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THE INDIAN ISLANDS GROUP AND ITS RELATIONSHIPS TO ADJACENT UNITS: RECENT DATA

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ABSTRACT

The Indian Islands Group and adjacent units in the Glenwood–Indian Islands area of northeastern Newfoundland were further examined in 2006. Field work indicated again that the Duder Complex, although highly deformed, is not a mélange containing exotic blocks of gabbro but rather is a highly deformed zone containing boudinaged mafic dykes. About 1.5 km east of Rocky Pond, rocks assigned to the Upper Ordovician–Lower Silurian Badger Group stratigraphically overlie pelite and volcanic ash that are probable correlatives to the Middle Ordovician Davidsville Group. The Badger Group is in fault contact with the sandstones of the Botwood Group along the north shore of Western Indian Island. The basalts of the Lawrenceton Formation, the lowest formation of the Botwood Group, may have been faulted out.

Conodonts were obtained from three of ten limestone samples collected in 2005 from rocks previously assigned to the Indian Islands Group and the Ten Mile Lake Formation. Two conodont faunas indicate that their host limestones are significantly older than previously published. Limestone, within a sequence of siltstones assigned to the Silurian Ten Mile Lake Formation (based on proposed stratigraphic relationships), contains a Late Ordovician conodont fauna. The assignment of this part of the sequence to the Ten Mile Lake Formation is, therefore, in doubt. Limestone from a sequence north of Horwood and previously assigned to the Silurian Indian Islands Group contains a conodont fauna that indicates a probable Late Ordovician age for the sequence. This is in conflict with the previously assigned Silurian age. A third limestone sample contained a conodont element that did not provide age data.

A coarse-grained gabbro dyke, within a pelitic sequence, east of Duder Lake was dated at 453 Ma; this dyke hosts the Goldstash gold prospect; the age indicates that the Duder Complex host rocks are Late Ordovician or older. An age of 411 Ma was obtained from granite of the Mount Peyton Intrusive Suite south of Glenwood. This age is in agreement with known geological relationships between the gabbro and granites of the suite and also provides a minimum age for the Indian Islands Group and possibly the Ten Mile Lake Formation.

INTRODUCTION

The geology of the Indian Islands Group in northeastern Newfoundland (Figure 1) and its relationship to the adjacent units was critically reviewed in Dickson (2006). The geology of the area had been presented in a series of papers and maps by Currie (1992a, b, 1993, 1994, 1995a, b, c, 1997a, b), Currie and Williams (1995), Williams (1992, 1993) and Williams *et al.* (1993) and compiled and slightly modified in Currie (1997c). In particular, Dickson (2006) discussed the distribution of the rocks of the Upper Ordovician–Lower Silurian Badger Group, the Silurian Indian Islands Group, the age and significance of the Duder Complex (formerly termed Duder group by Currie, 1993) and the Dog Bay Line of Williams *et al*. (1993).

Williams *et al*. (1993) and Currie, (1995a) have proposed that the Dog Bay Line was a Silurian terrane boundary. However, Dickson (2006) indicated that Upper Ordovician–Lower Silurian Badger Group conglomerates, that lie mainly to the west of the Dog Bay Line, had probable correlatives to the east of the line, and that the Silurian Indian Islands Group, to the east of the line, could have correlatives in the fossiliferous siltstones that lie to the west of the Dog Bay Line. These siltstones (Boyce and Dickson, 2006) contain the mid-Silurian (late Homerian, i.e., latest Wenlock or around 423 Ma) bryozoan *Stictopora scalpellum* Lonsdale, 1839, that has also been found in siltstones assigned to the Indian Islands Group. The siltstones also contain a variety of other mid-Silurian fossils and the fauna is summarized in Boyce and Dickson (2006). These correlations cast doubt on

