

REGIONAL TILL-GEOCHEMISTRY SAMPLING AND ICE-FLOW MAPPING ALONG THE SOUTHERN SHORE OF THE AVALON PENINSULA

D. Taylor
Geochemistry, Geophysics and Terrain Sciences Section

ABSTRACT

Till samples were collected from along the southern shore of the Avalon Peninsula, extending from St. Catherine's in St. Mary's Bay along the southern shore highway to the community of Mobile, as part of the continued regional till-geochemistry survey. Sampling along all major roadways was at a spacing of one sample per 1 km². Sampling started on the Avalon Peninsula in 2003, and with an additional 373 samples collected in 2008, the total number of till samples collected on the Avalon Peninsula is currently 2605.

Ice-flow indicators (predominantly striations) recorded on the southern Avalon Peninsula show that the area was affected by three separate ice-flow phases, all of which are tentatively assigned as late Wisconsinan. The earliest phase was southward along the axis of St. Mary's Bay. The second phase, likely at the glacial maximum, shows a radial ice-flow pattern centred over St. Mary's Bay and the Trepassey highlands, and a strong westward flow across the Cape St. Mary's sub-peninsula. Southeastward ice flow was also identified across the tip of the Trepassey sub-peninsula at St. Shotts. The final phase (during deglaciation) resulted from the collapse of the main ice centre toward the Trepassey Highlands, from which ice flow was westward into St. Mary's Bay and eastward across the Trepassey sub-peninsula into the Atlantic Ocean.

INTRODUCTION

This report describes the progress of a regional till-geochemistry project that started on the Bonavista Peninsula (Batterson and Taylor, 2001a, b); continued onto the western Avalon Peninsula and isthmus (Batterson and Taylor, 2003a, b); the central Avalon and Bay de Verde peninsulas (Batterson and Taylor, 2004a, b); the northern Burin Peninsula (Batterson *et al.*, 2006; Batterson and Taylor, 2006); and the southern Burin and southwest Avalon peninsulas (Batterson and Taylor, 2007 and 2008). These and similar projects elsewhere (*e.g.*, Batterson *et al.*, 1998; Liverman *et al.*, 1996, 2000; McCuaig, 2002, 2005), were successful in generating exploration activity, with over 5000 claims staked following the release of the open-file reports. These surveys also provide baseline data for environmental geochemistry applications.

The traditional regional till-geochemistry project combines surficial geology mapping (a combination of aerial photograph analyses and field verification), paleo ice-flow mapping, and sampling of till for geochemical analyses. The latter two components are complete for this project, with the production of a surficial geology map not required for this project. The emphasis of the 2008 field season was on sam-

pling for till-geochemical analyses and ice-flow mapping interpretation.

LOCATION AND ACCESS

The Avalon Peninsula is located in the eastern part of the province, comprising an area of about 9700 km². The peninsula is connected to the main part of the Island by an isthmus that is only 5.8 km wide at its narrowest point.

The till-geochemistry project of the southern Avalon follows the transportation corridor across nine 1:50 000-NTS map sheets (1K/11 Trepassey, 1K/12 St. Shotts, 1K/13 St. Mary's, 1K/14 Biscay Bay River, 1K/15 Renewes, 1N/02 Ferryland, 1N/03 St. Catherine's, 1N/04 Placentia, and 1N/07 Bay Bulls; Figure 1).

Access to the margins of the study area was generally good along the southern shore highway, which follows the coast from the community of St. Catherine's at the head of St. Mary's Bay in the west to the community of Mobile in the east. Side roads to the community of St. Shotts and the Cape Race lighthouse provide access to the headlands on the west and east side of Trepassey Bay. Access to the interior of the peninsula was generally poor and restricted to ATV

