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SILURIAN SUBAERIAL ROCKS NEAR LEWISPORTE, CENTRAL NEWFOUNDLAND

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ABSTRACT

Silurian subaerial rocks of the Botwood Group outcrop southwest of Lewisporte, where they have been mapped at 1:50 000 scale. They are faulted against probable Early to Middle Ordovician marine volcanic and sedimentary rocks to the north, and against Late Ordovician and Early Silurian turbidite-related rocks to the east and south. The group is divided into the lower, mainly volcanic Lawrenceton Formation, and the upper, mainly sedimentary Wigwam Formation.

The Lawrenceton Formation consists of mafic and intermediate lavas and associated volcaniclastic breccias, and contains minor amounts of felsic lava and tuff. Conglomerate is a significant component of the upper part of the formation. Three zones of pyritic quartz-sericite schist and silicified rock have been mapped; the largest zone is discordant to the stratigraphy.

The Wigwam Formation consists of medium- to thick-bedded, quartz-rich sandstone, which commonly has both planar and trough crossbedding and is likely to be of a fluviatile origin. In the lower unit, the sandstone is green-grey, whereas in the upper unit it is red. There are also restricted occurrences of felsic volcanic rock and conglomerate.

The outcrop pattern of the Botwood Group is dominated by an anticline–syncline pair, which has fold axes plunging to the southwest. The syncline, which has several smaller folds associated with it, is responsible for the bend in strike to a north–south direction; at least two faults emanate from the synclinal fold core and are presumed to be related to the folding. Parts of the Lawrenceton Formation are foliated, but the foliation does not appear to bear a rational relationship to the simple southwest-plunging folds defined by facing directions and lithological mapping. It is therefore likely that the rocks have been affected by more than one deformation.

The rocks of greatest economic interest in the area are the pyritic quartz-sericite alteration zones in the Lawrenceton Formation, which are promising targets for gold exploration. Prospecting has already identified gold occurrences in the general area.

INTRODUCTION

During the summer of 1993, 1:50 000-scale mapping was done in the part of the Botwood (NTS 2E/3) map area that lies between Lewisporte and the Bay of Exploits, in central Newfoundland. The area is bounded in the west by the Bay of Exploits, in the south by Norris Arm, in the east by Route 340 linking Lewisporte to the Trans-Canada Highway, and in the north by the boundary of NTS 2E/3 and by Route 341 to Laurenceton.

The southern half of NTS 2E/3 was mapped by W.L. Dickson during 1993 and his work has been combined with the work reported in this paper to produce a 1:50 000-scale open-file map (Dickson and Colman-Sadd, 1993). Mapping in the remaining part of the area has been done by B.H. O'Brien and preliminary coverage is shown by O'Brien (1993a); this mapping will be updated to include the results of the 1993 field season and will be combined with the results of Dickson and Colman-Sadd (1993) to produce an integrated map of NTS 2E/3 in 1994. The 1993 work of both W.L. Dickson and B.H. O'Brien is reported elsewhere in this volume.

NTS 2E/3 lies within the Exploits Subzone of the Dunnage Zone (Williams *et al.*, 1988), but the principal geological unit underlying the area described in this paper belongs to the Botwood Group, which is a part of the Silurian overlap sequence. The Botwood Group consists of a lower unit, the Lawrenceton Formation, which is formed mainly of mafic and intermediate volcanic rocks, and an upper unit, the Wigwam Formation, which is almost exclusively sedimentary. The Wigwam Formation between Lewisporte and the Bay of Exploits is dominated by thick-bedded sandstones of a probable fluviatile facies, whereas in the southwestern part of NTS 2E/3, thinner bedded rocks of a lacustrine facies are common (Dec, personal communication, 1993; Dickson, *this volume*). The only evidence of a marine influence is provided by a single fossil locality near the junction of Route 340 with the Trans-Canada Highway, which contains bivalves of Wenlock or younger age (Boyce and Ash, *this volume*).

Within the area of Figure 1, all of the contacts of the Botwood Group with other units are faulted. West of Lewisporte and Route 340, the group is inferred to be overthrust north and east across marine Ordovician and Early Silurian rocks (O'Brien, 1993a). The southern boundary, just