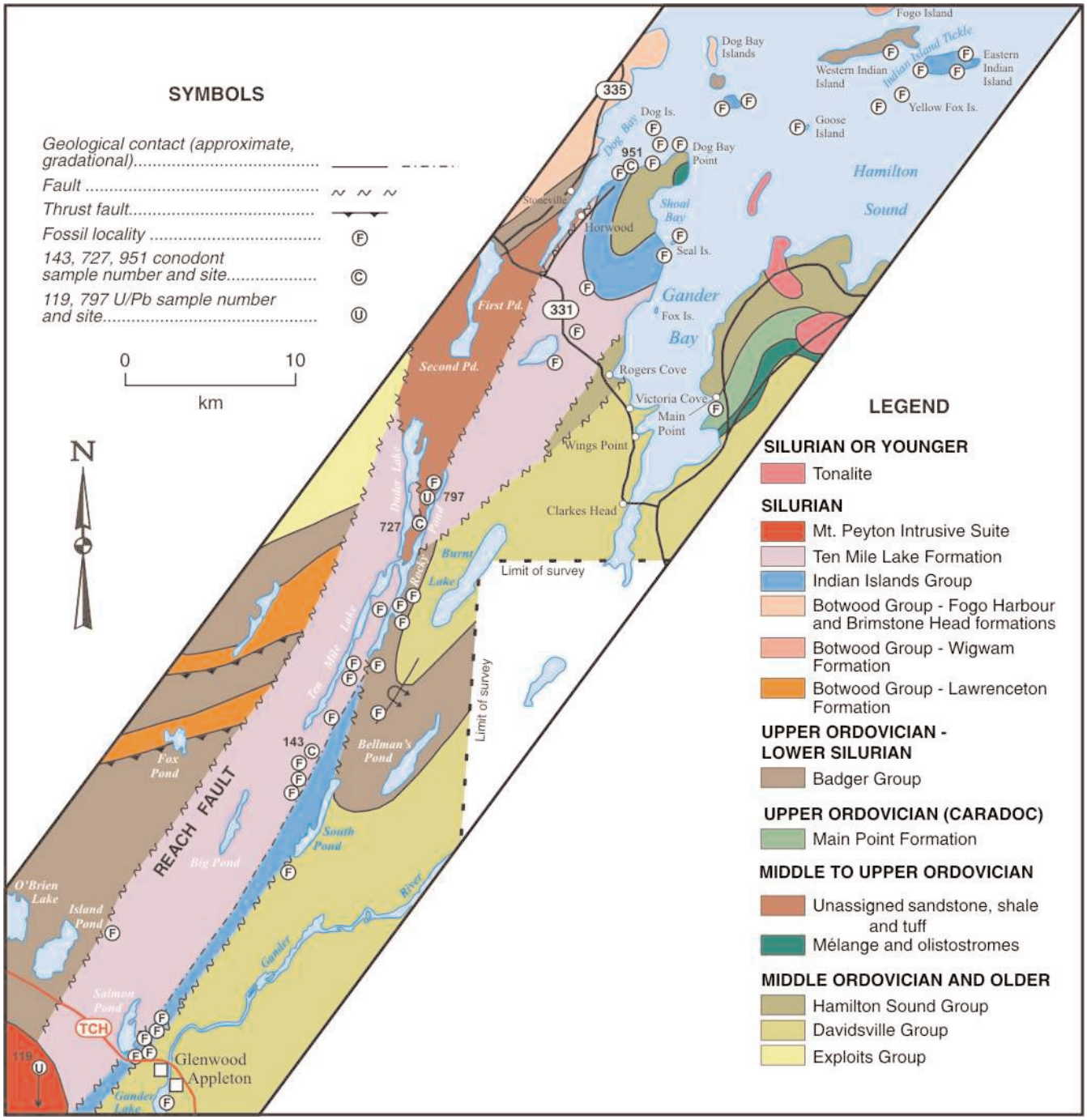

Figure 1. *General geology of the area between Indian Islands and Glenwood based locally on interpretations by Currie (1997a) and O'Brien (2003).*

the Dog Bay Line being a Silurian terrane boundary in northeastern Newfoundland.

Currie (1997c) indicated that the deformation of the Duder Complex could be as young as the Silurian, based on his interpretation that the Duder Complex contained fossiliferous blocks of the Silurian Indian Islands Group. The significance of such fossiliferous blocks was reinterpreted by Dickson (2006). It was also reported (e.g., Currie, 1997c) that the Duder Complex and the Indian Islands Group were unconformably overlain by the Silurian Ten Mile Lake Formation and had been intruded by gabbro of the Mount Peyton Intrusive Suite. The gabbro was reported by Dickson (1994) to have a U–Pb zircon age of ca. 424 Ma. Boyce and

Ash (1994) reported that the upper part of a sequence of rocks assigned to the Indian Islands Group contained bivalves that indicate an uppermost Silurian age (approximately 417 Ma; see discussion below on the Mount Peyton Intrusive Suite). Subsequently, new field and laboratory data have been obtained that provide new insights and raise problems with the currently proposed ages of some units.

