

# THE SILURIAN INDIAN ISLANDS GROUP AND ITS RELATIONSHIPS TO ADJACENT UNITS

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## ABSTRACT

The Silurian Indian Islands Group (IIG) and adjacent units were surveyed from Indian Islands to Glenwood, in central Newfoundland. Previous workers had shown that the group extended west to a major structure called the Dog Bay Line. An examination, in 2005, of the more accessible areas of the IIG has led to the interpretation that it extends beyond the Dog Bay Line. In agreement with some recent work, the IIG is conformably overlain by the Ten Mile Lake Formation along a zone that generally coincides with the Dog Bay Line. The Ten Mile Lake Formation should be included in the IIG. The Late Ordovician-Early Silurian Badger Group is extended to the east of the IIG, and would now include areas previously mapped as part of the Middle Ordovician Davidsville Group. The Duder Complex is abandoned as a stratigraphic unit and is interpreted to be a zone of mainly pelite and minor volcanic rocks related to the Badger Group, which, along with diabase dykes, has been strongly deformed.

## INTRODUCTION

### LOCATION AND ACCESS

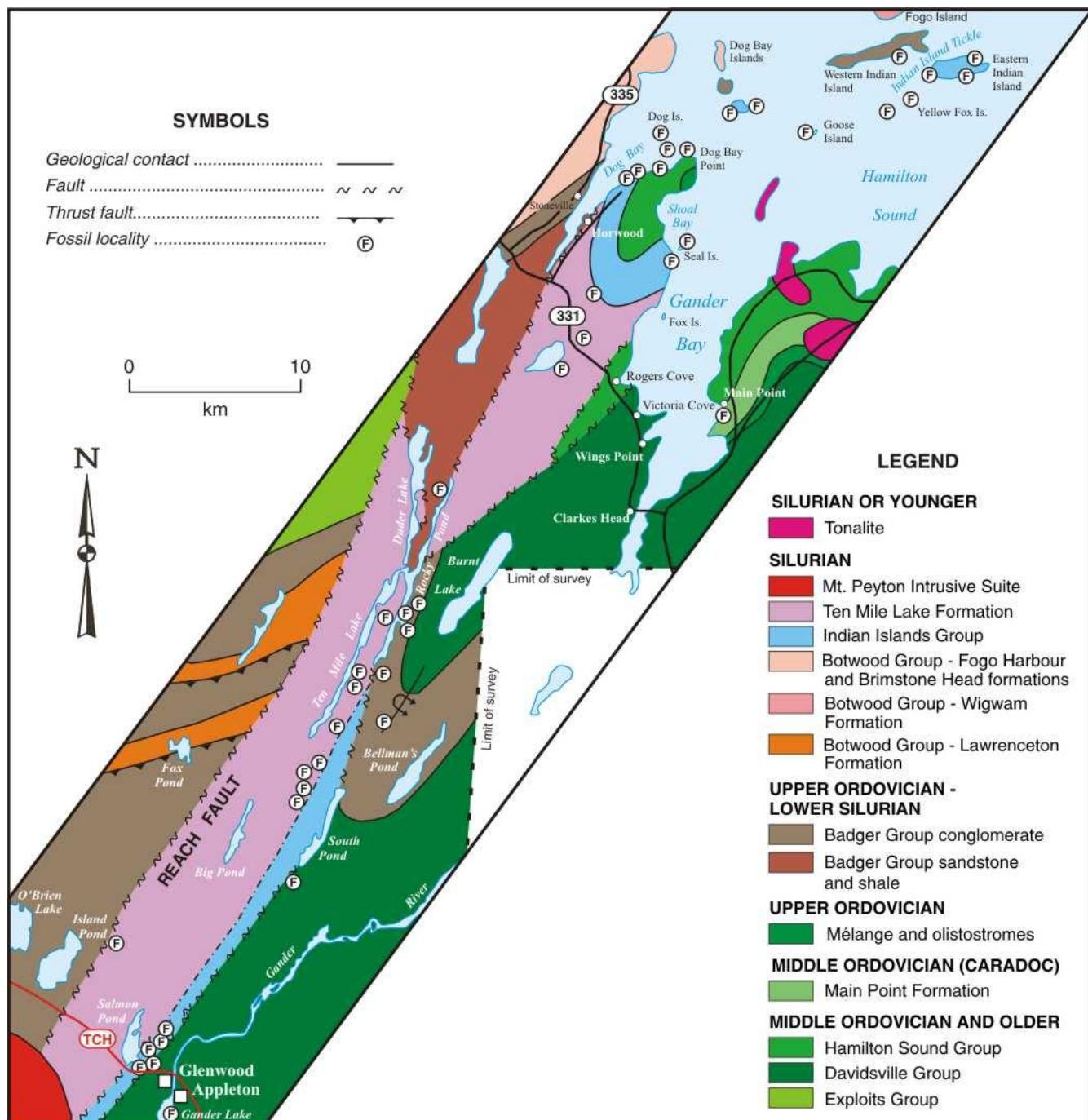
The Silurian Indian Islands Group (IIG; Baird, 1950) forms a narrow belt of polydeformed sedimentary rocks that extends from the Indian Islands, located south of Fogo Island in northeastern Newfoundland, southwestward through Glenwood to the Northwest Gander River in east-central Newfoundland (distribution partly shown in Figure 1); the area is accessible by paved highways and a network of forestry roads. The extensive coastal exposures and numerous islands are usually accessible by small boat. There are several large lakes in the area but time constraints permitted an examination of only Rocky Pond. There are several small towns and communities in the area including Glenwood-Appleton, Horwood, Stoneville, Rogers Cove, Victoria Cove, Wings Point and Clarkes Head. Several junior mineral-exploration companies and prospectors have carried out extensive studies in the area to assess its gold potential (e.g., Rubicon Minerals, Crosshair Exploration and the Quinlan family of Birchy Bay, Newfoundland).

### REVIEW

The earliest geological examination of the IIG was carried out by Howley in 1871, as part of his survey of the Notre Dame Bay and Red Indian Lake area (in Murray and Howley, 1881). He noted the presence of slate, calcareous slate and thick beds of fossiliferous limestone, 3 to 8 m thick,

containing encrinites (i.e., crinoids), corals, possibly including *Zaphrentis* sp., and a “spiral univalve” resembling *Murchisonia* sp. (a gastropod). He suggested that the Indian Islands strata formed the northern limb of an east-trending syncline that reappeared in the Gander Bay area.

Twenhofel and Shrock (1937), Shrock and Twenhofel (1939), and Twenhofel (1947), carried out detailed palaeontological studies on the limestones and siltstones in the Indian Islands, Yellow Fox Island, Dog Bay Islands, Dog Islands and Dog Bay areas. This resulted in the discovery of several fossil localities and the identification of many species of Clinton age i.e., early Middle Silurian or approximately middle Llandovery-Wenlock and several new species were also described. The fossils identified were mainly solitary and colonial corals including *Cyathophyllum* cf. *articulatum*, *Favosites gothlandicus*, *Favosites hisingeri*, *Zaphrentis* cf. *stokesi*, and the stromatoporoid *Clathrodictyon vesicolosum*; crinoid fragments were found but not identified. They determined that the IIG sequence younged from north to south. The main fossil localities that were examined in detail were on the south shore of Eastern Indian Island and Yellow Fox Island, 3 km west-southwest of Eastern Indian Island. These localities form the upper parts of the succession examined by Twenhofel and Shrock (1937). In the Seal Island area on the west side of Gander Bay, Twenhofel (1947) reported the gastropods cf. *Hormotoma* and cf. *Cyclonema*, the colonial corals *Favosites* sp., *Heliolites* sp., the solitary coral *Streptelasma* sp., and the stromatoporoid *Clathrodictyon?* sp.



**Figure 1.** General geology of the area between Indian Islands and Glenwood based locally on interpretations by Currie (1997a) and O'Brien (2003).

Geological mapping carried out in the 1950s and early 1960s indicated that the IIG was restricted to the Indian Islands–Gander Bay–Dog Bay (Horwood Bay) area, e.g., Baird (1950, 1958), Patrick (1956) and Williams (1964). Both Eastern and Western Indian islands and the middle and southern Dog Bay Islands were shown to be underlain by IIG rocks. The main rock types noted were pelite, conglomerate,

sandstone and quartzite along with minor fossiliferous limestone and calcareous siltstone. Highly deformed mafic dykes were described by Baird (1950, 1958), and Patrick (1956) further indicated that the IIG contains a core of volcanic rocks and chert exposed on islands along the axis of a syncline in Dog Bay and also on shore near the head of Dog Bay.

Eastler (1969, 1971) also included the Indian Islands (Eastern and Western), Dog Bay Islands, Dog Islands and part of the shoreline north of Stoneville in the IIG. Further, he included only the southern part of Middle Dog Bay Island and placed the northern portion of the island in the Hare Island Formation (now part of the Botwood Group). The two groups were separated by a major thrust termed the Indian Islands Thrust. Eastler (1971) identified many fossils from the IIG of Early Silurian age. His thesis area included Change Islands and he reported that the North End Formation, now termed Lawrenceton Formation and which forms the lowest unit of the Botwood Group, locally contained patches of highly fossiliferous limestone. These fossils indicated an Early Silurian (Llandovery) age for the base of the Lawrenceton Formation.

Williams (1972) compiled a list of all known fossil localities and identifications in a description of the geology of the Botwood map area (NTS 2E). The fossils in his Indian Islands and Botwood groups were of Ashgill to Llandovery age; most fossils found in the IIG were too deformed for identification. However, fossils collected from the limestones on Goose Islands, which are assigned to the IIG, indicated a possible late Llandovery age.