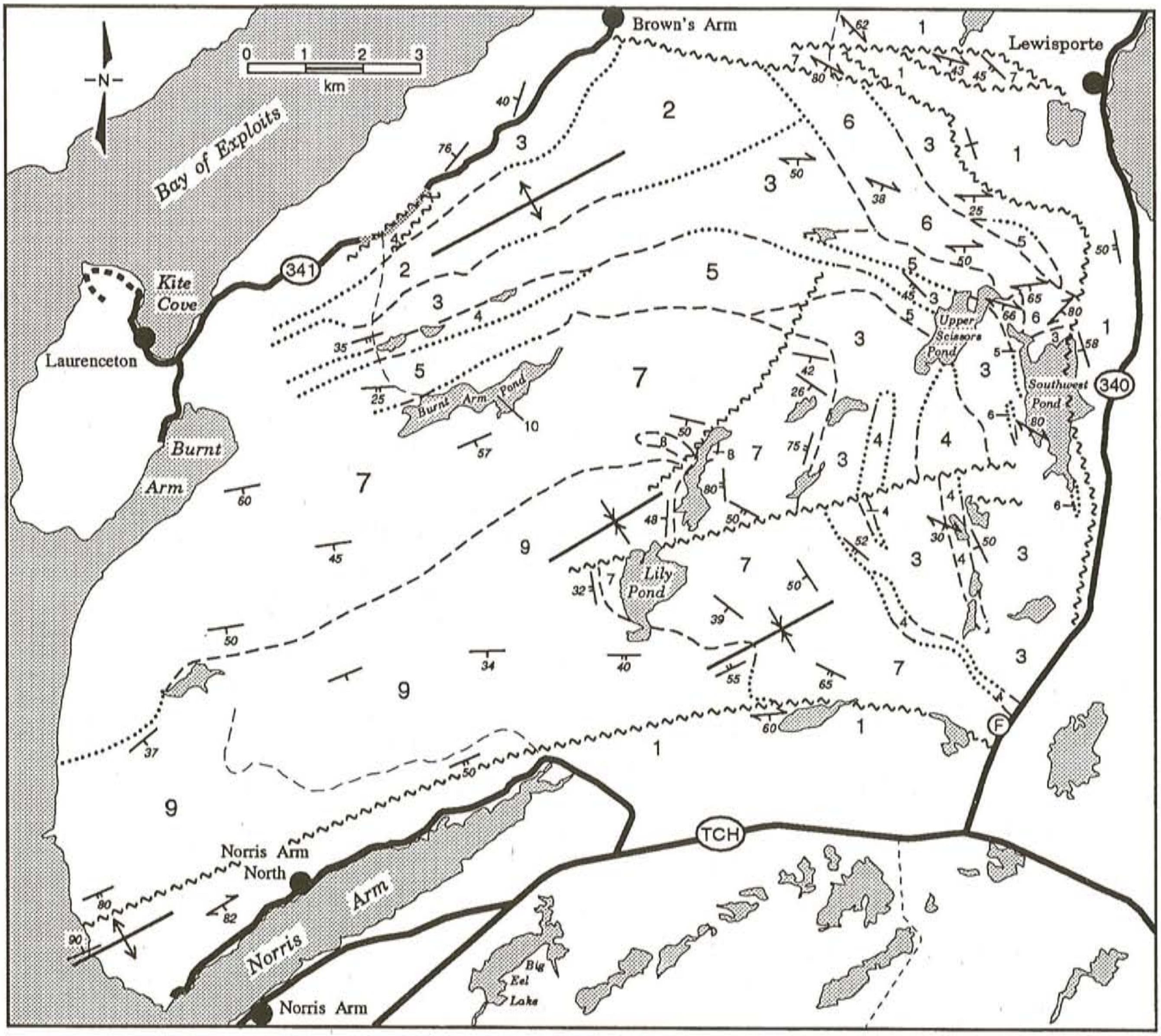

Figure 1. *Geology of the Botwood Group, southwest of Lewisporte, NTS 2E/3.*

north of Norris Arm, is also interpreted to be a thrust fault, but one on which the Botwood Group forms the footwall.

The only previous geological mapping in the area before the current projects were begun by the Geological Survey Branch was 1:250 000-scale mapping by Williams (1964) for the Geological Survey of Canada. Since that time, numerous geologists have made observations along the coast and highways. However, the less accessible interior has been largely ignored and the geology shown for these parts on the 1:63 360-scale map of Dean (1977) is simply an enlarged reproduction of Williams' map. As a precursor to the mapping reported here, B.H. O'Brien did reconnaissance work by helicopter and canoe during 1992 and the results are shown on his 1:50 000-scale map (O'Brien, 1993a).

A limited amount of mineral-exploration work has been done within the map area during the last five years and results are discussed in the section on mineral potential.

GENERAL GEOLOGY

The following descriptions concentrate on the two formations of the Botwood Group, which are the dominant units in the area. The Ordovician and Early Silurian marine rocks of Unit 1 are described last, despite their relative age, because the main point of the description is to highlight characteristics used to distinguish them from the Botwood Group. These characteristics are important because they provide the underlying justification for revising the unit boundaries shown on previous maps.

LEGEND (for Figure 1)

INTRUSIVE ROCKS

10 *Gabbro*

SILURIAN SUBAERIAL ROCKS

Botwood Group

Wigwam Formation

9 *Mainly red and maroon, parallel and crossbedded, medium to thick-bedded, quartz-rich sandstone. Locally, includes matrix-supported, shale-flake conglomerate, beds of nodular limestone, and polymict, clast-supported conglomerate. Rocks are altered to buff and pale green close to the major fault zones*

8 *Red, aphanitic, flow-banded, felsic volcanic rock*

7 *Greenish grey, pink- to white-weathering, parallel and crossbedded, medium- to thick-bedded, quartz-rich sandstone. Rocks are altered to buff and pale-green colours close to major fault zones*

Lawrenceton Formation

6 *White, buff and light grey, pyritic, quartz–sericite schist and silicified rocks. Includes unseparated felsic volcanic rocks south and west of Southwest Pond*

5 *Grey to purple, purple-weathering, plagioclase-porphyritic, intermediate to mafic lava flows, and oligomict and polymict, volcaniclastic breccia. Includes beds of clast-supported, poorly sorted, polymict conglomerate, composed of subangular to subrounded cobbles and pebbles of volcanic and sedimentary rocks. May be equivalent to parts of Unit 3*

4 *Light to dark grey, felsic to intermediate volcanic rocks, including banded, plagioclase-porphyritic and aphanitic lava flows, banded ignimbrite, and massive crystal-lithic tuff. Includes unseparated beds of polymict conglomerate*

3 *Mainly green to dark grey, commonly plagioclase-porphyritic and amygdaloidal basalt. Includes brecciated, red or maroon lava, associated with laminated red sandstone lenses and septa, especially at flow tops. West and southwest of Upper Scissors Pond, may be equivalent to parts of Unit 5*

2 *Grey, green and purple, purple-weathering, plagioclase-porphyritic, intermediate to mafic lava flows and oligomict volcaniclastic breccia*

ORDOVICIAN AND EARLY SILURIAN MARINE ROCKS

1 *Grey and green, polymict, clast-supported, moderately well sorted, conglomerate, interbedded with minor coarse, graded sandstone beds. Dark grey, thinly bedded, shale and fine-grained, graded sandstone. Green, mafic lithic tuff, mafic, plagioclase-porphyritic lava flows, and volcanogenic sandstone*

CONTACT RELATIONSHIPS

The boundaries of the Botwood Group being faults, the base of the group is not seen and the relationship of the Lawrenceton Formation to surrounding, older, marine rocks is not known. It is reasonable, however, to suppose that the contact was originally similar to the one described by Williams (1993) for equivalent units on the Port Albert Peninsula. The contact at the latter location is clearly stratigraphic and Williams (*op. cit.*) interprets inclusion of volcanic boulders in the greywacke, and greywacke in the volcanic rocks, as evidence that there was temporal overlap between marine deposition and the early Botwood Group volcanism. If the same relationship applies near Lewisporte, the base of the group is probably of Llandovery C3 age, corresponding to the youngest fossils found in the adjacent marine sequences (Boyce and Ash, *this volume*).

The Botwood Group is the youngest stratified unit in the area so its stratigraphic top and upper age limit are undefined. In central Newfoundland, rocks that are included in the Botwood Group have been interpreted to be unconformably overlain by the Stony Lake volcanic sequence (Colman-Sadd and Russell, 1982), dated at 423 $^{+3}_{-2}$ Ma (Dunning *et al.*, 1990), but the relationship is ambiguous. Reports of Botwood Group intruded by granite of the Mount Peyton intrusive suite northeast of Miguels Lake (Colman-Sadd, 1989) are at present of little use for determining the upper age of the group because the particular granite phase is undated, and the correlation of the intruded rocks with other parts of the Botwood Group requires confirmation.

The contact between the two formations of the Botwood Group is interpreted to be conformable and there is no evidence of tectonic disturbance during deposition. However, some interformational erosion is to be expected because both are subaerial and the volcanism of the Lawrenceton Formation would almost certainly have resulted in topographic irregularity. Evidence for such erosion can be found in the volcanogenic conglomerate that occurs in the upper parts of the Lawrenceton Formation.