2006 FIELD SURVEY

Further field and laboratory studies of the Indian Islands Group and associated rocks were carried out in 2006. This is a continuation of the work reported in Dickson (2006).The main area examined lies in the northeast part of central Newfoundland between Glenwood, in the south, and Indian Islands, 80 km to the north in the Hamilton Sound area, and is covered in the compilation map of Currie (1997c).

The Duder Complex of Currie (1997c) was further examined at the western end of Western Indian Island. Again it was determined that the gabbro blocks in the black pelite of the Duder Complex were intrusive but are intensely sheared along the margins of the now-boudinaged gabbroic dykes. Furthermore, low-angle, south-dipping thrusts within highly folded black pelite are well-exposed in some small coves on the southwest side of Western Indian Island. The presence of buff, schistose, sericitic ash (Plate 1) in this area is similar to that exposed in the Victoria Cove area and 3 km southwest of Dog Bay Point where the sequences were assigned to the Ordovician Hamilton Sound Group by Currie (1995c, 1997c) but in the Horwood area similar sequences were assigned to the Duder Complex (see Plate 6 in Dickson, 2006). It would appear that these pelite–ash sequences could all be assigned to the Hamilton Sound Group.

On the north side of Western Indian Island, Currie (1997c) indicated that the north-facing, steeply south-dipping Badger Group sandstone and conglomerate were conformably overlain, to the north, by the Lower Silurian Lawrenceton Formation (Llandovery; Eastler, 1969, 1971), the lowest formation of the Botwood Group. Eastler (1971) did not indicate any stratigraphic break in this area. In most areas of north-central Newfoundland, the Lawrenceton Formation is dominated by very thick, subaerial and minor submarine basalt flows including blocky and minor pillow lava, agglomerate and massive flows. This is the situation 6 km to the west of Western Indian Island, on Middle Dog Bay Island, where basalt overlies conglomerate. However, the small islands immediately northwest of Western Indian Island are underlain by highly cleaved, chlorite-rich siltstones, sandstones and granule to pebble conglomerates

Plate 1. *Strongly cleaved, light-coloured volcanic ash interbedded with grey pelite on the southwest shore of Western Indian Island. Locality LD06-0080.*

Plate 2. *Pebbly sandstone and conglomerate of the Badger Group exposed on an island off the north shore of Western Indian Island. This unit was assigned to the Lawrencetown Formation by Currie (1997a). Locality LD06-0086.*

(Plate 2) that were assigned to the Lawrencetown Formation by Currie (1997a, b). There is no indication of basalt or any other volcanic rock other than clasts in the conglomerate. It is more likely that these coarse clastic rocks should be assigned to the Badger Group.

About 2 km to the east of the small islands and just north of Western Indian Island, several islands and a peninsula are underlain by thick-bedded, coarsely crossbedded, steeply dipping, north-facing, micaceous sandstones (Plate 3) and minor calcareous sandstone that Currie (1997a, c) also assigned to the Lawrenceton Formation. These rocks should be assigned to the Fogo Harbour Formation, a central formation of the Botwood Group, which stratigraphically

Plate 3. *Crossbedded sandstone of the Fogo Harbour Formation (Botwood Group) that youngs to the north away from the north-younging Badger Group, north of Western Indian Island. This had been assigned to the Lawrenceton Formation by Currie (1997a, c). Locality LD06-0087.*

overlies the Lawrencetown Formation. The islands farther north had been assigned to the Fogo Harbour Formation by Currie (1997a). The contact between the Fogo Harbour Formation and the coarse clastic rocks is exposed on small peninsulas along the northwest shore of Western Indian Island and is a fault-brecciated zone that is cut along its length by two parallel, brecciated but uncleaved, mafic dykes. The breccia zone is interpreted to lie within a steeply dipping fault that parallels the shoreline. This would suggest that the Lawrenceton Formation basalts have either not been deposited within this sequence of rocks or have been faulted out.

A fault-bound sequence of conglomerates east of Rocky Pond, shown in Figure 2 of Dickson (2006) to be part of the Indian Islands Group (based on the presence of bryozoa), was found to be a misidentification. The supposed fossils are actually tiny vesicles in basalt cobbles in a conglomerate and this sequence should now be included in the Badger Group. This sequence, which stratigraphically overlies a sequence of strongly cleaved and sheared pelites and volcanic ashes, to the east, could be a correlative of the Middle Ordovician Davidsville Group (Blackwood, 1982).