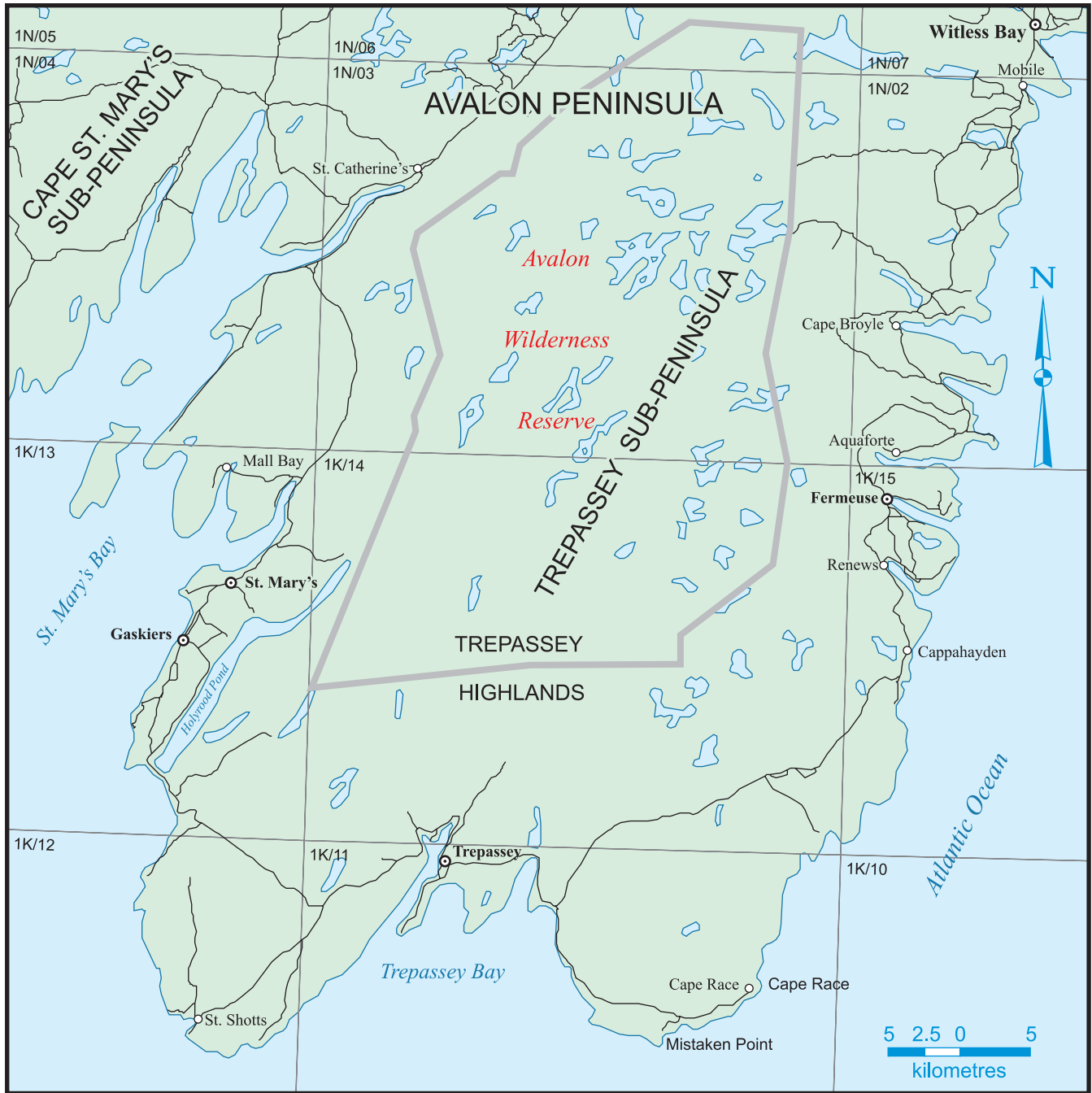


Figure 1. Location map and place names mentioned in text.

trails, most of which are not provincially approved. The interior of the Avalon Peninsula, which includes the Avalon Wilderness Area, is only accessible by helicopter. Sampling of this interior area was not a component of this project.

BEDROCK GEOLOGY

The southern Avalon area is composed of late Precambrian (Hadrynian) volcanic and clastic sedimentary rocks that are intruded by gabbro and granite and folded into

broad, upright, gently plunging anticlinoria and synclinoria (Williams and King, 1979; Figure 2).

The oldest rocks, the Harbour Main Group, comprise a bimodal volcanic assemblage. It is overlain by an assemblage of dominantly green, siliceous volcanoclastic sedimentary rocks of the Conception Group (Rose, 1952). Most of the volcanic rocks are bright red to pink and grey tuffs and agglomerates. Some are coarse and unsorted but fine-grained silicic tuffs, welded tuffs, lithic crystal tuffs and

flow-banded rhyolites are also represented. The mafic volcanic rocks are massive, fine-grained, dark-green to purplish basalts (Williams and King, 1979).

The Conception Group occurs throughout the field area and is dominated by green to grey siliceous sedimentary rocks and is divided into five formations: Mall Bay, Gaskiers, Drook, Briscal and Mistaken Point formations. The Gaskiers Formation includes a thick Precambrian glaciomarine unit toward its base and fossiliferous Precambrian strata at its top (Mistaken Point). In the east, the Drook Formation of the Conception Group conformably overlies the Harbour Main volcanics. In the west, the Drook Formation is underlain by the Gaskiers and Mall Bay formations with the base of the sequence unexposed. The Briscal Formation is coarse clastic facies of the Drook Formation. The Mistaken Point Formation is of uniform thickness throughout the map area, and its fossiliferous beds have been traced 12 km north to Cape Broyle (Williams and King, 1979).

Overlying the Conception Group is the St. John's Group; the latter is divided into three formations, the Trepassey, Fermeuse and Renew's Head formations. Grey sandstones of the Trepassey Formation are gradational and conformable with underlying, coarser and thicker bedded, pale-red sandstones at the top of the Conception Group (Williams and King, 1979).