LAWRENCETON FORMATION

Unit 2

The presumed lowest unit (Unit 2) of the Lawrenceton Formation consists of distinctive purple-weathering volcanic rocks that contain 1 to 3 mm white plagioclase phenocrysts. On fresh surfaces, these rocks are dark purplish grey or dark purplish green depending on the relative amounts of disseminated hematite and epidote. They have a dull lustre, suggesting a mafic or intermediate composition, and lack the brittle fracture expected of a felsic rock.

Most of this unit occurs as massive or blocky, amygdaloidal flows, in which the amygdales are commonly about 2 to 4 mm across and filled either with white calcite or dark-green chlorite. The flows contain discontinuous septa of fine-grained, red sandstone that form a network through the rock. The septa are mostly about 1 to 3 cm wide and the lava blocks that they enclose are 30 cm to 1 m across; sedimentary laminations occur in a few of the wider septa.

Parts of Unit 2 consist of volcanic breccia, composed mainly of fragments of the same lava as forms the flows. Other fragments are fine-grained sandstone, like that found in the septa, and variously coloured feldsparphyric volcanic rocks, some coated with red alteration or weathering rinds. The matrix either consists of the fine-grained volcanic rock or of red sandstone. In some exposures, fragments have a limited degree of rounding.

Within the outcrop area of Unit 2, about 1 km east of the Burnt Arm Pond access road, there are two occurrences of fine-grained, medium-grey felsic rock. Neither is more than 10 m across and they apparently form high-level intrusions.

Unit 3

Unit 3 overlies Unit 2 on both limbs of the anticline just south of Route 341. Similar rocks continue south and east into the region south of Upper Scissors Pond, where the entire width of the Lawrenceton Formation, excepting intercalations of felsic rocks, is composed of this unit. It is uncertain whether the rocks in the southeast are all time equivalents of those to the north. A more likely interpretation is that the part of the unit southwest of Upper Scissors Pond is relatively young and is equivalent to Unit 5 or overlies Unit 5 as the latter wedges out toward the southeast. The best and most accessible exposures of Unit 3 are along Route 341 and around the shores of Southwest Pond.

The dominant rock type of Unit 3 is a fine-grained, dark-greenish-grey basalt, which most commonly contains white plagioclase phenocrysts 1 to 3 mm long. However, there are some varieties in which the phenocrysts are about 1 cm long (Plate 1) and others that lack phenocrysts altogether. The colour of the basalt also shows some variation. Some exposures, notably along Route 341, contain a lighter greenish-grey rock, which is more brittle than the dark varieties and may be partly silicified. In other exposures, the basalt has a slightly purple tinge. The principal control on the colour range appears to be the proportion of red hematite and green epidote, which occur as patches and veinlets. Small amounts of pyrite and pyrrhotite are disseminated in some exposures and thin veins of calcite and quartz are common.

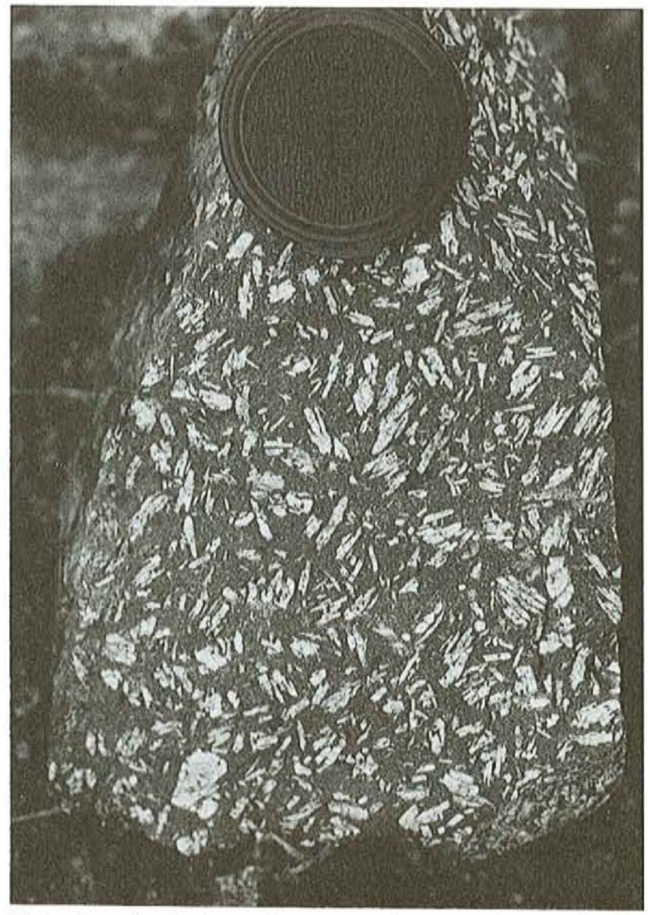

Plate 1. *Plagioclase phenocrysts in coarsely porphyritic basalt of Unit 3 of the Lawrenceton Formation, south side of Route 341, 2 km northeast of the turning to Burnt Arm Pond.*

The basalt characteristically contains large vesicles, 3 mm to 1 cm across, filled with white calcite or dark-green chlorite, although in some places it shows no sign of vesiculation at all. The most vesicular varieties also contain septa of fine-grained red sandstone (Plate 2), similar to those seen in Unit 2, which separate blocks of basalt 30 cm to several metres across. In some exposures along the Burnt Arm Pond road, vesicles are elongated parallel to the irregular traces of the sandstone septa and so define the flow of the lava during extrusion. Where the sandstone septa are

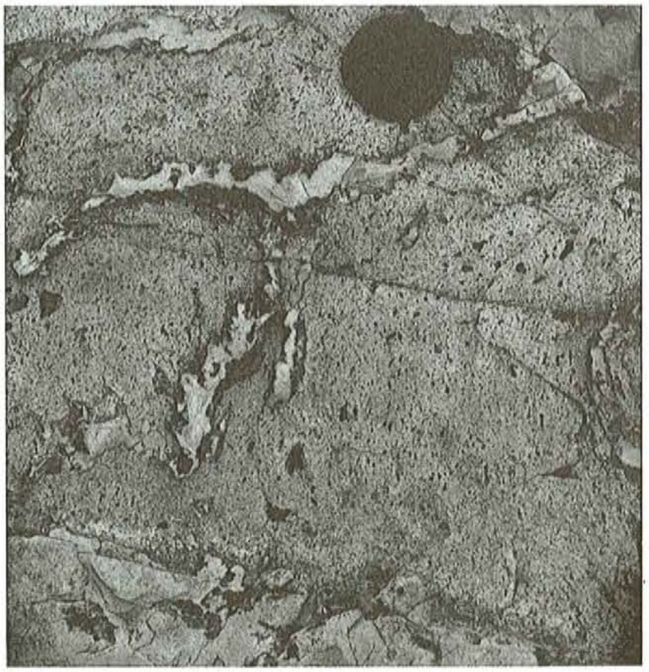

Plate 2. *Vesicular basalt containing septa of red sandstone, Unit 3 of the Lawrenceton Formation, Burnt Arm Pond road. Note the flow alignment of the elongated vesicles parallel to the septa.*

particularly wide, they form lenses in which crosslamination can be used to determine tops. There is a continuum from massive lava with a few discontinuous sandstone septa to volcanic breccia composed of blocks 10 to 30 cm across in a sandstone matrix, or in some cases a calcite or green epidote-rich matrix.