The shorelines of First Pond and Second Pond, located 3 km south of Stoneville, were examined. Currie (1997c) showed that the Badger Group conglomerate is in fault-contact to the south, along the Stoneville Fault, with the Duder Complex. The complex includes the pelitic member to the northwest and the member containing large igneous exotic blocks farther to the south. The Badger Group conglomerates dip steeply to the southeast, are strongly to intensely flattened, and contain a strong cleavage parallel to bedding; graded bedding indicates that the sequence youngs to the northwest. To the southeast within the Duder Complex, the pelitic sequence also contains sandstone and probable tuff. They are all highly deformed and locally cut by small faults and mafic dykes. To the south, in the area between First Pond and Second Pond and within the exotic block unit of the Duder Complex of Currie (Unit SDv; 1997c), the sequence is composed of well-bedded sandstone, mafic lapilli tuff and agglomerate, and black slates. This sequence is probably part of an, as yet, undetermined Ordovician unit but shows some similarities to the Ordovician Hamilton Sound Group.

Very thick, undeformed diabase dykes exposed at the south end of First Pond have intruded the sandstones and converted them to hornfels over tens of metres from the contacts. This indicates that the dykes are not exotic blocks as was suggested initially by Williams *et al*. (1993), and this sequence is clearly not part of a mélange because the structures and stratigraphy can be mapped out for several hundred metres, to the limits of outcrop. Near the southeastern corner of Second Pond, an isolated sequence of sandstone and pebbly conglomerate is cut by diabase dykes. This east-facing sequence could be part of the Badger Group.

CONODONT PALEONTOLOGY

Ten samples of limestone collected in 2005 from various areas of the Indian Islands Group, Ten Mile Lake Formation and Badger Group (Dickson, 2006) were submitted for conodont analysis. Most of the samples contained various body fossils including crinoids and corals. Nowlan (2006) reported that three samples contained conodonts.

Sample LD05-0727 (GSC locality C-450643) was obtained from a calcareous, quartz-rich sandstone outcropping in the southern part of the ridge between Duder Lake and Rocky Pond (NTS 2E/7, UTM coordinates 669992E 5462770N, NAD27) and contained one conodont element assigned to *Panderodus* sp. This unit had been assigned to the "Lower Unit" of the Silurian Botwood Group by Churchill and Evans (1992), to the Silurian Ten Mile Lake Formation by Currie (1997c), and to the Badger Group by Dickson (2006). Unfortunately, no age could be determined from this conodont element.

Sample LD05-0143 (GSC locality C-450644) was obtained from a 25-cm-thick bed of cleaved grey limestone (Plate 4) within a steeply dipping, red, cream and green siltstone-sandstone sequence (NTS 2E/02, UTM 664228E 5447371N, NAD27). This sequence was assigned by Currie (1997c) and Dickson (2006) to the Ten Mile Lake Formation that Dickson (2006) and Currie (1997c) interpreted to over-

Plate 4. *Fossiliferous limestone (right) and thin-bedded, cleaved red siltstone from which Late Ordovician conodonts were obtained. Locality LD05-0143 is about 22 km north-northeast of Glenwood.*

Plate 5. *Strongly cleaved, overturned crinoidal limestone of the Indian Islands Group from which Late Ordovician conodonts were obtained. Locality LD05-0951 is about 2 km north of Horwood.*

lie the Silurian Indian Islands Group. Nowlan (2006) reported that the sample contained 42 conodont elements from 10 conodont species and one indeterminate element. The fauna includes *Amorphognathus* sp., *Gamachignathus* sp., *Hamarodus?* sp., *Istorinus?* sp., *Scabbardella altipes* (Henningsmoen), *Strachanognathus parvus* Rhodes and *Taoqupognathus?* sp., indicating a Late Ordovician age, probably Ashgill. Clearly, the assignment of the limestone and associated rocks to a Silurian formation is in error. The limestone and associated rocks could, however, be assigned to the Badger Group, known to be of Late Ordovician to Early Silurian age. It is now apparent that some of the rocks assigned to the Ten Mile Lake Formation are of Late Ordovician age and therefore the age of Ten Mile Lake Formation may have to be extended into the Late Ordovician. However, the fossiliferous rocks may have been mistakenly assigned to the Ten Mile Lake Formation because of their red colouration.

From a paleobiogeographical perspective, the conodont fauna contains elements of the Mediterranean Faunal Province that occurs in several localities in western Europe and interpreted to be part of Gondwana (see Nowlan *et al*., 1997). The only known occurrence of this fauna in North America is from the Grog Brook Group in northwestern New Brunswick.