ICE-FLOW HISTORY

Much of the earlier work on the glaciation of the Avalon Peninsula suggested that the area was covered by eastward-flowing ice from the main part of the Island (Murray, 1883; Coleman, 1926; MacClintock and Twenhofel, 1940). However, the erosional evidence, mainly derived from striations, suggests that the Avalon Peninsula maintained an independent ice cap during the late Wisconsinan (Chamberlin, 1895; Vhay, 1937; Summers, 1949; Jenness, 1963; Henderson, 1972; Catto, 1998). The main ice centre was speculated to be located near the head of St. Mary's Bay (Henderson, 1972; Catto, 1998), with ice flowing radially into Placentia Bay in the west, southwest down St. Mary's Bay, eastward across the Trepassey sub-peninsula, and northward over the low cols into the Trinity and Conception bays' watersheds (Catto, 1998). Rogen moraines found north of St. Mary's Bay formed during this northward ice flow (Marich *et al.*, 2005). The radial flow from St. Mary's Bay had little effect on outlying sub-peninsulas, such as Carbonear sub-peninsula and St. John's sub-peninsula, (located north of the study area), which likely maintained their own ice caps (Summers, 1949; Catto, 1998); this is supported by the available striations data and the clast provenance of the till (Catto, 1998).

ICE-FLOW MAPPING

The most effective method of delineating ice flow (in the province) is by mapping striations; scratches on a bedrock surface produced by glacial erosion and oriented parallel to ice flow (Batterson and Liverman, 2001). Data from individual striations should be treated with caution because ice-flow patterns can show considerable local variation where ice flow has been deflected by local topography (Liverman and St. Croix, 1989), and regional-flow patterns can only be deduced after examining numerous striated outcrops. The orientation of ice flow can easily be determined from a striation by measuring its azimuth. The determination of any ice-flow direction can be made using many criteria. These include the striation pattern over the outcrop; where areas in the lee of ice flow may not be striated; the presence of such features as 'nail-head' striations and miniature crag-and-tails (rat-tails), and the morphology of the bedrock surface, which may show the effects of sculpting by ice (Iverson, 1991). At many sites, the direction of ice flow is unclear, and only the general orientation of ice flow (*e.g.*, northward or southward) can be deduced. Where striations representing separate flow events are found, the age relationships are based on the crosscutting of striation sets and the preservation of older striations in the lee of the younger striations. Striation data for the province are compiled in a web-accessible database (through the Surficial Geology options of the Interactive Maps at <http://gis.geosurv.gov.nl.ca>; Taylor, 2001). The database currently contains over 11 800 observations. Ice flow is interpreted from striations, and large-scale landforms such as either erosional *r*oches moutonnées features or depositional features such as Rogen moraines. These features were identified from aerial photographs or from Shuttle Radar Topography Mission (SRTM) data; (Batterson and Taylor, 2008) clast provenance also helped confirm glacial source areas.

Ice-flow indicators (mostly striations) are recorded from bedrock outcrops. These new data are supplement to previous measurements recorded in the area. Based on all available evidence, the area was affected by three major phases of ice flow, all of which are tentatively assigned to the late Wisconsinan, based on the fresh unweathered appearance of striations.

PHASE 1

Striation evidence indicates that the earliest ice flow in the study area was radial from a centre near the head of St. Mary's Bay. Ice flow was southward along the axis of St. Mary's Bay and northward toward Conception and Trinity bays (Figure 3).