Flow tops are identifiable at a number of locations in Unit 3. One of the best examples is in an exposure of coarsely porphyritic basalt on the south side of Route 341, about 2 km northeast of the turning to Burnt Arm Pond. The fresh basalt is dark grey, but within 100 cm of the flow top it is brecciated and pervasively reddened (Plate 3). The breccia is overlain by a thin layer of red sandstone, which in turn is overlain by dark-grey basalt of the next flow up the sequence.

Where Unit 3 forms the upper part of the Lawrenceton Formation, southwest of Upper Scissors Pond, it is associated with more sedimentary rocks than in the lower parts of the formation. Within about 1 km of the contact with the Wigwam Formation, flows are interbedded with red sandstone and clast-supported conglomerate beds that are tens of metres thick (Plate 4). Clasts in the the conglomerates are mainly composed of grey, purple or red feldsparphyric volcanic rock types. They are subrounded and are commonly as large as 20 cm in diameter.

Unit 4

Felsic volcanic rocks are a subordinate component of the Lawrenceton Formation. All occurrences, except those

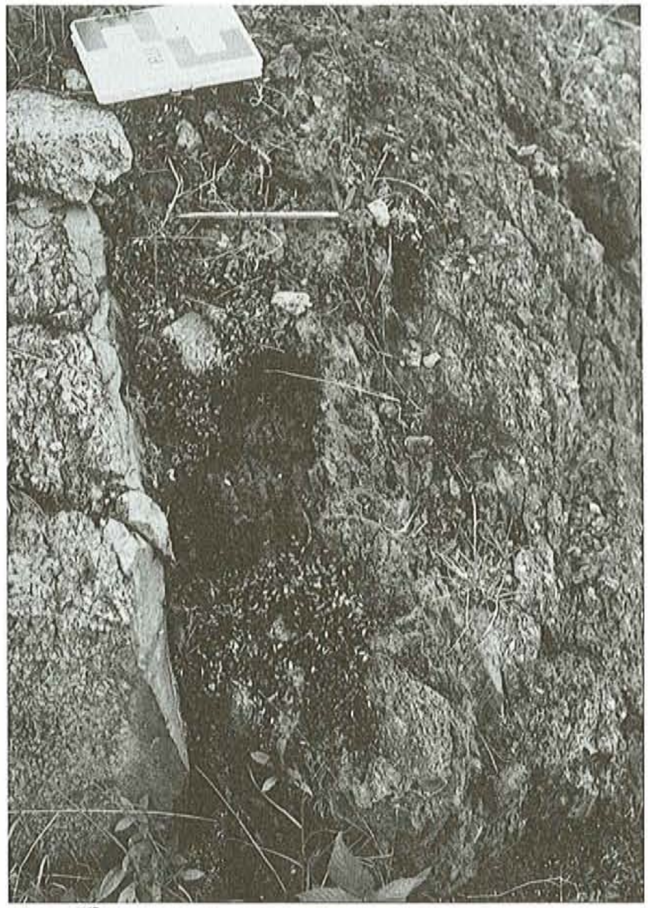

Plate 3. *Weathered flow top in coarsely porphyritic basalt of Unit 3 of the Lawrenceton Formation, south side of Route 341, 2 km northeast of the turning to Burnt Arm Pond. Dark-grey basalt near the right edge of the photograph passes upward into reddened and brecciated basalt at the flow top; this is overlain by a bed of red sandstone, which in turn is overlain, at the left edge of the photograph, by fresh dark-grey basalt forming the base of the next flow.*

associated with the altered rocks of Unit 6, are grouped together in Unit 4. It is likely that the two bands of Unit 4 that cross the Burnt Arm Pond road are the same horizon repeated by folding. The bands in the southeast of the area, however, occur at different levels in the stratigraphy and most likely represent different volcanic events.

The felsic volcanic rocks that are exposed on the Burnt Arm Pond road are terminated by faulting in the north but in the south can be traced along strike for at least 3 km. They are white-weathering, dark purple on fresh surfaces and mostly flow-banded (Plate 5). They contain abundant plagioclase phenocrysts in an aphanitic matrix, but no quartz crystals have been observed. The felsic nature of the rock is apparent from its brittle fracture and vitreous lustre. Locally, the rock is autobrecciated.

To the south of Upper Scissors Pond, the felsic rocks are quite variable. The band that lies adjacent to the contact

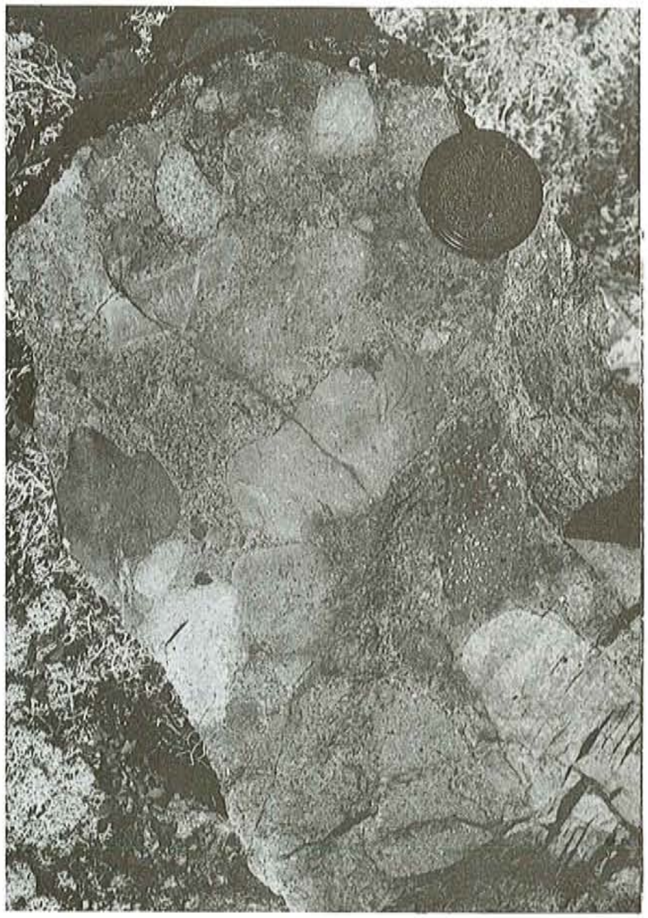

Plate 4. *Polymict conglomerate interbedded with basalt flows of Unit 3, Lawrenceton Formation, south of Upper Scissors Pond.*