Wu (1979) included the peninsula between Dog Bay (Horwood Bay) and Gander Bay in his thesis area and assigned all the strata on the peninsula, apart from the felsic and mafic intrusions, to the IIG. He subdivided the group into several formations with the basal unit being composed of Upper Ordovician slate (not equivalent to the fossiliferous Caradocian slate at Main Point), basalt and local olivine-stromatolite horizons and the uppermost unit was a sequence of Silurian green to red micaceous siltstone. The sequence had been folded into a series of generally northeast-trending, upright to slightly overturned anticlines and synclines. Also discovered were loose blocks of sandstone that contained a brachiopod identified as *Pentamerus* cf. *P. oblongus* J. deC. Sowerby, indicative of a late Llandovery to Wenlock age. The blocks also contained tabulate and rugose corals, but the source of these fossiliferous blocks has not been found.

Karlstrom *et al.* (1982) included the Indian and Dog Bay islands and the peninsula between Dog Bay and Gander Bay in a study of the structural geology of eastern Notre Dame Bay. They modified the mapping of Williams (1964) and Wu (1979) by separating out from the IIG, a large tract of ground west of Gander Bay in the Shoal Bay area, and assigning it to a mélange unit. This mélange was interpreted to be continuous with the Dunnage and Carmanville mélanges and to structurally underlie all the stratigraphic units in the area. Without specifying the names of the units, Karlstrom *et al.* (1982) implied that the Indian Islands and Botwood groups and the turbidites and conglomerates (now

assigned to the Badger Group of Williams, 1993) were in thrust contact with the underlying mélange. Because of similarities in structural style in all units, they also considered that the earliest deformation of these units either occurred between the Ordovician and the Middle Silurian, or was entirely post-Middle Silurian. The younger age of deformation is based on the age of the youngest fossils found in the area (cf., Twenhofel and Shrock, 1937).

Blackwood (1982) and Evans (1993) mapped the Gander River map area (NTS 2E/2) and indicated that the contact between the Davidsville and their Botwood groups was stratigraphic. Churchill and Evans (1992) produced a detailed map of the area between Duder Lake and Rocky Pond as part of a study of gold mineralization in the area. The map indicated that the basalts of the Lawrenceton Formation and the sandstones of the Wigwam Formation of the Botwood Group were in fault contact with slates of the Davidsville Group. Churchill *et al.* (1993) indicated that this contact was the Dog Bay Line (*see below*) and appeared to have controlled the intrusion of gabbro dykes and sills into their Davidsville Group. They also noted that chilled margins to the dykes and hornfelsing of the adjacent sedimentary rocks indicated an intrusive relationship.

In the 1990s, work by Currie (1993, 1994, 1995a, b, c; 1997a), Williams (1993), and Williams *et al.* (1993) indicated that the IIG should be extended to the southwest of Glenwood. Dickson (1993) indicated that rocks found about 25 km south of Glenwood were similar to those described earlier by Currie (1993) and assigned them to the IIG. Boyce *et al.* (1993) reported a variety of fossils, including Late Silurian to Early Devonian (Prídlolí to Gedinnian) bivalves, in rocks exposed along Careless Brook, about 20 km southwest of Glenwood, which they assigned to the Botwood Group; subsequently, Boyce and Ash (1994) reassigned these rocks to the IIG. With these changes and fossil discoveries, the IIG was extended, through a series of disconnected outcrops, to well southwest of Glenwood. Much of the former Botwood Group in the Glenwood area was therefore reassigned to the IIG (Williams *et al.*, 1993, page 2483) including nearly every known fossil locality within the Wigwam Formation of the Botwood Group (*see* Williams, 1972).

The contact between the IIG and the underlying Caradocian and older Hamilton Sound Group of Currie (1992a; previously assigned to the Davidsville Group of O'Neill and Blackwood, 1989), southwest of Dog Bay Point, was described as an unconformity (Williams, 1993; Williams *et al.*, 1993; Currie, 1997a) between fossiliferous IIG rocks and the underlying pelite. To the southwest, in the Rogers Cove area, the contact was shown to be a thrust between the IIG and the Ordovician Hamilton Sound and Davidsville groups that extended from Rogers Cove south-

west to Rocky Pond (Currie and Williams, 1995). In the Glenwood area (Currie, 1995b, 1997a), the IIG was shown to be in fault contact with the Davidsville Group.

Williams *et al.* (1993) and Williams (1993) proposed that the western boundary (= northern boundary in the Indian Islands area) of the IIG was a major structure, which they termed the Dog Bay Line (Dog Bay Fault of Currie, 1992b, 1993). This “Line” was described as a terrane boundary, marked by a mélange separating the Silurian IIG from Ordovician and Silurian rocks to the west, and these rocks included the newly defined Badger (Williams, 1993) and Duder groups (Currie, 1993). The Dog Bay Line extended from between the Eastern and Western Indian islands, along the east side of Dog Bay, through Rocky Pond to Glenwood. The Dog Bay Line is here replaced by a fault of undetermined nature in Figure 1. As a result, several areas north and west of the line, previously shown to be underlain by the IIG, were assigned to other units. The turbidites and conglomerates of Western Indian Island, Middle Dog Bay Island and along the west side of Dog Bay were reassigned to the Badger Group. The pelites and associated volcanic rocks in the area between Eastern and Western Indian islands, on Middle and South Dog Bay Island, along and south of Dog Bay and in the Duder Lake areas, were assigned to the Duder Group.

The Duder Group is described in Currie (1993) as being composed of dark shales, felsic tuffs and flows, pillow lavas and gabbro sills, siltstone of various colours, and conglomerate containing clasts of chert, siltstone, volcanic rocks and granite. The volcanic breccias locally contain interstitial limestone. Its age is described as “Middle Ordovician ?” and older than “pre-Llandovery or younger” as it is interpreted to be older than the “Llandovery or younger” Stoneville formation, which is assigned that age based on its assignment to the Badger Group (Currie, 1993). The Dog Bay Line is described as being marked by a mélange, termed the Garden Point Mélange in Williams *et al.* (1993), containing exotic blocks of volcanic and mafic intrusive rocks of presumed Ordovician age. Large lensoid blocks of gabbro within the complex were interpreted to be clasts in the mélange as there was no evidence for an original intrusive relationship between the gabbro and the enclosing slates. This conflicts with the descriptions presented by Twenhofel and Shrock (1937), Shrock and Twenhofel (1939), Patrick (1956), Baird (1958), Eastler (1971), Churchill and Evans (1992) and Churchill *et al.* (1993).

Currie (1994) renamed the Duder Group to Duder Complex (Currie, 1995a, b, 1997a) and the term Garden Point Mélange was dropped. Currie (1995b) indicated that the complex extended westward to the east side of the Reach Fault and as far south as the area west of Glenwood, where

it was truncated by the gabbro of the Mount Peyton Intrusive Suite dated by Dunning (1994) at  $424 \pm 2$  ( $2\sigma$ ) Ma. In Williams *et al.* (1993, page 2487), the Garden Cove Mélange was interpreted to be Ordovician and a possible correlative of the Dunnage Mélange. However, Currie (1995a, 1997a) indicated that the Duder Complex was deformed mainly in the Silurian with the possibility of an older deformation and he further noted that blocks of fossiliferous limestone, possibly from the IIG, were found in the complex.

Currie (1993) reported that the IIG was conformably overlain by the red siltstone and shale of the Centennial Formation. This formation was subsequently correlated with the Ten Mile Lake sandstone of the Botwood Group (Currie 1993, 1994). Currie (1995a, b) then separated out and renamed the red siltstone and shale east of the Reach Fault as the Ten Mile Lake Formation. That part of the Ten Mile Lake sandstone west of the Reach Fault was left with the Botwood Group but was no longer termed Ten Mile Lake sandstone. Currie (1995a, b, 1997a) states that the Ten Mile Lake Formation is both conformable on the Indian Islands Group and unconformably oversteps the Dog Bay Line and the Duder Complex, which is indicated to be, in part, slightly younger than the IIG. However, Figure 2 in Currie (1995a) clearly indicates a stratigraphic break between the IIG and the Ten Mile Lake Formation.

O’Driscoll and Wilton (2005) reported ages on some mafic and granitic units associated with mineralization. The ages were determined by LAM-ICP-MS analyses of zircons. A gabbro from the Corsair gold prospect in the Mount Peyton Intrusive Suite gave an age of  $427 \pm 4.2$  Ma ( $1\sigma$ ). A gabbro dyke that has intruded the Ten Mile Lake Formation of Currie (1997a), about 10 km north of Glenwood and east of the Reach Fault, was dated at  $429.3 \pm 4.2$  Ma ( $1\sigma$ ). The Charles Cove pluton, a granodiorite that is mapped by Currie (1997a) as having intruded the Ordovician Hamilton Sound Group, was dated at  $429 \pm 19$  Ma ( $1\sigma$ ). This granodiorite and the IIG are cut by a quartz vein that is associated with minor tungsten mineralization at the Tim’s Cove Show-ing.

Some preliminary work was carried out by Squires (2005) on the Titan gold showing, about 7.5 km west of Wings Point. A 15-m-thick, foliated, medium-grained gabbro dyke has intruded buff cleaved siltstone of the IIG and all are cut by auriferous quartz veins (Crosshair Exploration Ltd., 2005a). This dyke gave a U/Pb zircon SHRIMP age of  $381 \pm 5$  Ma ( $2\sigma$ ; early Late Devonian; *see* McNicoll *et al.*, *this volume*). Crustiform quartz veins and quartz-breccia float were also described by Squires (2005) from the east side of Dog Bay in Horwood. It was noted that the veins cut mylonitic graphite-sulphide pelite assigned by Currie (1994) to the Duder Complex.

## DESCRIPTION OF UNITS

### INTRODUCTION

The main units examined during 2005 were the IIG, the Ten Mile Lake Formation, the Duder Complex (Group) of Currie (1993, 1994, 1997a), and small parts of other groups adjacent to the IIG and Duder Complex. These include the Silurian Lawrenceton and Wigwam formations of the Botwood Group, the Late Ordovician to Early Silurian Badger Group, the Middle to Late Ordovician Hamilton Sound and Davidsville groups, and a variety of mafic and felsic dykes found in most units, although not shown in Figure 1. A total of 83 fossil localities were found between Glenwood and Eastern Indian Island, many of them being new localities. Three previously reported localities (in Williams, 1972) were not found. Some other fossil localities on Cooper Brook, 45 km south of Glenwood (Anderson and Williams, 1970; Williams and Tallman, 1995), and some other localities a few kilometres south of Glenwood were also examined and collections made from the limestones and sandstones. It is clear that the rock types and fauna along Cooper Brook and also those closer to Glenwood are similar to those found in the IIG and also in the Ten Mile Lake Formation north of Glenwood (see Boyce and Dickson, *this volume*). Further, the sandstone assigned to the Ten Mile Lake Formation at Cooper Brook appears to have been contact metamorphosed by granite of the Mount Peyton Intrusive Suite (see Lake and Wilton, *this volume*).