Sample LD05-0951 (GSC locality C-450650) was obtained from about 1 km northeast of Horwood (NTS 2E/08, UTM 681208E 5482719N, NAD27). The sample is from a thin-bedded, strongly cleaved, crinoidal limestone (Plate 5) interbedded with thick-bedded, trough-crossbedded, graded, calcareous, light-grey sandstone that is steeply overturned to the west. This sequence of rocks was indicated in Currie (1997c) and Dickson (2006) as being part of the Silurian Indian Islands Group. Nowlan (2006) obtained 4 conodont elements, identified as *Oulodus?* sp. and *Panderodus* sp., along with 2 indeterminate simple cone elements. The identified elements are similar to Middle and Late Ordovician species, but are more likely to be of Late Ordovician age, and thus a tentative Late Ordovician age can be applied to this sample. This may place in doubt the reported Early Silurian age for the oldest part of the Indian Islands Group (Currie, 1997c).

In an effort to confirm the age of the various rocks assigned to Indian Islands Group and the Ten Mile Lake Formation by Currie (1997c) and Dickson (2006), a further 28 samples of limestone were collected for conodont analyses. Samples were obtained from Eastern Indian Island, Dog Bay Islands, Dog Islands, and also at Change Islands where Eastler (1971) used mainly corals to assign the Lawrenceton Formation a Llandovery age. Samples were also collected from sites containing thin-bedded, fine-grained limestone along the shoreline northeast of Horwood. The fossiliferous outcrops near Glenwood, were reported in Boyce and Dickson (2006) to contain Wenlock bryozoa, and, those at Careless Brook, were reported in Boyce and Ash (1994) and Boyce and Dickson (2006) to contain Late Silurian (Přídolí) bivalves.

U–Pb GEOCHRONOLOGY

Gabbro Dyke within Deformed Pelite, near Duder Lake

A very thick, very coarse-grained diabase to gabbro dyke (LD05-0798, NTS 2E/07, UTM coordinates 670350E 5463794W, NAD 27) was sampled in 2005 for radiometric dating. This dyke hosts the Corvette gold prospect

(Churchill and Evans, 1992) and is located about 4 km south-southeast of the north end of Duder Lake, about 5 km east of Birchy Bay. Churchill and Evans's (1992) interpretation of the geology was that the dyke was Devonian and had intruded polydeformed slates of the Middle Ordovician Davidsville Group. Currie (1997c) indicated that the slates were part of the Duder Complex and were cut by a Devonian dyke (following Churchill and Evans, 1992). Dickson (2006) indicated that the slates were part of the Late Ordovician to Early Silurian Badger Group.

The gabbro sample was processed by McNicoll (2006) who extracted high-quality baddeleyite crystals from the gabbro. Baddeleyite analyses yielded an age of 453 ± 1.3 Ma, which is interpreted to be the crystallization age of the dyke. It further indicates that the host rocks are older than 453 Ma, which is in line with the Davidsville Group assignment by Churchill and Evans (1992).

Currie (1995a) reported that the diabase dykes that cut the Ten Mile Lake Formation in the area northwest of Glenwood are offshoots from the gabbroic component of the Mount Peyton Intrusive Suite. The reported 424 Ma age (Dunning, 1992, 1994) of the gabbro was used by Currie (1995a) to date the dykes and therefore the minimum age of the Ten Mile Lake Formation. Diabase dykes occur throughout the area from Glenwood to Indian Islands. The three dates have been obtained from diabase dykes by McNicoll (2006) and McNicoll *et al*. (2006), *viz.*, 453 Ma, 411 Ma and 381 Ma, are clearly different from the 424 Ma dates obtained by Dunning (1992, 1994) from the Mount Peyton Intrusive Suite gabbro. Thus the age of the dykes in the Ten Mile Lake Formation is in doubt. Further, there has been no geochemical analysis of the dykes to indicate a possible genetic relationship with the Mount Peyton Intrusive Suite. Evidence for the minimum age of the Ten Mile Lake Formation based on the age of the granitic portion of the suite is given below.