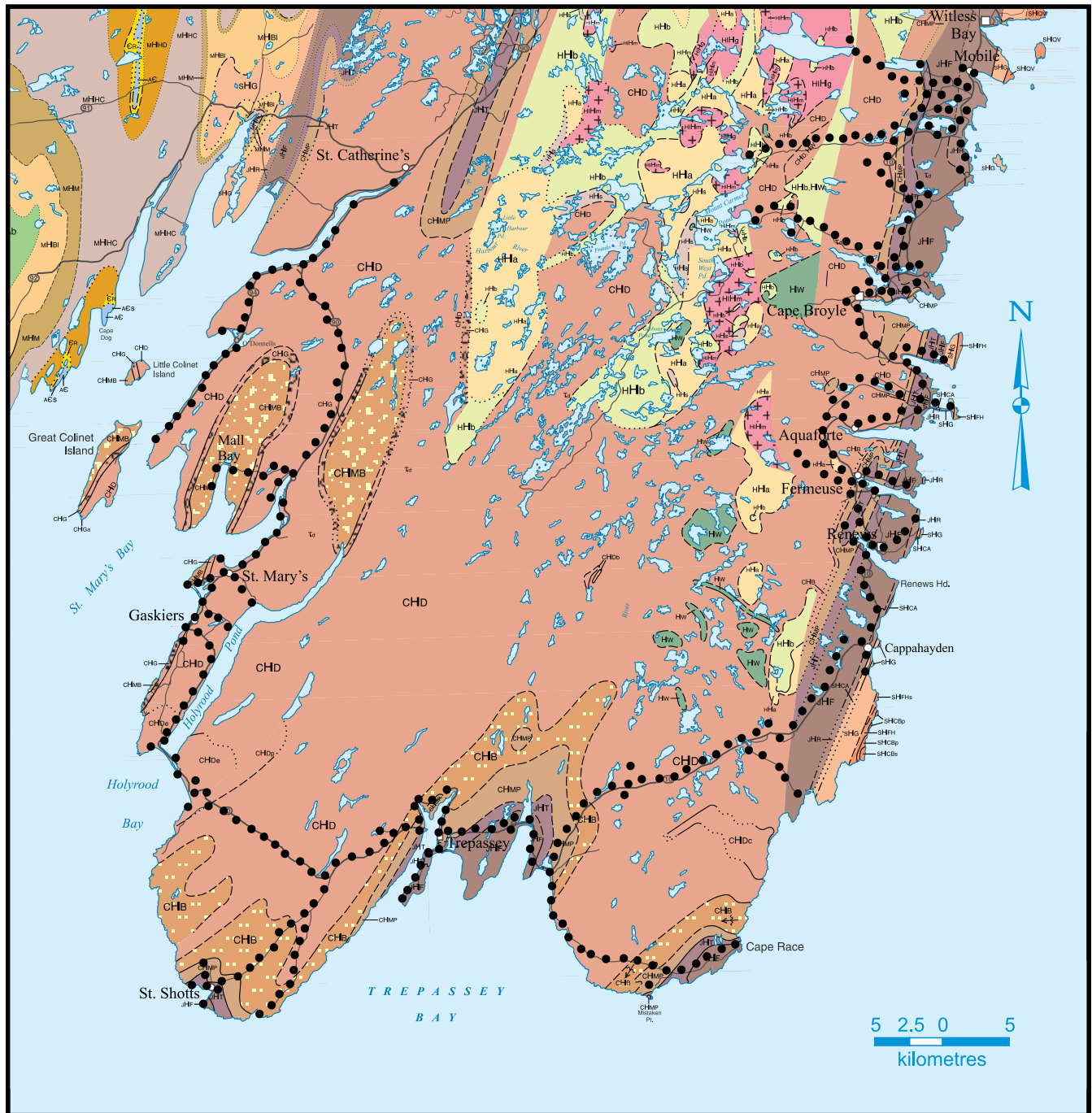


Figure 2. Sample locations on a regional bedrock geology map after King, 1988.

This phase is generally consistent with the reconstruction described by Catto (1998), who identified a southward flow from the White Hearts Pond ice centre north of St. Mary's Bay. Catto also suggests an early eastward flow from Cape St. Mary's sub-peninsula. However, no erosional evidence was found to support this flow, consistent with the findings of Batterson and Taylor (2008).

PHASE 2

The early (phase 1) flow was followed by a later (glacial maximum?) ice flow that shows a consistent radial pattern from a large ice-centre that had migrated and expanded from the head of St. Mary's Bay, to be located over St. Mary's Bay and the highlands north of Trepassey (Figures 1