### Davidsville Group

Rocks assigned to the Davidsville Group (see Currie, 1997a; Blackwood, 1982) extend from Gander Bay to south of Glenwood (see Blackwood, 1981). The sequence is dominated by grey slate and sandstone and locally contains thick units of cobble and pebble conglomerate in the Bellman's Pond and Rocky Pond areas. These conglomerates and associated slate and sandstone are here interpreted to form part of a more extensive Badger Group, located east of Rocky Pond and are described below.

Along the east-trending shoreline at Rogers Cove, dark-grey, cleaved pelite contains an inclusion of vesicular basalt (Plate 1). About 100 m to the west, a sequence of strongly cleaved, grey sandstones and slates contain medium- to thick-bedded, strongly cleaved, coarse-grained sandstones intermixed with shale clasts; the clasts contain the same cleavage as the host rock. This area of slate and sandstone and siltstone was assigned to the Outflow Formation of the Late Davidsville Group by Currie (1995c). The slates and sandstone are probably in fault contact with the Main Point Formation of the Hamilton Sound Group as the two formations have distinctly different orientations that cannot be explained by folding (see Currie, 1995, 1997a). To the west



**Plate 1.** Inclusion of basalt in grey sandstone of the Davidsville Group, Rogers Cove. LD05-476b

of the conglomerates and sandstones, along the shore at Rogers Cove, the pelites contain a few beds of highly calcareous, buff sandstone interbedded with grey pelite and sandstone. The calcareous sandstone could indicate that the sequence is part of the IIG as indicated in Currie and Williams (1995), but as yet no fossils have been found that could confirm this interpretation. The presence of conglomerates may indicate some affinity with the Badger Group as they are similar to one of the conglomeratic outcrops west of Bellman's Pond.

Near the top of the sequence at Glenwood, graptolites were obtained from a sequence of thin-bedded, dark grey slate and cherty siltstone on Salmon River. This is probably the same outcrop from which Anderson and Williams (1970) and Williams (1972) obtained the graptolites *Dicellograptus sextans* var. *exilis* E & W, *Climacograptus bicornis* (Hall) and *Leptograptus* sp. that indicated a Late Ordovician (Caradocian) age. Other fossiliferous outcrops are known from the Glenwood–Appleton area and these all indicate a Caradocian age for the upper part of the Davidsville Group (Williams, 1972; D. Boyce, unpublished data, 2004).

The granitic units at Bellman's Pond indicated and described in Currie (1995b) were not found. Instead, the outcrops found were of well-bedded and cleaved, steeply dipping grey sandstone and slate and interbedded conglomerate locally cut by quartz veins (cf., Blackwood, 1982). Graded bedding indicates that the sandstones are younging to the east.

### Hamilton Sound Group

Rocks assigned to the Hamilton Sound Group (see Currie, 1997a) are located in the Gander Bay and Dog Bay Point areas. The Hamilton Sound Group was introduced by Currie

(1992b), who separated it from the Davidsville Group as defined by O'Neill and Blackwood (1989). Williams (1972) reported the graptolites *Orthograptus quadrimucronatus* var. *spinigerus* Lapworth, 1876; cf. *Leptograptus flaccidus* Hall, 1865; *Orthograptus* cf. *O. quadrimucronatus* Hall, 1865, which indicated a Middle Ordovician (Caradoc) to possibly younger age for the pyritic slate and sandstones on the east side of Gander Bay at Main Point. These graptolitic shales were assigned to the (Middle Ordovician) Main Point Formation by Currie (1997a); the formation is overlain by the Carmanville Mélange, the matrix of which contains shale derived from the Main Point Formation (Currie, 1992b), which is in conflict with the interpretation of Karlstrom *et al.* (1982). On the west side of Gander Bay in the Victoria Cove area, strongly cleaved and folded, dark grey, locally pyritic slates are probable correlatives of the Caradocian Main Point Formation (Plate 2). These pyritic slates are interbedded with grey slate and siltstone that contains bands of yellow-green pelitic rock that may be tuffs. These possible tuffs are also found along the western shore at Rogers Cove and all are comparable with similar sequences in the Dog Bay and Dog Bay Islands areas (see section on the Duder Complex below).



**Plate 2.** Folded rusty pelite of the Caradocian Main Point Formation, Rogers Cove. LD05-479c

South of Dog Bay Point, part of the group has been mapped as the Dog Bay Point Mélange and correlated with the pre-Caradocian Carmanville and Dunnage mélanges (see Williams *et al.*, 1991; Williams, 1992). The Dog Bay Point Mélange is described by Williams (*op. cit.*) as being mainly bedded shale and siltstone with minor disrupted black and grey shale and blocks in a shaly matrix. Some of the larger blocks are gabbro and ultramafic rocks. In the few places, where the mélange was examined during the 2005 field work, the dominant rock types were thick- and thin-bedded sandstone, locally with vugs possibly reflecting dis-

solved-out calcareous patches. No blocks were found in the brief examination of the area but one bed was noted to be internally brecciated. At the southern end of the area mapped as mélange by Williams (1992), a rusty sequence of thin-bedded sandstone and cleaved siltstone was found. This rock type resembles the well-known Caradocian formations, which are typically pyritic. Currie (1993, 1997a) has correlated the Dog Bay Point and Carmanville mélanges and assigned them a post-Caradoc age, which is in conflict with the interpretations of Karlstrom *et al.* (1982) and Williams (1992).

The Hamilton Sound Group, southwest of Dog Bay Point, is underlain mainly by slightly calcareous, fine-grained sandstones. To the west toward Dog Bay, the group is composed mainly of steeply, east-dipping, highly deformed black slate containing interbedded green layers interpreted here as fine-grained sericitic tuffs. The black slate is in fault contact (e.g., Karlstrom *et al.*, 1982) with steeply east-dipping but west-younging sandstone, siltstone and fossiliferous limestone sequences assigned to the IIG (see Currie, 1997a).

About 2 to 2.5 km west of Dog Bay Point, rusty black pyritic pelite and sandstone and at one locality, minor limestone, form conspicuous outcrops along the shoreline. At 2.5 km west of Dog Bay Point, an approximately 3-m-thick sequence of thin-bedded, interbedded, limestone and siliceous limestone was found in apparent stratigraphic contact with a sequence of thin-bedded, highly pyritic black slate to the northwest, and a 3-m-thick quartz vein to the southeast (Plate 3). One bed of limestone contains a coral tentatively identified as *Favosites* sp. (Plate 4), a genus commonly found in the IIG rocks but having an age range from Ordovician to Devonian. However, without a precise identification this coral does not define the age of the sequence. The pyritic slate is somewhat similar to Caradocian shale and thus could indicate a possible Late Ordovician age for the limestone.

### Badger Group

The Badger Group (Williams, 1995), as previously mapped in the surveyed area, is characterized by thick-bedded, pebble and cobble conglomerate, interbedded coarse-grained sandstone and minor shale. The Badger Group has been shown, in other areas to the west in central Newfoundland, to conformably overlie Caradocian shale and chert, e.g., S.H. Williams (1993), Dickson (1999) and O'Brien (2003). At Change Islands, 8 km north of Dog Bay Islands (Easter, 1971; Currie, 1997b), and near Port Albert, 12 km to the north of Stoneville (Williams, 1993), greywackes of the Badger Group are unconformably overlain by basalts of the Lawrenceton Formation of the Botwood Group. On



**Plate 3.** Thin-bedded limestone within the Hamilton Sound Group, east of Dog Bay Point. LD05-956b



**Plate 4.** Thin-bedded limestone containing a coral, possibly *Favosites* sp., west of Dog Bay Point. LD05-956a

Change Islands, Eastler (1971) derived a Llandovery age from various corals and stromatoporoids in the Lawrenceton Formation near the stratigraphic contact with the Badger Group (his Change Islands Formation). Boyce and Ash (1994) obtained a Llandovery C<sub>3</sub> to C<sub>6</sub> (Telychian) age for the Badger Group from the faunas collected from sandstones and conglomerates at several sites west of Norris Arm.

