONIC SETTING

As defined by Szybinski (1995), the Catchers Pond sequence of the Western Arm Group comprises a compositionally mature island arc-related rock succession that accumulated, conformably or otherwise (Kean *et al.*, 1995), above the primitive oceanic rocks of the Lushs Bight Group.

Interpreted as a Laurentian continental margin sequence of volcanic and epiclastic sedimentary rocks, the type Catchers Pond Group contains relatively large volumes of felsic pyroclastic strata compared to other units in the Notre Dame Subzone. On the basis of their isotopic composition, Catchers Pond felsic volcanic rocks do not indicate the presence of continental crust within the source area of the felsic melts or show significant involvement of such crust during the ascent of the felsic magma batches (Swinden *et al.*, 1997).

It is possible that the Catchers Pond Group evolved above a pre- *ca.* 479 Ma deformed and metamorphosed ophiolite, which is partially preserved within the Hall Hill Complex (Unit 1 of O'Brien, 2003). Deposition of Catchers Pond sedimentary and volcanic strata could have occurred after the initiation of west-directed Taconic subduction in the early Arenig (*cf.* van Staal *et al.*, 2007) but prior to the formation of the *ca.* 473 Ma ophiolite slivers found in the Annieopsquotch accretionary tract (Zagorevski *et al.*, 2006). The southeast-directed thrust slices developed throughout the eastern part of the Notre Dame Subzone have been interpreted to have formed during and after Taconic subduction at various times in the Ordovician and the Silurian (*e.g.*, Szybinski, 1995; Zagorevski *et al.*, 2006).

INTERPRETATION

In the area surveyed, it is uncertain whether Silurian terrestrial strata were regionally folded prior to being intruded by any of the units assigned to the Topsails intrusive suite. Given the lack of any absolute dating of the dynamothermal metamorphism of the Ordovician marine strata, it is also uncertain whether the northeast-trending fold and reverse faults in the Silurian cover sequence were produced at the same time as similarly oriented structures in the presumed Ordovician basement. If Unit Tg granodiorite does indeed have a Llandovery crystallization age similar to that of other plutons in the Topsails intrusive suite (Whalen and Currie, 1988), then the late-formed structures in the Catchers Pond Group would predate deposition of the Llandovery and younger Springdale Group. The present structural boundaries of the Springdale Group are, of course, considerably younger than any ductile structure responsible for the inversion or excision of the sub-Springdale surface of unconformity (*see* AA' in Figure 3).

A transtensional graben situated near the Indian River has been identified on the southeastern part of cross section AA' (Figure 3). This structure is defined by a northeast-trending pair of subvertical transcurrent faults that are thought to have also had a dip-slip component of movement. A related half-graben near Shoal Pond is illustrated on the northwestern part of cross section AA', adjacent to a large horst block (Figure 3). In the Indian River–Shoal Pond area, these brittle fault structures offset altered rocks of the Topsails intrusive suite, the Springdale Group and the Catchers Pond Group. They were utilized by a regionally extensive swarm of late-stage diabase dykes during their emplacement and final crystallization.

The vertical down-dropping and lateral ejection of the bedrock in the Devonian (?) graben and half-graben are considered to have been instrumental in forming fossil valleys, two of which are presently occupied by the low-lying Holocene fluvial deposits of the Indian River and Shoal Pond Brook. These landforms partially bury a thick Quaternary fill, including glaciofluvial terraces and ridges developed above the limit of marine incursion (Liverman *et al.*, 2000a, b). However, they also locally preserve deeply weathered, cataclastically brecciated, hydrothermally altered bedrock.

Isolated occurrences of presumed Carboniferous strata are found near Black Brook, Indian Pond and South Brook in Green Bay District (Dean, 1977). The deposits near Indian Pond in the NTS 12H/8 map area are herein postulated to have accumulated near the former junction of the fossil valleys along Shoal Pond Brook and the Indian River. Farther northeast, similar alluvial, lacustrine and deltaic Carboniferous rocks are thought to crop out between Harry Brook and Corner Brook in the NTS 12H/9 map area and are well exposed at sea level near King's Point, adjacent to glacially striated ridges of pre-Carboniferous bedrock.

CONCLUSIONS

The Ordovician Catchers Pond Group is provisionally separated into four, regionally mapped lithostratigraphic units within the Indian River–Shoal Pond area. From oldest to youngest, these are: a subdivision dominated by basalt flows (Unit Cbc), a subdivision dominated by intermediate pyroclastic strata (Unit Cmi), a subdivision dominated by rhyolite flows and felsic pyroclastic strata (Unit Cfr), and a subdivision dominated by basalt breccia and epiclastic turbidites (Unit Cms).

Such marine volcanosedimentary strata were intruded by nested plutonic rocks and several suites of minor intrusions subsequent to the regional deformation and dynamothermal metamorphism of the Catchers Pond Group. Bodies of granodiorite (Unit Tg), granite (Unit Tm), diorite (Unit Td) and syenite (Unit Ts) have been mapped at 1:25 000 scale and been assigned to the Silurian Topsails intrusive suite.

The regional disposition of internal lithostratigraphic units in the southwestern part of the Catchers Pond Group is controlled by early-formed thrust faults. Late-formed folds are important structures in amplifying the tectonic relief of certain structural panels of prospective volcanic rocks. In the area surveyed, previously recognized massive sulphide deposits have been placed in the regional structural and stratigraphic setting of this part of the Catchers Pond Group.

Major transcurrent faults are responsible for tectonically juxtaposing the Silurian stratified rocks of the Springdale Group against the rocks of the Catchers Pond Group. In many localities, these brittle structures also displace the intrusive margins of propylitically altered Silurian plutons and their base metal-mineralized and brecciated Ordovician country rocks.

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