Legend

ADEYTON GROUP		HADRYNIAN	
AE	Red, pink and green shale or slate and thin limestone beds; basal conglomerate where formation rests directly on Precambrian rocks	JHR	Renews Head Formation: <i>Thin, lenticular bedded, dark-grey sandstone and minor shale</i>
ER	Random Formation: <i>white orthoquartzite interbedded with green, grey and red arkose and siltstone; local basal conglomerate</i>	JHF	Fermeuse Formation: <i>Grey to black shale containing thin lenses of buff-weathering sandstone and siltstone; mainly light-grey, thinly bedded, contorted shale and sandstone near base</i>
HADRYNIAN		JHT	Trepassey Formation: <i>medium to thinly bedded, graded, grey sandstone and shale; minor tuffaceous rocks</i>
MUSGRAVETOWN GROUP (not listed in stratigraphic order)		WHALESBACK GABBRO (and equivalents)	
MHC	Crown Hill Formation: <i>red pebble conglomerate and sandstone; locally, red siltstone at base; minor green conglomerate</i>	Hw	<i>Fine to coarse grained gabbro (age of intrusion uncertain)</i>
MHHD	Heart's Desire Formation: <i>olive-green sandstone</i>	CONCEPTION GROUP	
MHHC	Heart's Content Formation: <i>grey to black shale containing wispy sandstone laminae</i>	CHMP	Mistaken Point Formation (Upper part): <i>red and green tuffaceous siltstone and sandstone</i> (Lower part): <i>medium bedded, grey to pink sandstone and green to purple and red shale; minor thin tuff horizons; fossiliferous near top</i>
MHHCb	Bellevue Beach Member: <i>grey pebble conglomerate</i>	CHB	Briscal Formation: <i>Thickly bedded, coarse grained, grey sandstone, olive to grey argillite, red arkosic sandstone; local units of thinly bedded grey siltstone and shale</i>
MHM	Maturin Ponds Formation: <i>red sandstone and mudstone exhibiting distinctive wavy bedding; minor conglomerate</i>	DROOK FORMATION (not listed in stratigraphic order)	
MHBI	Big Head Formation: <i>wavy bedded, grey to green tuffaceous siltstone and arkose</i>	CHD	<i>Green siliceous siltstone and sandstone; silicified tuff</i>
BULL ARM FORMATION		CHDp	Peter's River Member: <i>grey, coarse grained sandstone</i>
MHBAa	<i>Felsic flows and tuffs, and clastic sedimentary rocks</i>	CHDe	Cape English Member: <i>grey to pale-red, thickly bedded sandstone</i>
MHBAb	<i>Mafic flows; includes minor felsic flows and clastic sedimentary rocks</i>	CHDr	Broad Cove River Member: <i>thickly bedded chert and sandstone</i>
MHBAc	<i>Predominantly crystal and lithic tuffs, commonly reworked</i>	CHG	Gaskiers Formation: <i>Grey mixtite (tillite); red mixtite overlain by red mudstone at top</i>
MHBAp	<i>Mafic to felsic variegated flows, and pyroclastic and clastic sedimentary rocks</i>	CHMB	Mall Bay Formation: <i>Green siliceous siltstone, argillite and tuff; thickly bedded quartzose sandstone</i>
SIGNAL HILL GROUP		HOLYROOD INTRUSIVE SUITE	
SHG	Gibbit Hill Formation: <i>Thickly bedded, light-grey sandstone; locally thinly bedded, greenish-grey to red sandstone, siltstone, tuff and conglomerate</i>	HIHm	<i>Medium grained, pink, green and gray quartz monzonite, and quartz diorite to gabbro</i>
QUIDI VIDI FORMATION		HARBOUR MAIN GROUP (not listed in stratigraphic order)	
SHQV	<i>Red and green sandstone; minor pebble conglomerate and mudstone</i>	HHs	<i>Red sandstone, conglomerate, slate; green tuffaceous siltstone and sandstone; includes minor felsic and mafic volcanic rocks</i>
CAPE BALLARD FORMATION		HHa	<i>Pink to grey felsic tuff and agglomerate; pink to red rhyolite and welded tuff; includes minor mafic volcanic and clastic sedimentary rocks</i>
SHCBs	<i>Thickly bedded gray sandstone and quartz-granule conglomerate</i>	HHb	<i>Green to purple basaltic flows and pyroclastic rocks; includes minor felsic volcanic rocks, clastic sedimentary rocks and gabbro</i>
SHCBp	<i>Gray shale and siltstone, minor purple shale</i>	FERRYLAND HEAD FORMATION	
FERRYLAND HEAD FORMATION		SHFH	<i>Thin to medium bedded, gray sandstone; minor conglomerate</i>
SHFHs	High Rocks Member: <i>red, wavy bedded sandstone and shale</i>	CAPPAHAYDEN FORMATION	
CAPPAHAYDEN FORMATION		SHCA	<i>Laminated gray siltstone</i>

Figure 2. Legend.

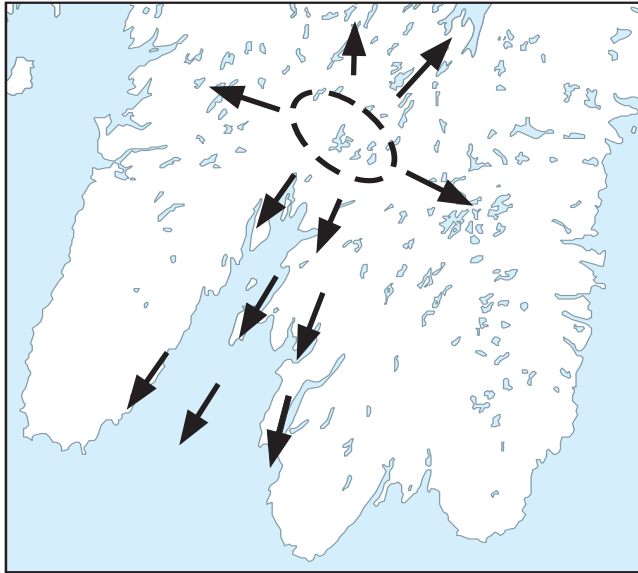


Figure 3. Phase 1. Radial ice flow from centre located near head of St. Mary's Bay.