Previous work has indicated that the extensive areas west of the Reach Fault, in the Fox Pond area, are underlain by conglomerates and sandstones now assigned to the Badger Group (e.g., Currie, 1997a; O'Brien, 2003). Conglomerates, east of the Reach Fault, are well exposed in the Stoneville area where they overlie highly deformed pelites that were previously assigned to the Duder Complex. The Badger Group at Stoneville, is dominated by strongly flat-

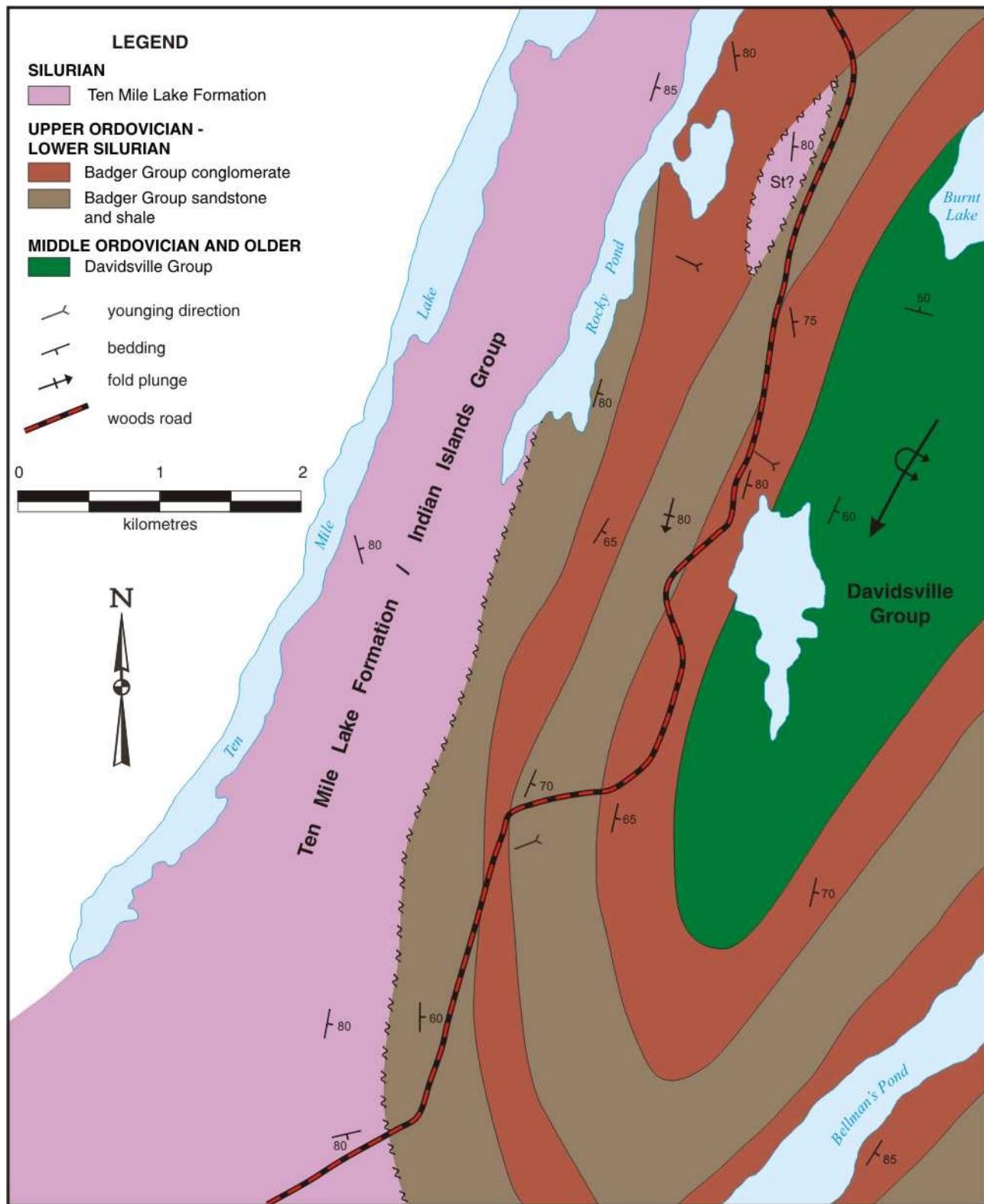
tened, thick-bedded, pebble conglomerate, very coarse-grained sandstone and minor slate, which is well exposed from the junction of Route 335 with Route 331 and north to Stoneville.

On the shoreline near the north end of Stoneville, the conglomeratic beds are underlain to the southeast by medium- to thin-bedded, grey and grey-green, medium- to fine-grained sandstone and siltstone that grade southward into grey, highly deformed and quartz-veined pelite. The top of the Duder Complex is defined in Williams *et al.* (1993) as the first occurrence of black shales that contain pebbles and cobbles of tonalite. This location is described by Currie (1995a) as coinciding with a highly sheared zone termed the Stoneville Fault. An examination of the shoreline provided no clear evidence for a fault between the conglomerates and the pelites. The only obvious fault is indicated by a prominent 150-m-long silicified quartz-vein breccia that is exposed along the shore near the centre of Stoneville, but the pelitic rock types on either side of the vein are identical. A similar breccia was found, in place, on a small island just offshore from Horwood. Blocks from this vein were also described and illustrated in Squires (1995).

Toward the southern part of Stoneville, exposures along the shoreline and on the main road contain isolated granule and pebble conglomerate beds within the pelite sequence. It is possible that these coarser grained beds indicate that the Badger Group continues to the south, rather than being part of the Duder Complex. Within the sequence of contorted black slates some beds are rich in pyrite. About 200 m north of the peninsula at the south end of Stoneville, thin sequences of mafic and felsic lapilli tuff are interbedded with the pelite. Currie and Williams (1995) suggested that these are exotic blocks within the Duder Complex. On Route 331, thin beds of felsic lapilli tuff are interbedded with grey pelite and sandstone and are clearly not exotic clasts.

Conglomerates were noted by Williams (1964) and Blackwood (1982) in outcrop along the eastern shore of Rocky Pond and they form a northeast-trending belt that is now assigned to the Badger Group (Figure 2). The conglomerate is dominated by chert pebbles and is interbedded with grey sandstone and slate. Fossils were obtained from this conglomerate, including corals and crinoids, but no precise identifications were possible (Williams, 1972).

Recent woods-road construction southeast of Rocky Pond has exposed numerous new outcrops of coarse conglomerate and pebbly sandstone, sandstone, interbedded grey and dark grey slate and a thick unit of volcanic ash (Figure 2). The conglomerates were assigned to the Exploits Group by Williams (1964), in part, of a possible Silurian



**Figure 2.** Structural interpretation of the Rocky Pond–Ten Mile Lake area.

sequence. The area to the southeast of Rocky Pond was assigned by Williams (1964) to the lower part of the Botwood Group (now part of the Badger Group of Williams, 1993, 1995), whereas Blackwood (1982) and Currie (1994, 1995b) assigned it to the Davidsville Group. The dominant clasts in the conglomerate are chert, silicic siltstone, slate and minor limestone. The slate clasts are overprinted by post-incorporation cleavage. Numerous clasts in the conglomerate contain fossils including solitary and colonial corals, crinoids, and rarely bryozoa, but specific identifications have yet to be made. This sequence has been intruded by a number of gabbro and diabase dykes, some of which are over 50 m thick.

West of Bellman's Pond, several outcrops of thick-bedded conglomerate contain clasts of a variety of rock types. At one locality 1 km west of the south end of Bellman's Pond, the clasts are mainly sandstone, vein quartz and granite; at another locality, 4 km to the northeast, the conglomerate forms a series of small outcrops and contains cobbles and pebbles of gabbro, tonalite, and possibly felsic tuff in a fine-grained, pebbly sandstone matrix (Plate 5). Some interbeds of sandstone are rich in quartz and feldspar and look like a granite wash. About 1 km farther west, the conglomerates are composed of dark grey, shale rip-ups in a sandy matrix and are interbedded with dark grey, coarse-grained sandstone.



**Plate 5.** Conglomerate containing clasts of gabbro and felsic tuff, west of Bellman's Pond. This unit is assigned to the Badger Group. LD05-831c

Along the road between Rocky Pond and Burnt Lake, thick-bedded, locally crossbedded sandstone is interbedded with sandstones containing mainly angular to subrounded chert clasts. The clasts are mainly matrix supported, but in some beds the clasts are much more abundant and there is little matrix. The conglomerate locally contains numerous

limestone and calcareous sandstone clasts containing corals and crinoids and the coarse-grained sandstone contains crinoid fragments. It is possible that this variety of conglomerate could be comparable with the conglomerate described from the eastern shore of Bellman's Pond that Blackwood (1982) notes contains abundant chert clasts. The conglomerate on the Burnt Lake road continues to the north and is interbedded with dark grey slate. Toward the end of the road, the conglomerate is succeeded by a thick unit of thin- to medium-bedded, grey-green, strongly cleaved volcanic ash (Plate 6) and a thin unit of pyritic slate. A similar sequence of ash was located on another new road about 3.5 km to the southwest where the sequence has an apparent thickness of about 500 m. Steeply plunging, tight and isoclinal folds, along with shear bands (Plate 6), are found in the ash sequence.



**Plate 6.** Thin-bedded and cleaved, probable volcanic ash cut by a shear band. The ash overlies fossiliferous conglomerates assigned to the Badger Group, east of Rocky Pond. LD05-208c

Of significance in this area is the observation that the ash and locally pyritic slate are in probable fault contact with fractured, steeply dipping, uncleaved, buff siltstone that contains zones of weathered-out bryozoa (Figure 2) that have not yet been identified; the siltstone is in stratigraphic contact, to the west, with thick-bedded sandstone. The other area of ash to the southwest, is also in fault contact with a sequence of uncleaved, very thick-bedded, rusty, fossiliferous coarse-grained sandstone and pebble conglomerate (Plate 7) containing a variety of crinoids, solitary corals and bryozoa, none of which have been specifically identified. These two areas of uncleaved fossiliferous rocks are interpreted to be fragments of a younger unconformable sequence that has been faulted into the ash and conglomerate sequence. It may be part of the Ten Mile Lake Formation or possibly an as yet undetermined unit.



**Plate 7.** Rusty, uncleaved, pebble conglomerate that locally contains corals and crinoids is in fault contact with strongly cleaved ash, cf. Plate 6. LD05-836

A sequence of rocks also interpreted to be volcanic ash, was found along a new woods-road along a peninsula near the northeast corner of Duder Lake; it lies to the west of a sequence of slate and sandstone that is locally cut by thick diabase dykes. A glacial erratic of uncleaved calcareous sandstone was found about 2.5 km to the south that contains brachiopods, a gastropod, crinoids and a *Favosites* sp. coral. The angular nature of the block and its fragility indicates that it has probably not travelled far and could indicate that an unconformity exists nearby that is possibly similar to that postulated for the Rocky Pond area.

A preliminary interpretation of the structure of the conglomerates and associated sandstones and volcanic ash, in the Rocky Pond–Bellman’s Pond area, is that of a steeply southwest-plunging, overturned anticline that closes to the southwest (Figure 2).

### Indian Islands Group

The Silurian Indian Islands Group (IIG) was originally defined by Baird (1950) as a belt of polydeformed sedimentary rocks in the Indian Islands to Dog Bay Islands area. The group extends, possibly discontinuously, from Eastern Indian Island in northeastern Newfoundland, southwestward through Glenwood (Figure 1) to the Northwest Gander River.