Mount Peyton Intrusive Suite

The Mount Peyton Intrusive Suite (Blackwood, 1982) is a large composite batholith composed mainly of fine-grained gabbro and medium-grained granite that was interpreted by Dickson (1993) to be in fault contact with the Indian Islands Group along its eastern margin. Boyce and Ash (1994) reported that unmetamorphosed, fine-grained fossiliferous sandstone in the upper part of the Indian Islands Group section at Careless Brook, about 15 km south of Glenwood, contained Late Silurian (Prídolí) bivalves (age modified in Boyce and Dickson, 2006, page 227), indicating an age of approximately 417 Ma based on the International Commission on Stratigraphy (2004) stratigraphic chart. Lake and Wilton (2006) reported that, along Cooper Brook about 40 km south of Glenwood, red sandstone forms the upper part of the Indian Islands Group in this area and has been contact metamorphosed to a grey hornfels by granite of the Mount Peyton Intrusive Suite that outcrops about 200 m upstream. Drill core from the nearby antimony mine contained the bryozoa *Stictopora scalpellum* Lonsdale, 1839, which indicates a latest Wenlock age for some of the rocks in this area (Boyce and Dickson, 2006).

Dunning (1992) obtained U–Pb zircon ages of 424 ± 2 Ma from a gabbro pegmatite dyke in a layered gabbro sequence, at Rolling Brook in the southwest of the suite, and Dunning (1994) also obtained an age of 424 ± 2 Ma from coarse-grained gabbro segregations in medium-grained gabbro from the northern margin of the suite, near the Rattling Brook turnoff to Norris Arm from the Trans-Canada Highway. Dunning and Manser (1993) dated granophyric granite from the eastern margin of the Mount Peyton Intrusive Suite in the Red Rocks Brook area, about 20 km south of Glenwood. A mixing-line U–Pb age of 419 ± 2 Ma was obtained from three zircon fractions. Dunning and Manser (1993) noted that this age required that the three fractions contain some older inherited zircon. An alternative age interpretation of 439.5 +9/-6 Ma was also indicated by Dunning and Manser (1993) using the two other zircon fractions and one of the three used in the 419 Ma age. This older age was in conflict with geological relationships that everywhere indicated that the granite had intruded the gabbro and should have an age younger than 424 Ma (Dunning, 1992, 1994). The possibility exists that this granite is an older granite as contact relationships with both the gabbro and the nearby siltstones are either unexposed or faulted.

To resolve this problem, another sample of granite was collected for radiometric dating by G. Squires (formerly with the Newfoundland and Labrador Geological Survey) from a site noted by Dickson (1993, page 217) to show clear intrusive relationships between the undeformed, medium-grained, biotite granite and an older fine-grained gabbro (Plate 6). At the contact, angular blocks of gabbro lie within the granite, and the gabbro contains veins of granite. The sample site is about 10 km southwest of Glenwood (LD92-0119, NTS 2D/14, UTM coordinates 645913E 5423797N, NAD 27; note that the current NTS map is NAD 83).

McNicoll (2006) analyzed the sample and noted that it contained abundant, good-quality euhedral zircons ranging in morphology from elongate to stubby prisms. Inherited cores in these grains are not visible using a binocular microscope; however, all of the multigrain TIMS analyses were slightly to moderately discordant and interpreted to contain minor inherited components. Backscatter SEM imaging revealed the presence of potential cores in some of the zircons and the sample was further analyzed on the GSC

Plate 6. *Mount Peyton Intrusive Suite: gabbro cut by granite veins at locality LD92-0119. Photo by G. Squires.*

SHRIMP II. A Concordia age, utilizing all of the SHRIMP analyses (n = 27), is calculated to be 411 ± 2.6 Ma (MSWD of concordance and equivalence = 0.65, probability = 98 %). This date is interpreted to be the age of the granite in the eastern portion of the Mount Peyton Intrusive Suite.

The 411 Ma age for the granite obtained by McNicoll (2006) is significantly younger than two 424 Ma ages obtained from gabbro of the Mount Peyton Intrusive Suite reported in Dunning (1992, 1994). The 411 Ma age would agree with the intrusive relationship with the Indian Islands Group reported by Lake and Wilton (2006). However, the odd sandstones, forming the upper part of the Indian Islands Group, could be part of the Ten Mile Lake Formation. Thus the minimum age of the formation would be approximately 411 Ma or lowermost Devonian.

The ages of the gabbro and the granite would also suggest that the genetic relationship between the gabbro and the granite proposed by Strong (1979) and Strong and Dupuy (1982), based on an interpretation of the geochemistry of the suite, is unlikely considering the difference in age of the gabbro and the granite.

SUMMARY

Recent mapping combined with paleontological and geochronological data indicate that there are problems with the assignment of rock units to a particular formation. The proposed nature and significance of the Dog Bay Line and the Duder Complex are still the subject of conjecture. The analyses of the limestone samples for conodonts may provide better control of the age of the various stratigraphic units and lead to a better understanding of the structure and stratigraphy of the area.

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