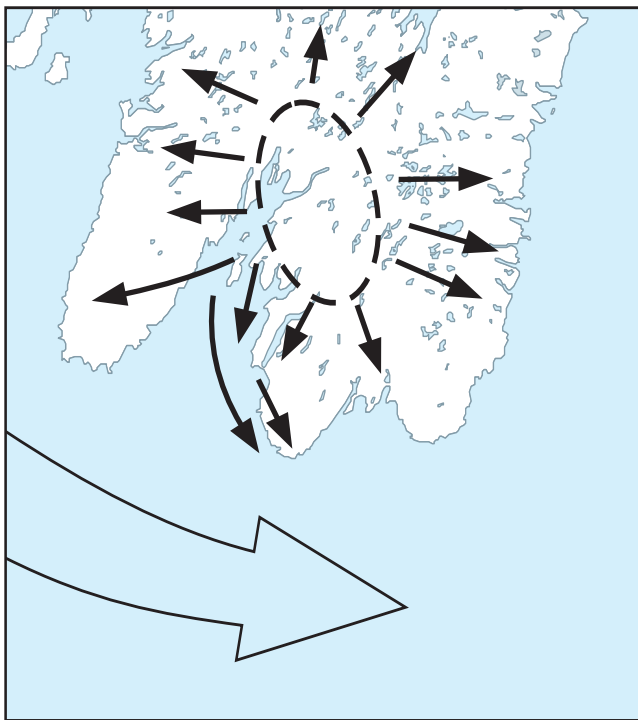


Figure 4. Phase 2 (glacial maximum?). Radial ice-flow pattern from large centre located over St. Mary's Bay and highlands north of Trepassy. Southward flow merged with Laurentide ice flow down the Cabot Strait toward the continental slope.

and 4). Dispersal of tillite clasts onto the west side of St. Mary's Bay from the Gaskiers Formation, which outcrops on the east side of the bay (Figures 1 and 2) and crosscuts the striations, indicate that ice flowed west across St. Mary's

Bay and onto the Cape St. Mary's sub-peninsula. On the Trepassy sub-peninsula, the striation record shows southward flow toward the community of Trepassy and eastward flow across the Trepassy sub-peninsula. Glacially carved valleys at Holyrood Pond, Cape Broyle and Aquaforte are evidence of radial flow from the Trepassy sub-peninsula ice centre. The exception is the tip of the peninsula at St. Shotts, where crosscutting striations indicate a southeastward flow (Figure 4). This southeastward deflection across the peninsula may be explained by the presence of Laurentide ice within the Cabot Strait, originating from the Gulf of St. Lawrence (Shaw *et al.*, 2006). The barrier this created, would have blocked southward-flowing ice along St. Mary's Bay causing it to thicken until it was sufficient to overtop uplands to the east.

This flow pattern is generally consistent with the reconstruction determined by Catto (1998), although it is argued here that the ice centre was located west of that suggested by Catto (*op. cit.*). This slight modification is based on the westward dispersal of tillite clasts, from the Gaskiers Formation near the community of Gaskiers, found on the east side of the Cape St. Mary's sub-peninsula, and the lack of onshore striation evidence supporting eastward ice flow on the Trepassy sub-peninsula.

PHASE 3

During the third phase of flow (deglacial?), the ice centre collapsed and migrated eastward from St. Mary's Bay to the highlands north of Trepassy (Figures 1 and 5). The striation evidence indicates the ice centre remained active and

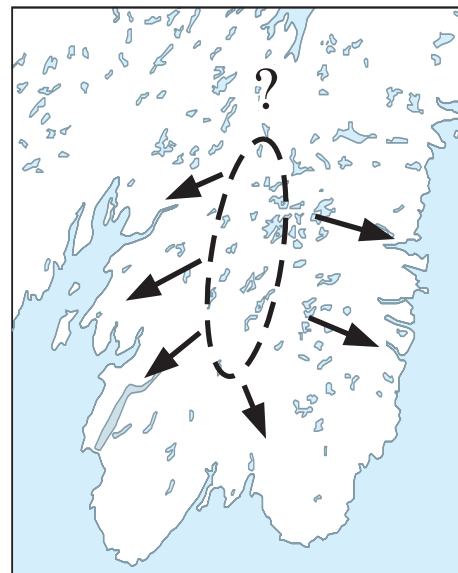


Figure 5. Phase 3 (deglaciation?). The main ice centre migrated eastward from St. Mary's Bay to the highlands north of Trepassy.