The Badger Group is interpreted to stratigraphically underlie the IIG, although the contact is now highly disrupted and the IIG is conformably overlain by the Ten Mile Lake Formation. The upper contact would lie within a transitional zone, in part faulted, extending from Salmon River, near Glenwood, to Horwood. Using the presence of fossiliferous limestone to define the western margin of the IIG, the strati-

graphic contact would lie along the peninsula between Rocky Pond and Ten Mile Lake. Using the presence of fossils in calcareous siltstone and sandstone to define a contact would take the contact up to 1 km farther west.

The dominant rock types in the IIG are grey, dark grey and buff, thin-bedded, polydeformed slate and siltstone, grey, medium- to thick-bedded sandstone, grey and brown, thin-bedded, calcareous and dolomitic siltstone and sandstone, thin- to medium-bedded, minor fossiliferous limestone and jasper-rich coarse-grained sandstone and rarely pebble conglomerate locally containing granite clasts. Deformed mafic to intermediate dykes are common and there are also a few felsic dykes. Of all the rock types in the IIG, limestone has been considered to be the most diagnostic rock type because it is generally rare in the adjacent formations.

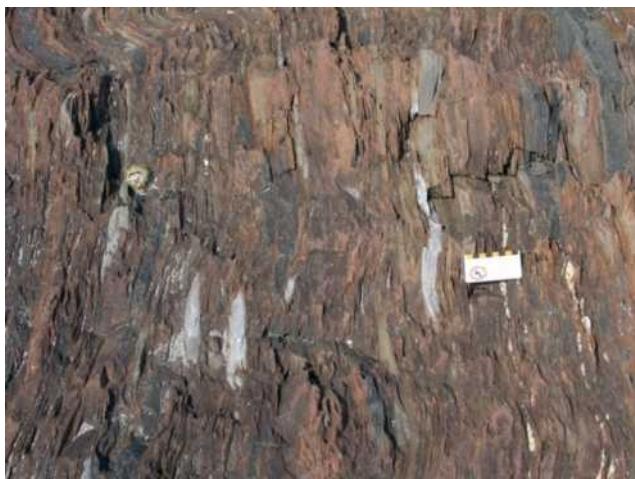
The sequence on Eastern Indian Island and Yellow Fox Island generally dips steeply to the north and is cut by a steep, south-dipping cleavage. Steeply plunging, isoclinal and open folds are seen in a few places as noted above. Twenhofel and Shrock (1937) considered the top of the succession to be the southern islands such as Yellow Fox Island and the south side of Eastern Indian Island based on cleavage–bedding relationships. Few clear younging criteria were found but graded beds of coarse-grained sandstone generally support their interpretation of a south-facing sequence. However, at one locality, steeply dipping, coarse-grained, graded sandstone indicates younging to the north (Plate 8).



**Plate 8.** Plan view of steeply north-dipping, coarse-grained sandstone in the Indian Islands Group, Western Indian Island. LD05-339b

Along the north coast of Eastern Indian Island and on the numerous islands along Indian Islands Tickle between Eastern and Western Indian islands, the dominant rock type

is highly deformed, dark grey pelite and locally, black pelite and sandstone. This sequence was assigned to the Duder Complex by Williams *et al.* (1993) and Currie (1997a). Along the axis of Eastern Indian Island, the dominant rock type is cleaved, polydeformed brown- or grey-weathering siltstone containing minor sandstone and limestone (Plate 9). Limestone is more abundant toward the top of the succession at the southwest corner of Eastern Indian Island where it is interbedded with grey slate and siltstone. Twenhofel and Shrock (1937) indicate that the limestone-rich strata of Yellow Fox Island and nearby islands would lie stratigraphically above Eastern Indian Island. The southern Goose Island also contains a significant amount of fossiliferous limestone interbedded with grey slate and sandstone (Plate 10) and these lie along strike from Yellow Fox Island. The northern Goose Island is underlain by highly cleaved grey-green sandstone and minor siltstone.



**Plate 9.** Strongly deformed and cleaved, brown sandstone containing boudins of grey limestone, north shore of Eastern Indian Island. LD05-544c

Currie (1993, 1997a) and Williams *et al.* (1993) report that the base of the IIG is exposed on the large island about 500 m west of the Seal Islands in Gander Bay. This contact was examined and is interpreted to be a steeply dipping, west-trending, folded, fault contact between highly brecciated and quartz-veined fossiliferous limestone and thick-bedded sandstone of the IIG and polydeformed, crenulated grey slate that may be part of the Hamilton Sound Group (Plate 11). The contact is clearly not a simple basal unconformity. To the south on the mainland, contacts between fossiliferous limestone and strongly cleaved pelite could be interpreted as unconformities although both the limestone and the siltstone are strongly cleaved (Plate 12). An unconformity was indicated in this area by Karlstrom *et al.* (1982) and partly by Currie (1995b, 1997a). The Ordovician age of the pelite below the postulated unconformity is uncertain as it has also



**Plate 10.** Interbedded, cleaved, fossiliferous grey limestone and calcareous sandstone, at Goose Island. LD05-225b



**Plate 11.** Faulted contact between thick-bedded limestone of the Indian Islands Group (left) and pelites, possibly of the Hamilton Sound Group, Seal Islands area, Gander Bay. LD05-237c

been interpreted as being part of the IIG (Williams, 1964; Wu, 1979). Farther south, thin beds of fossiliferous limestone are interbedded with the pelite and this is possibly the justification for their assignment to the IIG by Currie and Williams (1995).

Limestone also occurs along the northeast shore of Eastern Indian Island as local concentrations of thin and medium beds and lenses where it is interbedded with an extensive, sequence of brown-weathering siltstone. This sequence has probable correlatives as far west as the Dog Islands. Along the channel between Western and Eastern Indian islands and also the south coast of Western Indian Island, isolated thin units of limestone occur as dismembered beds and rare augen. These occur in thick sequences



**Plate 12.** Strongly cleaved, crinoidal limestone in contact with strongly cleaved siltstone on the west side of Gander Bay, 1 km southwest of Seal Islands. LD05-248b

of strongly deformed, grey and dark grey pelite. The presence of these limestones has probably been taken by earlier (pre-1990s) workers to indicate the continuity of the IIG onto Western Indian Island. Williams *et al.* (1993) assigned most of the rocks on Western Indian Island to the Badger Group apart from selvages of Duder Complex found along its southern coastline.

On the Dog Islands and Dog Bay Islands, thick and thin beds of cleaved fossiliferous limestone as well as isolated colonial corals are found in strongly deformed, brown slate sequences (Plate 13). The fossils most commonly found are crinoid fragments some of which are up to 20 cm in length; the colonial corals are mainly *Favosites* sp. (Plates 14 and 15). Along the eastern shoreline of Dog Bay, 500 and 700 m north of Horwood, two limestone sequences were found and these contained abundant crinoid debris. The more northerly sequence is part of a sequence of calcareous sandstone and siltstone and is probably the fossil occurrence indicated in Patrick (1956) and Williams (1964). Here, the limestone is thick bedded, partly silicified and interbedded with very thick-bedded, east-dipping, overturned, trough crosslaminated and graded calcareous sandstone (Plate 16).

Just north of the Route 331, along a woods-road, about 3.5 km northwest of Rogers Cove (Figure 1), an outcrop of fossiliferous, buff, friable, calcareous siltstone is located and assigned to the IIG. The unit contains a variety of fossils including the coral genera *Halysites*, *Heliolites*, *Coenites* and *Favosites*, crinoids and an encrinurid trilobite (Boyce and Dickson, *this volume*). This site is informally termed the Fancey Locality after prospector Derek Fancey, who discovered the fossils (*see* Boyce and Dickson, *this volume*, for a listing of the fossils). The fossiliferous siltstone is possibly in fault contact, to the south, with nearby thick-bedded grey



**Plate 13.** Strongly cleaved, interbedded, crinoidal limestone and brown-weathering siltstone of the Indian Islands Group, southwest side of the south Dog Bay Island. LD05-796a



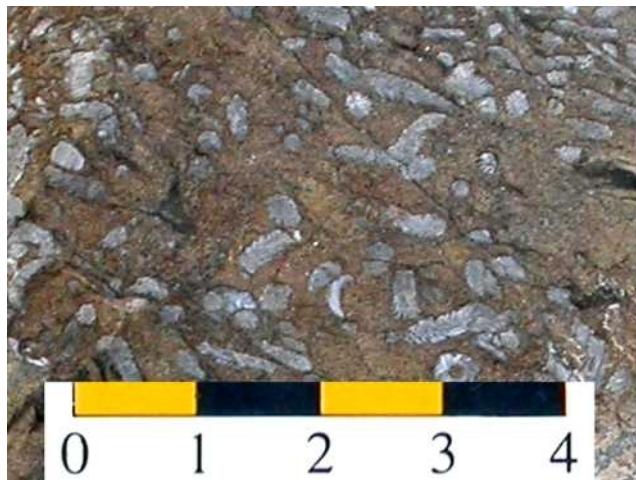
**Plate 14.** Vertical cross section of *Favosites* sp. coral in steeply dipping, strongly cleaved siltstone of the Indian Islands Group, on small islet east of south Dog Bay Island. LD05-781a

sandstone and cleaved, thin- to medium-bedded siltstone to the north. Both of these rock types are also assigned to the IIG.