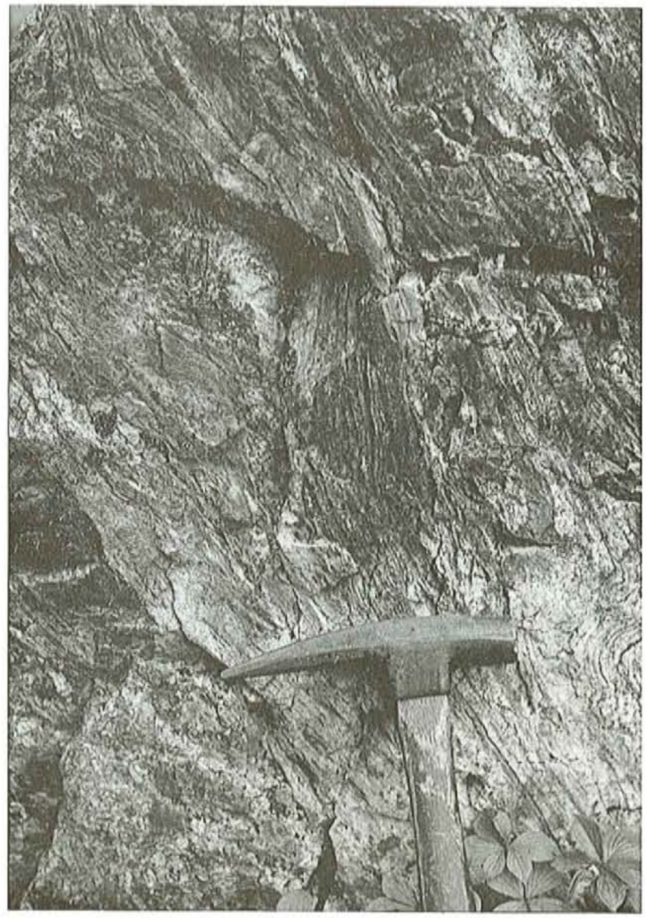

Plate 5. *Flow-banded felsic volcanic rock of Unit 4, Lawrenceton Formation, Burnt Arm Pond road.*

with the Wigwam Formation is a red, massive, feldspar-porphyritic rock that is probably a flow. The large band to the east of it consists in part of well-banded, welded, ash-flow tuff with flattened pumice fragments up to 20 cm long (Plate 6). This tuff is represented as fragments in a coarse volcanic breccia that occurs along strike to the north. Due west of Southwest Pond, a crystal-lithic tuff unit can be traced for over 1 km. It is massive, except where it has a slight tectonic cleavage, and consists of 1 to 2 mm feldspar crystals and red or purple feldsparphyric lithic fragments in a very siliceous fine-grained matrix.

Unit 5

The uppermost unit of the Lawrenceton Formation in the area around Burnt Arm Pond (Unit 5) is lithologically distinct from the clearly mafic rocks of Unit 3 and the much more siliceous rocks of Unit 4. Its volcanic component does, however, resemble the volcanic rocks of Unit 2 and is probably mafic to intermediate in composition. The relationship of Units 3 and 5 around Upper Scissors Pond is problematic and is tentatively regarded as one of stratigraphic interlayering without structural repetition.

About half of the exposures of volcanic rock within the unit consist of dark-purplish-grey, purple-weathering lava that is rich in 1 to 2 mm white plagioclase phenocrysts. Some of the rocks are vesicular but generally the vesicles are only about 1 mm across, as opposed to the much larger vesicles common in Unit 3. As in both Units 2 and 3, discontinuous red septa of fine-grained sandstone are common. There is a gradation into coarse breccia where the septa become better developed and separate the lava into blocks 30 cm or more in diameter. The red sandstone is also found as exotic lithic fragments within the lava.

Volcanic breccia included in Unit 5 is characterized by purple, feldsparphyric fragments, up to 30 cm in size. The fragments are angular and many have reaction rims; a few have poorly defined flow banding. The breccia also contains exotic fragments that include green or red sandstone, chert and dark-grey basalt. A slightly different breccia occurs along the south edge of Unit 5 half way between Burnt Arm and Upper Scissors ponds and is shown unseparated in Figure 1. This breccia consists of green flow-banded fragments in a fine-grained red-sandstone matrix and contains abundant spheroidal accretionary lapilli.

Conglomerate is a significant component of Unit 5. Two horizons, each at least 100 m thick, are exposed on the Burnt

Plate 6. *Flattened pumice fragments in ash-flow tuff of Unit 4, Lawrenceton Formation, south of Upper Scissors Pond.*

Arm Pond road, and another occurs farther to the northeast. The conglomerate is clast-supported, moderately sorted and bedding is indeterminable. The clasts range in size up to 60 cm and are subangular to subrounded. They consist mainly of purple, feldsparphyric, intermediate to mafic lava, but also include flow-banded felsic rock, grey and red sandstone, chert and jasper. Conglomerate forms the youngest part of Unit 5 and is presumed to be in stratigraphic contact with sandstone of Unit 7 at Burnt Arm Pond, although the actual contact is not exposed.

Volcanic rocks of Unit 5 north and east of Upper Scissors Pond have a strong penetrative cleavage. The intensity of the cleavage increases toward the altered zone of Unit 6, in which the cleavage is also well developed.

Unit 6

Within the Lawrenceton Formation, there are several zones of pyritic quartz-sericite schist or more massive silicified rock (Unit 6). The large zone north of Southwest Pond is entirely bounded by mafic or intermediate composition flows and breccias, and the protolith is not readily identifiable. This zone is clearly discordant to the stratigraphy immediately north of Southwest Pond and this relationship is assumed where the map pattern is open to interpretation in the poorly exposed area west of Lewisporte. Furthermore, there appears to be a gradation from Unit 5 into Unit 6 between Upper Scissors and Southwest ponds, suggesting that in this area Unit 6 is derived by alteration of mafic to intermediate volcanic rocks. The two smaller zones, south and west of Southwest Pond, are conformable with the stratigraphy and may be related to felsic volcanism.

Unit 6 north of Southwest Pond consists mainly of buff, well-cleaved, sericite schist, in many places with a green or purple tinge. Massive, fine-grained, buff- to light-grey silicic rock is commonly interlayered with the schist and in places there are relict 1 to 2 mm plagioclase phenocrysts. Pyrite is ubiquitous in the unit as disseminations or stringers. The pyrite and common limonite-filled cavities result in most exposures having a characteristic rusty-weathering colour. Networks of quartz veins occur in some exposures.