Table 1. Elements (and LOI) analyzed by the GSNL and commercial laboratories

Method	Elements Analyzed
Gravimetric analysis	LOI
Inductively-Coupled-Plasma-Emission Spectrometry (ICP-ES)	Ag, Al, Ba, Be, Ca, Ce, Co, Cr, Cu, Dy, Fe, Ga, K, La, Li, Mg, Mn, mo, Na, Nb, Ni, P, Pb, Sc, Sr, Ti, V, Y, Zn, Zr
Instrumental Neutron Activation Analysis (INAA)	As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Na, Nd, Rb, Sb, Sc, Sm, Tb, U, Yb

ice continued to flow radially toward the coast. Crosscutting striations on the western side of the Trepassey sub-peninsula shows evidence of this late westward flow into St. Mary's Bay. Striations along the southern shore highway between Cappahayden and Witless Bay show a consistent east to southeastward flow throughout the late Wisconsinan, exiting glacially carved valleys at Renewes, Aquaforte, and Cape Broyle.

Catto (1998) suggested a similar collapse of the late Wisconsinan maximum ice centre over St. Mary's Bay and identifies several small, remnant ice centres over the Trepassey sub-peninsula. The timing of these ice-flow phases is speculative, as no absolute chronology exists for this area because of the lack of radiocarbon material that can be dated. The exception is an organic lake-sediment sample date, of $10\ 100 \pm 250$ years BP, from Golden Eye Pond on the Hawke Hills. The sample was collected from the base of the postglacial pond, which indicates that the eastern Avalon Peninsula was ice free before about 10 ka (MacPherson, 1996).

REGIONAL TILL SAMPLING

A regional till-sampling program was conducted along the southern shore of the Avalon Peninsula extending from St. Catherine's in St. Mary's Bay along the southern shore highway to the community of Mobile. Glaciofluvial, fluvial, marine and aeolian sediments were excluded as sampling media. Most samples were from the C- or BC-soil horizon, taken from test pits at about 0.5 m depth or from quarries or roadcuts at about 0.5 to 1.0 m in depth. In rare cases, the lack of surface sediment necessitated the sampling of bedrock detritus. Sample spacing was controlled by access along existing roadways, as well as the availability of the appropriate medium. Sample density was about 1 sample per $1\ \text{km}^2$; the samples were sieved in the field through a 5-mm-mesh sieve and approximately 1 kg of sediment was placed in a paper bag.

A total of 373 samples were collected (Figure 2) and submitted to the Geological Survey's geochemical laboratory in St. John's for analysis, either internally by gravimetric

analysis and Inductively Coupled Plasma-Emission Spectrometry (ICP-ES) using an aqua regia digestion, or externally by a commercial laboratory using Instrumental Neutron Activation Analysis (INAA). These methods and the elements analyzed are summarized in Table 1. Data quality is monitored using field and laboratory duplicates (to determine analytical precision), and standard reference materials (to determine analytical accuracy). In all cases, the silt/clay fraction (less than 0.063 mm) is analyzed. Data release is anticipated before the summer of 2009.

ACKNOWLEDGMENTS

The author would like to acknowledge the contribution of the following to this project. Barry Wheaton and Gerry Hickey provided their usual competent logistical support. Dave Leonard prepared the final figures. Martin Batterson and Pauline Honarvar provided a critical review of the manuscript.

REFERENCES

- Batterson, M.J. and Liverman, D.G.E.
2001: The contrasting styles of glacial dispersal in Newfoundland and Labrador: Methods and case studies. Geological Society of London, Special Publication 185, pages 267-285.
- Batterson, M.J. and Taylor, D.M.
2001a: Quaternary geology and till geochemistry of the Bonavista Peninsula. *In* Current Research. Department of Mines and Energy, Newfoundland Geological Survey, Report 01-1, pages 267-278.
- 2001b: Till geochemistry of the Bonavista Peninsula area, Newfoundland. Department of Mines and Energy, Newfoundland Geological Survey, Open File NFDL 2734, 181 pages.
- 2003a: Regional till geochemistry and surficial geology of the western Avalon Peninsula and Isthmus. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 03-1, pages 259-272.