In a disused gravel pit about 4 km north of Glenwood, well-preserved bryozoa have been identified as *Stictopora scalpellum* (Lonsdale, 1839; Plate 17; *see* Boyce and Dickson, *this volume*) and indicate a Wenlock age (Middle Silurian) for the western side of the IIG. This locality lies a few hundred metres east of another locality that contains a variety of corals and crinoids. To the south, along the Trans-Canada Highway in Glenwood, shelly calcareous sandstone beds contain a variety of fossils including the brachiopods



**Plate 15.** Horizontal cross section of flattened Favosites sp. coral in strongly cleaved siltstone on a small island, southwest of the largest Dog Island. LD05-897b



**Plate 17.** The Wenlock bryozoan Stictopora scalpellum (Lonsdale, 1839) in calcareous sandstone of the Indian Islands Group, 4 km north of Glenwood. LD05-064d



**Plate 16.** Trough crosslaminated calcareous sandstone of the Indian Islands Group, 1 km northwest of Horwood. The sandstone is associated with crinoidal limestone. LD05-951a

*Atrypa recticularis* (Linné) and *Leptostrophia* sp., which indicate a Wenlock or younger age for these rocks (see Boyce and Dickson, *this volume*, for a more comprehensive listing and description of the fossil localities in the IIG and associated rocks). Both of these fossil occurrences are a few hundred metres east of the western margin of the IIG.

Between Horwood and Rocky Pond, two areas of slate and sandstone were assigned by Currie (1993) to the Horwood Formation of the IIG. The formation is described as being 20 to 30 m thick and in transitional contact, to the east, with the Ten Mile Lake Formation. Along Route 331, 400 m east of the Horwood turnoff, the northeastern end of a large rock cut contains thin- to medium-bedded, brown-green,

fine-grained, micaceous sandstone and siltstone containing a cleavage parallel to bedding. This rock type is interpreted to be the lower part of the Ten Mile Lake Formation (e.g., Currie, 1993, 1997a; Currie and Williams, 1995) and to grade eastward into red and purple siltstone and sandstone assigned to the Ten Mile Lake Formation. The brown-green sandstone sequence grades to the west into green-brown slate and then into dark grey, phyllitic slate, which is the Horwood Formation of Currie (1993). Tight upright, gently south-plunging folds of bedding are seen in slate. Along the Horwood road and adjacent shoreline, the main cleavage and steeply dipping beds are folded into gently south-plunging, open folds with gently south-dipping axial planes (Plate 18). Along the Horwood road, the contact between the Hor-



**Plate 18.** Vertically cleaved and bedded siltstone of the Horwood Formation of the Indian Islands Group, south of Horwood. The linear structures dipping to the right are open  $F_2$  folds of bedding and cleavage. LD05-444a

wood Formation including the overlying Ten Mile Lake Formation and the main part of the IIG is shown to be a thrust that would coincide with the appearance of strongly cleaved shale-flake conglomerate, graded sandstone beds and slate containing quartz-carbonate veins.

Diabase and rare felsic dykes occur throughout the IIG, particularly in the Indian Islands area where contact metamorphism has converted adjacent limestone to marble. Many of these dykes are strongly deformed and strings of boudins parallel to the cleavage are locally well displayed. About 7 km southwest of Rogers Cove, some dykes are over 100 m thick, and vary in grain size from medium to coarse grained and some of the dykes contain the regional penetrative fabric, e.g., at the Titan gold prospect, (see McNicholl *et al.*, *this volume*) but this is rare. The dykes generally have had a minimal metamorphic effect on the host rocks. The felsic dykes are undeformed, leucocratic and have a granular texture and are up to 1 m thick. Examples were found on Goose Island, where the dyke has cut interbedded limestone and calcareous sandstone (Plate 19), and at Bussey's Point, near Wings Point, where greywacke assigned to the Davidsville Group, is cut by a similar dyke (locality described, in part, in Squires, 2005). Gold mineralization is associated with some of the dykes, in particular those containing pyrite and/or quartz veins.



**Plate 19.** Massive, leucocratic felsic dyke in the Indian Island Group at Goose island. The dyke has cut the limestone and sandstone seen in Plate 10. LD05-225c

The rocks of the IIG are generally highly deformed having steeply dipping beds containing a cleavage commonly parallel to bedding. The group is most intensely deformed in the Indian Islands to Dog Bay area where the rocks are, locally, highly folded and  $S_1$  cleavage is parallel to bedding reflecting steeply plunging isoclinal folds (Plate 20). Later deformations have folded cleavage and the chevron and box



**Plate 20.** Isoclinal folds of thin-bedded limestone and siltstone of the Indian Islands Group, northeast corner of Eastern Indian Island. LD05-543d



**Plate 21.** Chevron-folded, cleaved, brown siltstone of the Indian Islands Group, north shore of the largest Dog Island. LD05-902e

folds (see e.g., Karlstrom *et al.*, 1982) and kink bands have produced, locally, very complicated fold patterns (Plate 21). This style of deformation is best displayed in the abundant pelitic units in the vicinity of the Dog Bay Line of Williams *et al.* (1993). However, polyphase deformation is not restricted to this area and can be seen several kilometres to the south, in the Goose Island area, where later deformation has folded cleavage.

### Ten Mile Lake Formation

The Ten Mile Lake Formation (Currie, 1995a, b; Currie and Williams, 1995; formerly the Centennial formation of Currie, 1993, and Ten Mile sandstone of Currie, 1994) lies to the west of the IIG. The formation is composed mainly of

medium- to thick-bedded, red, pink, maroon, buff, green and grey, medium- to fine-grained, locally micaceous sandstone and siltstone (Plate 22). Minor rock types include limestone and shale-flake and pebble conglomerate. The buff siltstone and sandstone, east of Ten Mile Lake are commonly calcareous and locally contain fossiliferous, limestone-rich lenses that are, in places, highly weathered to brown mud. Locally, the sandstone is dark grey, where it has been contact metamorphosed by the numerous diabase dykes. Grad-ed-bedding, crossbedding and dessication cracks are found in a few places.



**Plate 22.** Medium-bedded, steeply dipping, interbedded maroon sandstone and siltstone of the Ten Mile Lake Formation, 13 km north of Glenwood. LD05-089b

Red sandstones are more common toward the western part of the formation and bedding is generally thick. Sedimentary structures include trough crossbedding and grading. These sandstones are quite similar to the Wigwam Formation of the Botwood Group. Fossils were found at a locality, 1.5 km northeast of Island Pond, in the western part of the Ten Mile Lake Formation and include undetermined solitary corals, crinoids and bryozoa (see also Williams, 1972).

Fossils were discovered mainly near the eastern margin of the Ten Mile Lake Formation, and these include, locally, well-preserved bryozoa identified as *Stictopora scalpellum* (Lonsdale, 1839; see Boyce and Dickson, *this volume*), solitary and colonial corals, crinoid ossicles and rarely, brachiopods. The fossils occur mainly in buff siltstone and would indicate a Wenlock age for the lower part of the Ten Mile Lake Formation. Red, fine-grained sandstone interbedded with fossiliferous limestone containing crinoids and corals was found about 2 km southwest of Rocky Pond. Bedded conglomerate containing clasts of fossiliferous limestone with crinoids and corals, reported in Currie (1995b) as occurring in a window into the Badger Group, is

here interpreted to be a large glacial erratic. No contacts with the adjacent rocks were found. Float in the area indicates that the bedrock is cleaved beige siltstone.

The Ten Mile Lake Formation is generally a steeply dipping sequence of rocks that has been folded into steeply plunging folds and having a near vertical axial-planar cleavage (Plate 23). In many areas, however, the dips of bedding are moderate to shallow and reflect large, gently plunging, open folds.



**Plate 23.** Steeply plunging, open fold in grey siltstone of the Ten Mile Lake Formation, 3 km south of Ten Mile Lake. LD05-142a

Massive diabase dykes are common in the Ten Mile Lake Formation and generally trend northeastward; a few are sheared, veined by quartz and contain pyrite. The dykes are generally fine to medium grained and equigranular, rarely greater than 15 m thick and display chilled margins. There is no evidence of dykes over 200 m thick as indicated in Currie (1995b, 1997a); rather, there are closely spaced dykes, each with chilled margins and separated by selvages of sandstone and siltstone that vary in width from a few to tens of metres. Contact metamorphism by these dykes has resulted in the sandstones and siltstone being converted to dark grey hornfels. Some of the sheared and quartz-veined, mafic dykes have been assessed for gold mineralization by exploration companies and prospectors, e.g., Crosshair (2005b).

#### Indian Islands Group–Ten Mile Lake Formation Relationships

The reconnaissance mapping of the IIG, carried out between Glenwood and Indian Islands, shows that it is more extensive than shown in Currie (1997a); it extends to the west and north of the Dog Bay Line as indicated in Williams

*et al.* (1993) and Currie (1997a). This is based primarily on the presence of numerous outcrops that contain faunas and limestones similar to the main area of the IIG. About 3 km north of Glenwood (Figure 1), numerous new fossil localities and beds of limestone and calcareous siltstone were found along the forest-access roads. These localities contain a variety of corals and crinoids, mainly in limestone beds, and calcareous bryozoa in sandstone. The bryozoa have been identified as *Stictopora scalpellum* (Lonsdale, 1839; Plate 17) and indicate a Wenlock age (Middle Silurian; *see* Boyce and Dickson, this volume) for the western side of the IIG.

About 17 to 28 km north of Glenwood, along the forest-access roads between Ten Mile Lake and Rocky Pond (Figure 1), the same bryozoan *Stictopora scalpellum* was found in buff siltstone. Solitary corals and crinoids were found in lenses of limestone within the siltstone. This area was assigned to the Ten Mile Lake Formation (e.g., Currie, 1997a), but the presence of limestone may indicate an affinity with the IIG. These occurrences all lie to the west of the Dog Bay Line, which is shown by Williams *et al.* (1993) and Currie (1997a) to lie to the east beneath Rocky Pond.

Currie (1994, 1997a) reported a transitional contact between the upper portion of the IIG and the Ten Mile Lake Formation. This is well displayed in several localities in the Ten Mile Lake–Rocky Pond area, where, over a distance of about 150 m, buff and red siltstone are interbedded and red sandstone and siltstone become dominant to the west. Further indications of a transitional contact are outcrops of interbedded red sandstone and grey, crinoidal and coralline limestone (Plate 24) and nearby outcrops of buff siltstone that also contain bryozoa tentatively identified as *Stictopora scalpellum* (Lonsdale, 1839).