The occurrences of Unit 6 south and west of Southwest Pond consist of buff, pyritic siliceous rock, which is brecciated rather than cleaved. Exposures west of the pond define a unit that is about 50 m wide, at least 500 m in strike length, and bordered on both sides by mafic flows of Unit 3 that show no alteration and have been only slightly deformed.

The intense alteration of Unit 6 makes it an attractive target for precious metals exploration. Eleven grab samples were collected for assay from north of Southwest Pond and one each from the exposures south and west of the pond, but none of the samples gave gold or silver values above the detection limits (2 ppb for gold; 2 ppm for silver).

WIGWAM FORMATION

Unit 7

The lower part of the Wigwam Formation consists of pink-weathering, green-grey sandstone of probable fluviatile origin (T. Dec, personal communication, 1993). The sandstone is well-sorted and fine grained (clast size 0.25 mm or less). It is quartz-rich and contains accessory clastic muscovite and unidentified deep red clasts that may be jasper. Laminations within beds are defined by concentrations of ferromagnesian minerals. Pyrite is a common accessory mineral but does not appear to be clastic. Pelite is present as rare, very thin beds. It also occurs as clasts in a matrix-supported, shale-flake conglomerate that was observed at three locations.

Beds of the green-grey sandstone vary from 3 cm to 3 m in thickness, but most commonly lie in the range of 20 to 60 cm. They are either massive or laminated. Laminations, when present, are parallel to bedding, planar crossbedded or trough crossbedded; the upper surfaces of some beds are rippled (Plate 7). Opposing apparent dips of crossbeds on single rock faces suggest cross sections of large-scale trough crossbedding. Individual crossbedded sets are generally between 10 and 100 cm thick. Channels eroded into the underlying beds are common, especially where massive sandstone overlies laminated beds (Plate 8). The few pelite beds that occur are less than 5 cm thick and the shale-flake conglomerate beds do not exceed 20 cm.

Except in the fault slices west of Lewisporte, cleavage in Unit 7 is only clearly visible in the pelite beds, which are so thin that in all occurrences, the cleavage appears to have been rotated parallel to bedding. The sandstone has no discernible fabric in the main outcrop, but is locally crossed by fractures and intruded by undeformed quartz veins. However, in the fault slice immediately west of Lewisporte, the typical green-grey sandstone of Unit 7 has a well-developed fracture cleavage, in which the cleavage surfaces

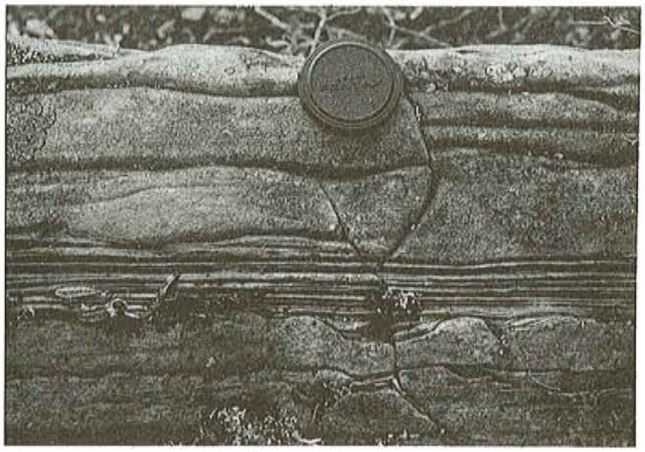

Plate 7. *Ripples on the upper surface of a massive sandstone bed and channelling of an overlying bed into laminated sandstone, Unit 7 of the Wigwam Formation, Burnt Arm Pond.*

Plate 8. *Laminated trough crossbedded sandstone, channelled by an overlying bed of massive sandstone, Unit 7 of the Wigwam Formation, east of Burnt Arm Pond.*

are 1 to 2 cm apart and oblique to the bedding. The next fault slice to the west is exposed at one location only, where a bleached buff sandstone, presumed to belong to the Wigwam Formation, has a strong cleavage spaced between 5 mm and 1 cm apart and is oblique to the bedding.

Unit 8

A thin band of felsic volcanic rock (Unit 8) occurs near the top of Unit 7 about 200 m from the contact with Unit 9. The band is less than 100 m wide and its original lateral continuity was probably no more than 1 km; it is now broken into two parts by a fault. The volcanic rock is assumed to be felsic because of its vitreous lustre and intense brittle fracturing. It is maroon and different shades define an indistinct flow-banding. In one of the exposures to the west of the fault, small buff patches may represent feldspar phenocrysts and, in an exposure east of the fault, small quartz crystals are visible. Except in these two exposures, the rock is aphanitic. On the west side of the fault, the rock contains a few bleached, rusty-weathering, pyritic patches several centimetres across.

Unit 9

The upper part of the Wigwam Formation is distinguished mainly by its colour. It consists of red sandstone and minor amounts of red conglomerate, but in most respects, other than colour, it is very similar to Unit 7.

The sandstone is generally fine grained, well sorted, quartz rich, and contains prominent accessory muscovite. Beds are 30 to 100 cm thick in exposures where they can be identified, but a number of large, apparently massive exposures imply bed thicknesses of several metres. Sedimentary structures within individual beds are more difficult to see than in Unit 7 because dark laminations do not show up well against the initially dark colour of the rock. Good exposures do, however, indicate that there is a similar assemblage of parallel and crosslaminations occurring in sets between 10 cm and 2 m thick. The crosslaminations are both planar and trough-shaped and opposing apparent dips are common within single exposures. Channelling of massive sandstone into underlying laminated sandstone is also common. In the western part of the area, south of Burnt Arm, a few thinner beds contain ripples and climbing ripples (Plate 9).