- 2003b: Till geochemistry of the western Avalon Peninsula and Isthmus. Newfoundland Department of Mines and Energy, Geological Survey, Open File NFLD 2824, 169 pages.
- 2004a: Till geochemistry of the central Avalon and Bay de Verde peninsulas, Newfoundland. Newfoundland Department of Natural Resources, Geological Survey, Open File NFLD/2869, 189 pages.
- 2004b: Regional till geochemistry and surficial geology of the central Avalon and Bay de Verde peninsulas. *In* Current Research. Department of Mines and Energy, Newfoundland Geological Survey, Report 2004-1, pages 93-106.
- 2006: Till geochemistry of the northern Burin Peninsula and adjacent areas, Newfoundland. Newfoundland and Labrador Department of Natural Resources. Open File 1M/0573, 145 pages.
- 2007: Till geochemical surveys and preliminary Quaternary mapping of the Burin Peninsula and adjacent areas. *In* Current Research. Newfoundland Department of Natural Resources, Geological Survey, Report 07-1, pages 197-214.
- 2008: Ice-flow history and regional till-geochemistry sampling on the Burin and Avalon peninsulas. *In* Current Research. Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 08-1, pages 13-23.
- Batterson, M.J., Taylor, D.M., Bell, T., Brushett, D. and Shaw, J.
2006: Regional ice-flow mapping, surficial geology and till geochemistry of the northern Burin Peninsula and adjacent Placentia Bay. *In* Current Research. Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 06-1, pages 161-176.
- Batterson, M.J., Taylor, D.M. and Davenport, P.H.
1998: Till geochemistry of the Grand Falls-Mount Peyton area. Newfoundland Department of Mines and Energy, Geological Survey, Open File NFLD/2664.
- Catto, N.R.
1998: The pattern of glaciation on the Avalon Peninsula of Newfoundland. *Géographie physique et Quaternaire*, Volume 52, pages 23-45.
- Chamberlin, T.C.
1895: Notes on the glaciation of Newfoundland. *Bulletin of the Geological Society of America*, Volume 6, page 467.
- Coleman, A.P.
1926: The Pleistocene of Newfoundland. *Journal of Geology*, Volume 34, pages 193-223.
- Henderson, E.P.
1972: Surficial geology of the Avalon Peninsula, Newfoundland. Geological Survey of Canada, Memoir 368, 121 pages.
- Iverson, N.R.
1991: Morphology of glacial striae: Implications for abrasion of glacier beds and fault surfaces. *Geological Society of America Bulletin*, Volume 103, pages 1308-1316.
- Jenness, S.E.
1963: Terra Nova and Bonavista map-areas, Newfoundland (2D E1/2 and 2C). Geological Survey of Canada, Memoir 327, 184 pages.
- King, A.F.
1988: Geology of the Avalon Peninsula, Newfoundland (parts of 1K, 1L, 1M, 1N and 2C). Newfoundland Department of Mines, Mineral Development Division, Map 88-01.
- Liverman, D.G.E. and St. Croix, L.
1989: Quaternary geology of the Baie Verte Peninsula. *In* Current Research. Newfoundland Department of Mines, Geological Survey of Newfoundland, Report 89-1, pages 237-247.
- Liverman, D.G.E., Klassen, R.A., Davenport, P.H. and Honovar, P.
1996: Till geochemistry, Buchans-Roberts Arm Belt (NTS 2E/5, 2E/12, 12A/15, 12A/16, 12H/1 and 12H/8). Newfoundland Department of Mines and Energy, Geological Survey, Open File NFLD/2596.
- Liverman, D., Taylor, D., Sheppard, K. and Dickson, L.
2000: Till geochemistry, Hodges Hill area, central Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey, Open File NFLD/2704, 51 Pages.
- MacClintock, P. and Twenhofel, W.H.
1940: Wisconsin glaciation of Newfoundland. *Bulletin of the Geological Society of America*, Volume 51, pages 1729-1756.

- Marich, A., Bell, T. and Batterson, M.
2005: Morphological and sedimentological analysis of rogen moraine, central Avalon Peninsula, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 05-01, pages 1-14.
- MacPherson, J.B.
1996. Delayed deglaciation by downwasting of the northeast Avalon Peninsula, Newfoundland: An application of the early Postglacial pollen record. *Géographie physique et Quaternaire*, Volume 50, pages 201-220.
- McCuaig, S.
2002: Till geochemistry of the Alexis River region (NTS map areas 13A/10, 14 and 15). Newfoundland Department of Natural Resources, Geological Survey of Newfoundland and Labrador, Open File 013A/0046.

2005: Till geochemistry of the Snegamook Lake area (NTS map areas 13K/3, 6 and 11). Newfoundland Department of Natural Resources, Geological Survey of Newfoundland and Labrador, Open File 013K/0283, 139 pages.
- Murray, A.
1883: Glaciation in Newfoundland. *Proceedings and Transactions of the Royal Society of Canada*, 1, pages 55-76.
- Rose, E.R.
1952: Torbay map-area, Newfoundland. Geological Survey of Canada, Memoir 265, 64 pages.
- Shaw J., Piper D.J.W., Fader G.B., King E.L., Todd B.J., Bell T., Batterson M.J. and Liverman, D.G.E.
2006: A conceptual model of the deglaciation of Atlantic Canada. *Quaternary Science Reviews*, Volume 25, pages 2059-2081.
- Summers, W.F.
1949: Physical geography of the Avalon Peninsula of Newfoundland. M.Sc. thesis, McGill University, Montreal, Quebec.
- Taylor, D.M.
2001: Newfoundland Striation Database. Newfoundland Department of Mines and Energy, Geological Survey Branch, Open File NFLD/2195, version 4.
- Vhay, J.S.
1937: Pyrophyllite deposits of Manuels, Conception Bay. Newfoundland Geological Survey, Bulletin 7.
- Williams, H. and King, A.F.
1979: Trepassey map-area, Newfoundland. Geological Survey of Canada, Memoir 389, 24 pages.