Approximately 3 to 5 km northwest of Rogers Cove, numerous exposures of thin-bedded, locally calcareous sandstone have been assigned to the IIG and shown as overlying the Hamilton Sound Group, e.g., Currie and Williams (1995). This area contains the highly fossiliferous “Fancy Locality”. To the north and west, the sandstones dip steeply to the west and also young to the west. At the northern end of the main forest-access road, a few crinoid ossicles were found in thick-bedded, laminated sandstone (fossil locality approximately 4 km south of Horwood, *see* Figure 1). About 1 km to the west, syneresis (desiccation) cracks were found in thick-bedded, green and light purple sandstone and siltstone. These mud-filled, polygonal cracks occur both at the top (Plate 25), and within, the beds thus producing three-dimensional polygons. These are taken to indicate that the sandstones are shallow-marine or possibly terrestrial sandstones. The purple colour may also indicate that these sand-



**Plate 24.** Interbedded red siltstone and fossiliferous, buff sandy limestone containing corals and crinoids. This outcrop is located 2 km south-southwest of Rocky Pond. LD05-378



**Plate 25.** Mud cracks in thick-bedded sandstone of the Ten Mile Lake Formation, 5 km northwest of Rogers Cove. LD05-426c

stones should be correlated with the Ten Mile Lake Formation. If correct this would indicate that the distribution of Ten Mile Lake Formation in this area, as shown in Currie and Williams (1995) and Currie (1997a) is too restricted. This is in agreement with Wu (1979) who assigned this area to the Big Indian Pond Formation, which is generally equivalent to the Ten Mile Lake Formation. It is proposed that the Ten Mile Lake Formation should be included in the IIG.

### Botwood Group

A small part of the Botwood Group occurs along the western margin of the surveyed area. Fresh basaltic flows of

the Lawrenceton Formation, containing minor interbedded red sandstone outcrop to the west of the Reach Fault, where they are have been interpreted to be part of thrust slices containing conglomerates and sandstones of the Badger Group (O'Brien, 2003; Currie, 1995b). The basalt flows are mainly massive but local amygdaloidal, pillow basalt and agglomerate are also present. Minor alteration is indicated by green zones, which are possibly rich in epidote or sericite; cleavage and bedding are rarely apparent. Five kilometres west of Ten Mile Lake, steeply dipping and strongly cleaved lapilli tuff and sandstone are associated with pillowed and massive basalt flows and these are possible correlative of the Lawrencton Formation; the cleavage may indicate the presence of a local fault.

### Lamprophyre Dykes

Three lamprophyre dykes were found during the survey and are probably of Jurassic age (Strong and Harris, 1974). One is located in a large rockcut on Route 331, about 1.5 km west of the turnoff from Route 331 in Rogers Cove. Another is located 5 km north of Rogers Cove on the mainland northwest of Fox Island. The third was found on the shoreline about 400 m north of Horwood. The dykes are about 50 cm to 1 m thick, are appear fresh and undeformed with finer grained outer margins interpreted as chilled margins. The highway lamprophyre dyke, which is uniform, equigranular and steeply dipping, has intruded dark-grey sandstone hornfels that are also cut nearby by a plagioclase-porphyritic dia-base dyke. The two lamprophyre dykes on the shorelines are conspicuously layered with apparently symmetrical layers parallel to the sides of the dykes. Each layer is about 3 to 8 cm thick and the inner layers appear to be chilled against the older outside layer. The dyke north of Horwood has intruded cleaved sandstone, siltstone and fossiliferous limestone of the IIG and is concordant to the steep bedding. It contains small phenocrysts of possible olivine and also small calcite blebs. The dyke north of Rogers Cove is also zoned and is concordant with the steeply east-dipping beds of grey sandstone and slate that are possibly part of the IIG. The outer zones are mainly equigranular containing small holes possibly representing weathered-out phenocrysts of olivine. The core of the dyke is about 30 cm thick, distinctly pink, and contains abundant prominent phenocrysts of olivine and augite, up to 1 cm in length. This zone also contains abundant ovoid to elongate inclusions of pink to orange, leucocratic, equigranular, undeformed, medium-grained granite, up to 8 cm long. Some inclusions have a yellow tinge indicating alteration to sericite. The granite inclusions differ from nearby granitic intrusions that are described as mainly grey, medium-grained, biotite-hornblende tonalite or granodiorite (e.g., Currie, 1997a). Clearly this dyke has sampled a granite not exposed in the area.

## DISCUSSION

### DUDER COMPLEX

The Duder Complex and the Dog Bay Line of Williams *et al.* (1993) and Currie (1997a) were examined during the field work. It is concluded that these geological features are not supported by the field work and some of the reasons are discussed below. The Duder Complex as defined, described and mapped by Williams *et al.* (1993), Currie (1993, 1994, 1995a, b, 1997a), and Currie and Williams (1995) contains a wide variety of rocks, most of which are highly deformed and some are also fossiliferous containing corals and crinoids. The Duder Complex is an arcuate belt, that extends from the Indian Islands, westward through Dog Bay Islands, Dog Islands and Dog Bay, then southwestward through Duder Lake to Rocky Pond. Other areas of rock assigned to the Duder Complex are shown to occur in the South Pond area about 15 km south of Rocky Pond and to the west along the east side of the Reach Fault in two fault-bound blocks extending from Island Pond north-northeast for 30 km to 4 km west of Duder Lake.

Features of the northern portion of the Duder Complex, as described in Williams *et al.* (1993) and Currie (1993, 1994, 1997a), are the common occurrence of highly deformed, dark grey pelite, which are commonly cut by swarms of small, sheared quartz veins, and the reported presence of exotic, mainly mafic volcanic and plutonic blocks that occur in parts of the complex, particularly in the area between Rocky Pond and Indian Islands. As noted above, the plutonic blocks are interpreted to represent deformed mafic, plutonic dykes and the mafic volcanic rocks are part of the stratigraphic succession because of their concordant stratigraphic relationships with the adjacent rocks. The eastern side of the Duder Complex, which is by definition the Dog Bay Line (Williams *et al.*, 1993), is in fault contact with the IIG, and lies off the northern shore of Eastern Indian Island (where most of the small islands are underlain by highly deformed and cleaved shale and siltstone), the north shore of the southern Dog Bay Island and also underlies a small peninsula in Horwood. These slates are in contact, to the north, with sandstone, slate and conglomerate of the Badger Group. The Dog Bay Line, where it is seen on land, is a fault but commonly the rocks on both sides of the fault are similar.

At South Pond, the eastern contact of the slates (assigned to the Duder Complex) is found with rocks that have been mapped as being part of the Davidsville Group (Blackwood, 1982). This Davidsville sequence might be part of the Badger Group based on the presence of pebble conglomerates and rare clasts, containing solitary corals.

Also, the slates could be a part of the Badger Group that are in fault contact with the sandstone of the Ten Mile Lake Formation.

At Stoneville, the contact between the Duder Complex and Badger Group conglomerate, sandstone and siltstone, is the “Stoneville Fault”, which was introduced by Currie (1995a) and Currie and Williams (1995) and described as a 1-km-wide ductile–brittle shear zone. Previously, this contact had been shown as a stratigraphic contact by Patrick (1956), Williams (1964, 1993), Williams *et al.* (1993) and Currie (1993). No evidence for a significant fault was found and it is proposed that the deformed pelite and associated volcanic rocks and minor conglomeratic beds could also be assigned to the Badger Group.

Along the shore at Horwood, the Duder Complex is dominated by highly contorted dark grey to black pelite cut by numerous quartz veins and within the pelite, are layers of green pelitic rock that are interpreted to be thin, altered tuff beds parallel to the bedding (Plate 26). Near the northeast corner of the peninsula, the sequence is thinly bedded and is possibly graded. Similar relationships and rock types were found between the southern shore of Middle Dog Bay Island and at the northeast corner of southern Dog Bay Island and also on the small islands south of Western Indian Island. These sequences are similar to rocks assigned to the Outflow Formation of the Davidsville Group at Rogers Cove (see Currie, 1997a) where they are associated with probable Caradocian slates.

A sequence of pelite and sandstone and crinoid- and coral-rich limestone was found on the largest and northernmost Dog Island. This island was originally shown to be part of the IIG in Currie and Williams (1995), but in Currie (1997a), the island is shown to be part of the Duder Complex; the abundance of limestone would be more typical of the IIG. Currie (1997a) accounted for the presence of such island-sized occurrences of IIG rocks by describing them as blocks in the Duder Complex (*mélange*). This could also be the justification for the Duder Complex, including the *mélange*, being given a Silurian age in Currie (1997a), when it was originally described as being Ordovician (e.g., Williams *et al.*, 1993). However, it is more likely that the strata found on the island are part of a deformed IIG and should not be separated out.

In the Indian Islands and Dog Bay Islands area, highly deformed dark grey and black pelite and sandstone that have been assigned to the Duder Complex are similar to much of the complex in the Horwood–Stoneville area, but readily recognizable volcanic rocks are rare. One islet, south of Middle Dog Bay Island, contains possible lapilli tuff interbedded with grey siltstone. Thin layers of pale green



**Plate 26.** *Strongly cleaved, pale green, thin-bedded sericitic, possible altered tuff and shale on the shore in central Horwood. LD05-451b*

and yellow sericite schist (possibly felsic tuffs) that are found on some islands are similar to those found in the Horwood area. On the south coast of Middle Dog Bay Island, highly deformed black slate previously assigned to the Duder Complex is in contact with strongly deformed pebble and cobble conglomerate that is part of the Badger Group (e.g., Currie, 1997a). However, the stratigraphic contact has been modified by late cross-faulting and, along with the covered intervals, prevents a conclusive determination of the nature of the contact. The conglomerate contains a few graded beds and youngs to the north, away from the shale, a situation comparable to that at Stoneville, where the sequence of conglomerate and pelite is interpreted to be part of a continuous succession.