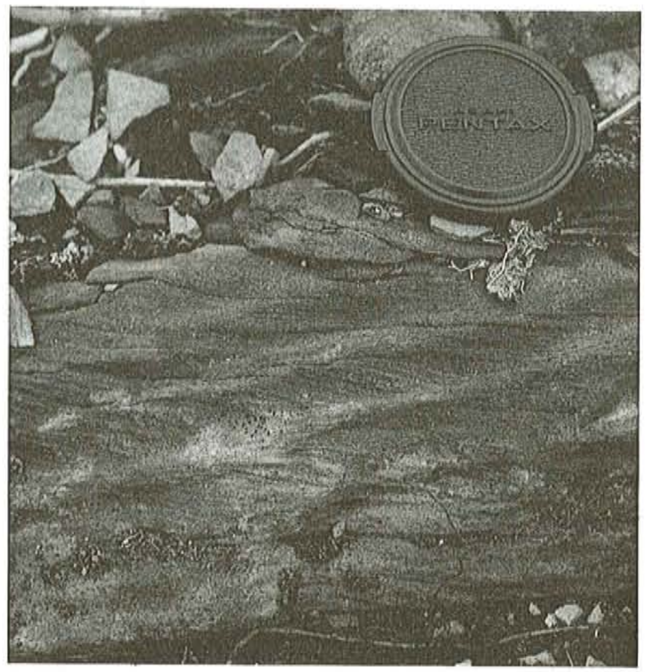

Plate 9. *Climbing ripples in red sandstone of Unit 9, Wigwam Formation, south of Burnt Arm.*

Interbeds of red pelite are thin and very uncommon. They are all strongly cleaved, either parallel to beds or at a small oblique angle. The pelite also occurs as clasts in a matrix-supported, shale-flake conglomerate (Plate 10). The conglomerate has eroded channels in underlying beds and

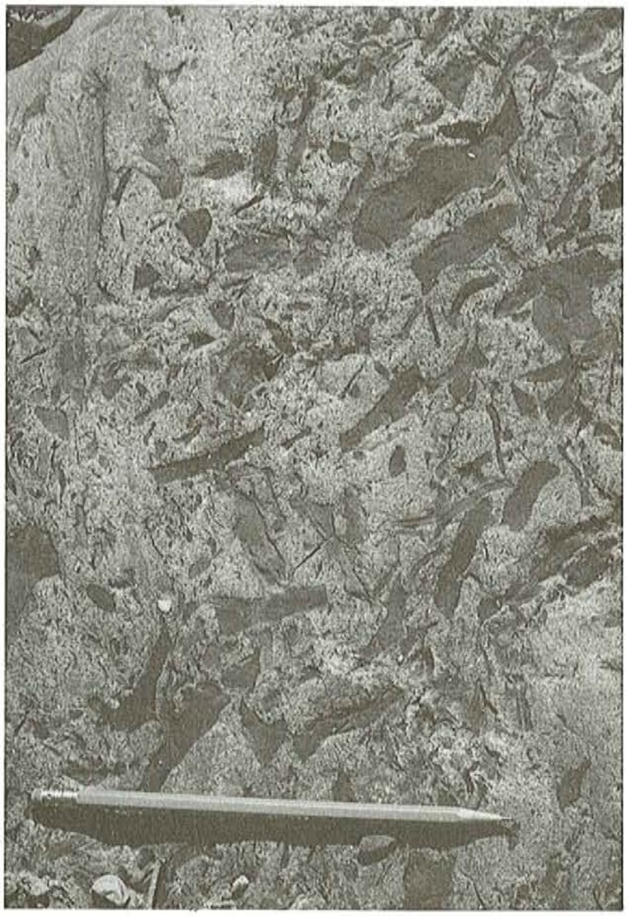

Plate 10. *Matrix-supported, shale-flake conglomerate in Unit 9 of the Wigwam Formation, north of Norris Arm North.*

in some places lenses of shale fill depressions in the top surfaces of these beds.

South of Lily Pond, a group of exposures within Unit 9 contain clast-supported, polymict conglomerate. The total thickness of this facies is probably less than 100 m and its lateral extent is likely to be about 1 km. The conglomerate is formed of a mixture of subrounded, volcanic and sandstone clasts, 1 to 3 cm across and fairly well sorted. One exposure consists entirely of unstratified conglomerate, but elsewhere the conglomerate is interbedded with sandstone and in one place is associated with a sandstone bed containing caliche-like calcite concretions.

Adjacent to the southern boundary fault of the Botwood Group, Unit 9 and possibly also part of Unit 7 have been altered, causing a colour change from red to buff in the sandstone, and red to pale green in shale clasts. The alteration is presumed to be mainly a reduction in the oxidation state of contained iron.

The sandstone of Unit 9 is apparently no more susceptible to cleavage formation than that of Unit 7. However, north and west of Lily Pond, Unit 9 occupies the core of the main fold in the area and has therefore been subjected to greater stress. Exposures close to fault lines are randomly fractured and others have a moderately developed, northeast-trending fracture cleavage. Some exposures in this area, while not especially fractured have a strong, flaggy parting parallel to beds, and the rock is unusually brittle. All parts of the Unit 9 are cut by scattered, undeformed quartz veins.

Intrusive Rocks (Unit 10)

One intrusive body has been found within the area underlain by Silurian rocks. This is gabbro of Unit 10, which only occurs on an island in Burnt Arm Pond and is nowhere in contact with any other unit. It is a medium-green rock, consisting of feldspar, a dark-green ferromagnesian mineral, and small amounts of accessory pyrite. The grain size is less than 1 mm. The gabbro is not foliated, but it has extensive epidote alteration and has been cut by a few narrow quartz veins.

DISTINCTION OF THE BOTWOOD GROUP FROM SURROUNDING UNITS

Marine Ordovician rocks that border the Botwood Group to the north, east and south are grouped together in Unit 1. They belong to two main stratigraphic levels. To the north, Early to Middle Ordovician volcanic and volcanogenic sedimentary rocks are exposed along the Brown's Arm logging road that extends southward from the northern edge of the map area. Rocks to the east and south of the Botwood Group belong to the Middle Ordovician and Early Silurian turbidite sequences of the Point Leamington Formation and the Goldson Conglomerate (Arnott *et al.*, 1985; Dickson, *this volume*).

At one exposure, the Early to Middle Ordovician rocks consist of conglomerate interbedded with sandstone and intruded by gabbro and, at another, of mafic lava and lithic tuff. The sedimentary rocks are green-grey and moderately well sorted. The most important feature that distinguishes them from sedimentary rocks of the Botwood Group is their clast composition. Volcanic clasts are both felsic and mafic but they do not include the felsparphyric types that dominate the Lawrenceton Formation and none of them are reddened. Also, the felsic volcanic clasts contain quartz phenocrysts, which are conspicuously absent from Lawrenceton volcanic rocks of all compositions. Other clasts consist of green sandstone, vein quartz and chert, but do not include jasper, celadonite or red clastic sedimentary rocks, which are common constituents in Middle Ordovician and younger conglomerates. The lava and lithic tuff are green and feldsparphyric and could be confused with parts of the Lawrenceton Formation, particularly Unit 3. There is, however, no red weathering, which is usually present to some degree in the Silurian rocks, especially the fragmental rock types.