A rare, but possibly significant aspect of the Indian Islands area is the presence of isolated occurrences of limestone, just south of Western Indian Island, in pelites previously mapped as being part of the Duder Complex (Currie, 1997a). The limestone occurs as small lenses and thin, isolated, disrupted beds in a pelitic matrix. At one locality, the limestone contains black, deformed crinoid ossicles. These may indicate that the limestone is part of the IIG but it could also be part of the Badger Group.

In the Fox Pond to Island Pond area, Currie (1995b, 1997a) assigned the rocks to the Duder Complex. The rocks in this area are highly deformed, buff sandstone, siltstone and conglomerate and minor grey siltstone. A few outcrops of highly deformed, mafic tuff were found within areas dominated by strongly deformed, coarse-grained, buff sandstone. The conglomerates are found in proximity to the mafic tuffs. The conglomerate contains clasts of limestone, grey and white chert, sandstone, slate, minor granite and mafic volcanic rocks in a rusty and calcareous sandy matrix.

Three kilometres northeast of O'Brien Lake, another area of strongly foliated cobble conglomerate was assigned to the Botwood Group by Currie (1995b, 1997a). The clast types found in the conglomerates commonly include red jasper, grey chert, granite, felsic and mafic volcanic rock, and sandstone (Plate 27; cf. Plate 29 in O'Brien, 2003). The pebbles and matrix of the conglomerate are strongly foliated but the cobbles of jasper and granite are undeformed. These rocks are similar to those of the Badger Group.



**Plate 27.** Cobble and pebble conglomerate containing jasper now assigned to the Badger Group. LD05-172b.

Large areas of fresh, massive, undeformed pillow basalt and basaltic agglomerate were found 4 km due west of the south end of Ten Mile Lake. This area had been mapped as that part of the Duder Complex containing inclusions of volcanic rock (e.g., Currie, 1997a). However, it is more likely that these volcanic rocks are part of the Lawrenceton Formation of the Botwood Group. The nearby outcrops include black slate and associated siliceous siltstone and also red sandstone. It is possible that the slate could be Caradocian. Red sandstone is interbedded with the basalt in one place and would indicate that the red sandstone is also part of the Botwood Group. The location of this site is about 3 km east of the Reach Fault as shown in Currie (1997a), which was described as the eastern limit of the Botwood Group.

About 500 m offshore from Horwood, a 3-km-long string of small islands was found to be composed of a steeply dipping sequence of weakly cleaved, steeply west-dipping, basaltic pillow lava, agglomerate and massive flows (Plate 28). The basalts contain interbeds of volcanic ash and thin-bedded chert and are cut by diabase dykes. This sequence continues to the southwest and pillow lava, flows and tuff were found to outcrop along Route 331, and also along a forest-access road south of Route 331 for about 4



**Plate 28.** Pillow lava from an island in central Dog Bay. LD05-947d

km. The total strike length of this apparently narrow volcanic unit is about 10 km and the width appears to be no more than 500 m. This sequence was included in the "Garden Cove Mélange" of Williams *et al.* (1993) but this term appears to have been dropped in later descriptions of the Duder Complex. An area of very weakly deformed basaltic pillow lava and pillow breccia at the south end of the peninsula between Duder Lake and Rocky Pond was assigned to the Lawrenceton Formation of the Botwood Group by Churchill and Evans (1992) and Churchill *et al.* (1993). The basalts were shown to be in fault contact with the grey slates and sandstone of the Davidsville Group. Currie and Williams (1995) and Currie (1994), however, indicated that these basalts were blocks in the Duder Complex. This 1 km<sup>2</sup> area is composed entirely of basalt and a few massive diabase dykes and lies approximately 15 km along strike from the "Garden Cove Mélange" and significantly increases the length of the mélange. The apparent linearity of this belt would suggest that it is not a series of exotic blocks in a mélange but is actually part of the stratigraphic sequence.

Highly deformed to relatively undeformed mafic dykes were also described as a feature of the Duder Complex in the Dog Bay to Indian Islands area. At Horwood, very large blocks of weakly foliated gabbro are found in a deformed matrix and were described in Williams *et al.* (1993; Plate 29). The contact between the blocks and the enclosing shale was also described as consistently sheared. However, the present mapping has discovered sharp contact between some gabbro blocks and the shale. Further, the margins of these blocks are fine grained at the contacts and are here interpreted to be chilled margins (Plate 30). These blocks are somewhat lensoid and are here interpreted to be remnants of a large boudinaged gabbro dyke.



**Plate 29.** Light grey-weathering gabbro boudin within the deformed pelites that are possibly part of the Badger Group on the shoreline at Horwood. LD05-454



**Plate 31.** Strongly deformed gabbro boudin (right) engulfed by strongly cleaved, dark grey pelite on an islet south of the central portion of Western Indian Island. LD05-573a



**Plate 30.** Sharp contact and chilled margin between the gabbro boudin (light grey, top) and pelite of Plate 29 at Horwood. LD05-455a

Most gabbro blocks are single boudins up to 25 m long and 15 m wide (Plate 31) but in a few places the blocks form strings of large boudins. The example shown in Plates 29 and 30 is that shown in Figure 3 of Currie (1995a) and is one block in a string of three boudins. In Indian Islands Tickle south of Western Indian Island (Plate 31), the cleavage is most intense at the margins and decreases toward the centre of the boudin. Locally, an intense mylonitic fabric is present at the edge of the dykes. South of Dog Bay, in the Duder Lake area, the mafic dykes are either highly altered or brecciated but show little ductile deformation. Most dykes are medium grained but locally the dykes are well over 50 m thick and coarse grained. One example has a wide, very coarse-grained pegmatitic core and the grain size decreases to coarse grained toward the margins. Churchill and Evans

(1992) and Churchill *et al.* (1993) have also described the dykes as being intrusive and to display chilled margins. It is concluded that none of the gabbroic augen are exotic blocks in a shale matrix.

Black pyritic slate assigned to the Duder Complex at Horwood and Stoneville, e.g. (Williams *et al.*, 1993) is comparable to similar pyritic, locally graptolitic (Caradocian) slates assigned to the Hamilton Sound Group in the Gander Bay area at Shoal Bay, Victoria Cove, Main Point, west of Dog Bay Point (e.g., Currie, 1997a), and to the Davidsville Group in the Glenwood–Appleton area. It would appear that part of the Duder Complex could indeed have an Ordovician protolith as described in Williams *et al.* (1993) and Currie (1997a) and be possibly part of the Davidsville Group (e.g., Churchill *et al.*, 1993) or the Hamilton Sound Group.

It is likely that the assignment of the conglomerates and associated finer grained sediments in the area northeast of O'Brien Lake should be to the Badger Group rather than the Duder Complex. Further, the nearby outcrops of massive, subaerial, reddened basalt flows in areas previously assigned to the Duder Complex, e.g., Currie (1997a), indicates that the Lawrenceton Formation of the Botwood Group is also present in this area. It is known from other areas that Badger Group, is overlain by the Lawrenceton Formation, e.g., Eastler (1971), Williams (1993) and Currie (1997b).

## DOG BAY LINE

One consequence of the recent work is that the IIG is now known to occur several kilometres north and west of the Dog Bay Line, particularly in the Ten Mile Lake–Rocky Pond and the Indian Islands–Dog Islands–Dog Island

areas. Thus, the location of a major suture, if it exists, has to be modified. There may be a fault that coincides with the trace of the Dog Bay Line. However, as similar rock types containing similar fossils occur on both sides of this line it cannot be a terrane boundary. The Duder Complex appears to contain units that could be assigned to the IIG. Extensive mappable units of volcanic rock within the complex argue against it being a mélange formed from a Dunnage Zone overstep sequence. A more likely explanation is that much of the complex is of Ordovician age and it has been deformed with the Indian Islands Group. Williams *et al.* (1993) proposed a sequence of Ordovician events for the formation of the Dog Bay Line and Duder Complex. As the Duder Complex and Dog Bay Line are interpreted by Currie (1997a) to include and to offset the Early to Late Silurian IIG, then the interpretations of the structural history of the area need reassessment. As fossiliferous IIG rocks, possibly as young as Early Devonian (Boyce and Ash, 1994) and a  $381 \pm 5$  Ma (early Late Devonian) gabbro dyke at the Titan gold showing (McNicoll *et al.*, *this volume*), are deformed and cleaved, the age of deformation of the IIG could be as young as Late Devonian. It is hoped that the various fossil collections along with the samples collected for conodont extraction and radiometric dating will assist in providing a framework on which to base further models of the geological evolution of the area.

#### EXTENT OF THE BADGER GROUP

The interpretation described above indicates that the conglomerates, slates, sandstones and associated volcanic ash, exposed between of Rocky Pond and Bellman's Pond, are part of the Badger Group. This requires that the group either underlies much of the Ten Mile Lake Formation as extension of the main part of the Badger Group, exposed west of the Reach Fault, or forms a separate basin. If it is continuous with the main Badger Group basin then this would argue against a major boundary, the Dog Bay Line, being a fundamental break. If it was a separate basin then it would appear that the source of detritus would be similar as indicated by the abundance of chert clasts. The presence of volcanic ash, not recognized in other areas of the Badger Group, could indicate a significantly different geographic location.

#### SUMMARY

The IIG is dominated by polydeformed slate, siltstone, sandstone and limestone; its distribution has been redefined. There is a conformable relationship with the younger Ten Mile Lake Formation. The Badger Group is interpreted to be more extensive than shown by mapping in the 1990s and to extend into areas previously mapped as Davidsville Group. The Duder Complex probably does not exist as a separate

stratigraphic unit and its various components can generally be assigned to other units. The Dog Bay Line is generally a zone of strong deformation and faulting but the probable existence of the Ordovician-Silurian Badger Group and the Silurian IIG on both sides of the line preclude its interpretation as a terrane boundary. The most intense deformation appears to coincide with wide belts of pelite cut by diabase. Uncleaved but steeply dipping fossiliferous siltstone, sandstone and conglomerate, possibly part of the Ten Mile Lake Formation, are in fault contact with highly deformed and cleaved rocks assigned to the Ordovician-Silurian Badger Group and would indicate a regional unconformity between the two units.

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