The Middle Ordovician to Early Silurian turbidite sequences adjacent to the Botwood Group are dominated by conglomerates. These are distinct from the Botwood Group conglomerates in that they lack the reddened feldsparphyric volcanic clasts derived from the Lawrenceton Formation. Their principal clast types, including mafic volcanic rocks, granite, vein quartz, jasper and celadonite, are all represented in Botwood Group conglomerates, but only in subordinate amounts. Most of these conglomerates also contrast with those in the Botwood Group in that they are green rather than red or purple. An apparent exception is the Goldson Conglomerate along the north side of Norris Arm, which is stained red along joint surfaces and appears red on exposed surfaces. When the rock is broken, however, this is seen to be a superficial effect, perhaps related to its proximity to the red beds of Unit 9. Another reddened exposure of Goldson Conglomerate occurs southwest of Lewisporte, but can be traced into typical green rocks.

The Goldson Conglomerate commonly has sandstone interbeds that display the graded bedding characteristic of turbidite deposits. It is in contact with fine-grained turbidite deposits of the Point Leamington Formation, which consist mainly of grey argillite with thin beds of grey, fine-grained, graded sandstone.

Two other contrasts between Unit 1 and the Botwood Group are less well defined, but are obvious nonetheless. In almost all exposures of Unit 1, it is possible to identify and measure a penetrative tectonic fabric. Most exposures of the Botwood Group, excepting the highly altered rocks of Unit 6, lack a penetrative fabric. The presence of a fabric in some of the Botwood Group rocks suggests that the difference is most likely a function of rock composition and physical position during deformation. The second contrast is that only one igneous intrusion has been found within the Botwood Group in this area, whereas several diorite and diabase dykes occur in Unit 1, which is of much more limited extent. The implication is that the volcanism of the Botwood Group represents the last major igneous event. However, it is important to note that mafic dykes have been found cutting Botwood Group rocks on the west side of the Bay of Exploits (Dickson, *this volume*) and that Mesozoic intrusions are documented both east and west of the map area (Strong and Harris, 1974).

REGIONAL STRUCTURE

The outcrop pattern of the Botwood Group is dominated by an anticline–syncline pair, which has fold axes plunging to the southwest and is asymmetrical to the northwest. The inference of an anticlinal axis in the Lawrenceton Formation north of Burnt Arm Pond depends on two north-facing top determinations in the steep, north-dipping rocks along Route 341; one of these determinations was from the weathered top of a basalt flow and the other from crosslaminations in sandstone septa within a flow. The rocks farther south toward Burnt Arm Pond dip shallowly to the south and are assumed to face south in conformity with the crossbedded sandstones of Unit 7.

The main synclinal axis passes just north of Lily Pond and is responsible for the bend in the strike of the whole Botwood belt to a north–south direction. At least two faults emanate from the fold core and are presumed to be related to the folding. The clearest evidence for the more northerly fault is the offset of the felsic volcanic rocks of Unit 8, but there is also a faint lineament on air photographs, which can be traced to the southern boundary of the Lawrenceton Formation. The southern fault offsets the boundary between Units 7 and 9 west of Lily Pond and the boundaries of Units 7 and 3 east of the pond. The sense of offset is different in each case because dips in Unit 7 are shallower south of the fault than to the north and this is reflected in the width of outcrop of the unit. Smaller anticline and syncline pairs have been identified southeast of Lily Pond by opposing dip directions of bedding. They have the same plunge and asymmetry as the major folds.

Parts of the Lawrenceton Formation, especially in the east, are well foliated and the foliation is particularly intense within and adjacent to Unit 6. The attitude of the foliation changes across the area and to some extent it follows the change in strike of the formation. It does not appear to bear a rational relationship to the simple southwest-plunging folds that have been defined by facing directions and lithological mapping. It is therefore possible, as indicated by O'Brien (1993a), that the rocks were affected by an earlier deformation. This deformation may have been responsible for the cleavage, for as yet undefined folds, and for the boundary faults of the Botwood Group, which conform to the sinuous trend of the stratigraphy. The best test of an early deformation would be to establish repetition by folding of the Lawrenceton stratigraphy southwest of Southwest Pond. This would require folding around north–south axes and would imply refolding of these axes around the southwest-plunging folds. Unfortunately, it has not proved possible during the present mapping to gather enough information on facing directions in this crucial area to reach a firm conclusion.

An alternative cause of the changing cleavage trend is suggested by the Z-shaped sinuosity of the trend as it crosses Unit 6, north of Upper Scissors Pond (see Figure 1 and Dickson and Colman-Sadd, 1993). If Unit 6 is regarded as a discordant zone of shearing and alteration, the trend of the cleavage would imply dextral strike-slip movement, which would be similar to the effect of the northwest-trending D4 structures of O'Brien (1993b). The principal problem with this hypothesis is that discordant cleavage directions have been measured in a number of locations south of Upper Scissors Pond where there is little or no evidence for northwest-trending shear zones.

MINERAL POTENTIAL

Past mineral-exploration work in the area has been limited to two projects, one in the Lawrenceton Formation and one in rocks of Unit 1 near Brown's Arm. Both projects targeted gold mineralization.

An assessment report by Butler (1990a) describes prospecting work on a claim block that straddled the Burnt Arm Pond road. The block was one of several in the area staked in response to the release of lake-sediment gold geochemistry data by the Newfoundland Department of Mines and Energy (Davenport and Nolan, 1988). The data showed a value of 3.7 ppb gold for one lake in the claim block. Prospecting revealed rhyolitic flows and tuffs having sericitic alteration and cut by stockwork quartz veining. Specularite was noted in the quartz veins and pyrite in silicified rhyolite. The most encouraging result was the discovery of rhyolite float containing fine-grained arsenopyrite and assaying 440 ppb gold and 5710 ppm arsenic.

Butler (1990b) also submitted an assessment report on work done on a claim at Brown's Arm but the report is not currently available. Descriptions of the claim are, however, provided in a report submitted by Inco Limited, who optioned the property (Bell, 1990), and in a report by Evans (1992). The claim overlaps the northern edge of the present map area and extends from the coast of the Bay of Exploits, west of Brown's Arm, to just west of the logging road between Brown's Arm and Lewisporte. Inco Limited optioned the property because a silicified shear zone in gabbro yielded a grab sample that assayed 10.7 g/ton gold. The gabbro intrudes pillow lavas and turbidites equivalent to the Early to Middle Ordovician part of Unit 1 (Figure 1). Arsenopyrite, pyrite, and minor stibnite mineralization were found in shear zones in the gabbro and the best assay was 17.3 g/ton gold from a 35 cm chip-sampled interval. In general, the highest grades were found in quartz veins that contained arsenopyrite.

The principal finding of economic interest during the current mapping project is the delineation of the altered, pyritic rocks of Unit 6. Although none of the assays from this unit gave elevated values of precious metals, the potential remains significant because the small number of samples leaves most of the unit untested. The proximity of the gold showings near Brown's Arm indicates the presence of suitable mineralizing fluids.

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