

ICE-FLOW HISTORY AND REGIONAL TILL-GEOCHEMISTRY SAMPLING ON THE BURIN AND AVALON PENINSULAS

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ABSTRACT

As part of a regional, till-geochemistry survey, till samples were collected from the Burin and Avalon peninsulas. Sampling was at a spacing of 1 sample per 1 km² in areas of good access to 1 sample per 4 km² where helicopter support was required. Regional sampling was completed on the Burin Peninsula and 246 samples were collected on the southern part of the peninsula, bringing the total number of samples collected over the entire Burin Peninsula to over 1900 samples. On the Avalon Peninsula, sampling continued from areas first sampled in 2003. A total of 491 samples were collected over the Cape St. Mary's Peninsula extending south of the Colinet to Placentia road.

On the Cape St. Mary's Peninsula, the earliest recorded ice flow was generally southward along the Placentia Bay and St. Mary's Bay coastlines, from sources north of the study area. This interpretation is supported by the orientation of striations and flutes recorded along the coast of St. Mary's Bay; the striations are southward directed. Southward-flowing ice along the Placentia Bay coastline was either from a source on the Isthmus, the White Hills Pond centre or the main Newfoundland ice flowing into Placentia Bay. The early ice flow was followed by a regionally extensive westward to southwestward ice flow from an ice centre in St. Mary's Bay. This flow was confluent with southward-flowing ice in Placentia Bay. During deglaciation, the Cape St. Mary's Peninsula was one of regional stagnation. Hummocky moraine is common on the peninsula, and eskers and deeply incised meltwater channels are found along the margins of the peninsula.

INTRODUCTION

This report describes the progress of a regional Quaternary mapping and till-geochemistry project that started on the Bonavista Peninsula (Batterson and Taylor, 2001a and b); continued onto the western Avalon Peninsula and Isthmus (Batterson and Taylor, 2003a and b); the central Avalon and Bay de Verde peninsulas (Batterson and Taylor, 2004a and b), and the northern Burin Peninsula (Batterson *et al.*, 2006; Batterson and Taylor, 2006). 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 provided baseline data for environmental geochemistry applications.

BURIN PENINSULA

Sampling in the interior of the southern Burin Peninsula (Plate 1) in 2007 (NTS map areas 1L/13, 1L/14, 1M/3, 1M/4; Figure 1) completes the regional till-geochemistry program for this area. The results of previous surveys were reported by Batterson and Taylor (2006). Field work in 2007



Plate 1. View looking north across Little Dantzig Cove towards the interior of the Burin Peninsula. This part of the area is characterized by thick exposures of Quaternary sediment overlain by extensive bogs.

was helicopter-supported (Plate 2) and produced 246 samples (Figure 2), including field duplicates, providing a total of 1908 samples for the Burin Peninsula and areas north of Fortune Bay.

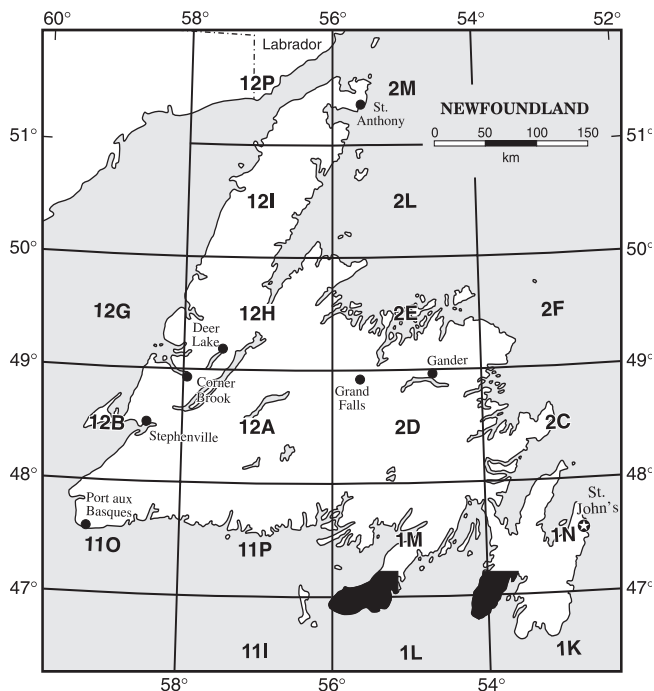


Figure 1. Index map. See Figures 2 and 3 for study areas.

Analyses from the 2006 survey have not been completed in their entirety due to renovations at the Geological Survey's geochemical laboratory in St. John's. However, in response to renewed interest in uranium exploration in the area, the uranium results (derived from analyses at an external laboratory) from the 2006 till-geochemistry survey (Batterson and Taylor, 2007a) have been released as an open file (Batterson and Taylor, 2007b). A total of 303 claims were staked in the week following the release.

AVALON PENINSULA

Sampling on the Avalon Peninsula continued in 2007 (NTS map areas 1K/13, 1L/16, 1M/1, 1N/3, 1N/4; Figure 1) to the south of areas sampled in 2002 (Batterson and Taylor, 2003a,b). A total of 491 samples (duplicates included) were collected on the Cape St. Mary's Peninsula (defined as the area south of the Colinet to Placentia road) by a combination of road traverses and helicopter-supported sampling.

LOCATION, ACCESS AND PHYSIOGRAPHY

The central part of the Cape St. Mary's Peninsula is a broad plateau (Plate 3) reaching elevations of about 275 m asl. The area has a thin sediment cover, extensive areas of thin (<1 m) bog and few bedrock outcrops. There are few large ponds on the peninsula, Great Gull Pond and Skin Cabin Pond being the largest, but there are numerous small ponds dotted throughout the area. Coastal areas show considerable contrast between the western and eastern side,



Plate 2. Helicopter-supported sampling is essential in remote areas of the Province. Tragically, the helicopter shown above belonging to Newfoundland Helicopters crashed near Postville, Labrador in October 2007, killing the pilot.

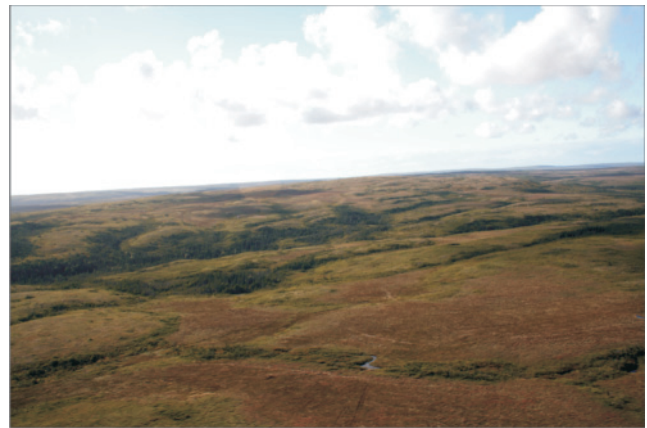
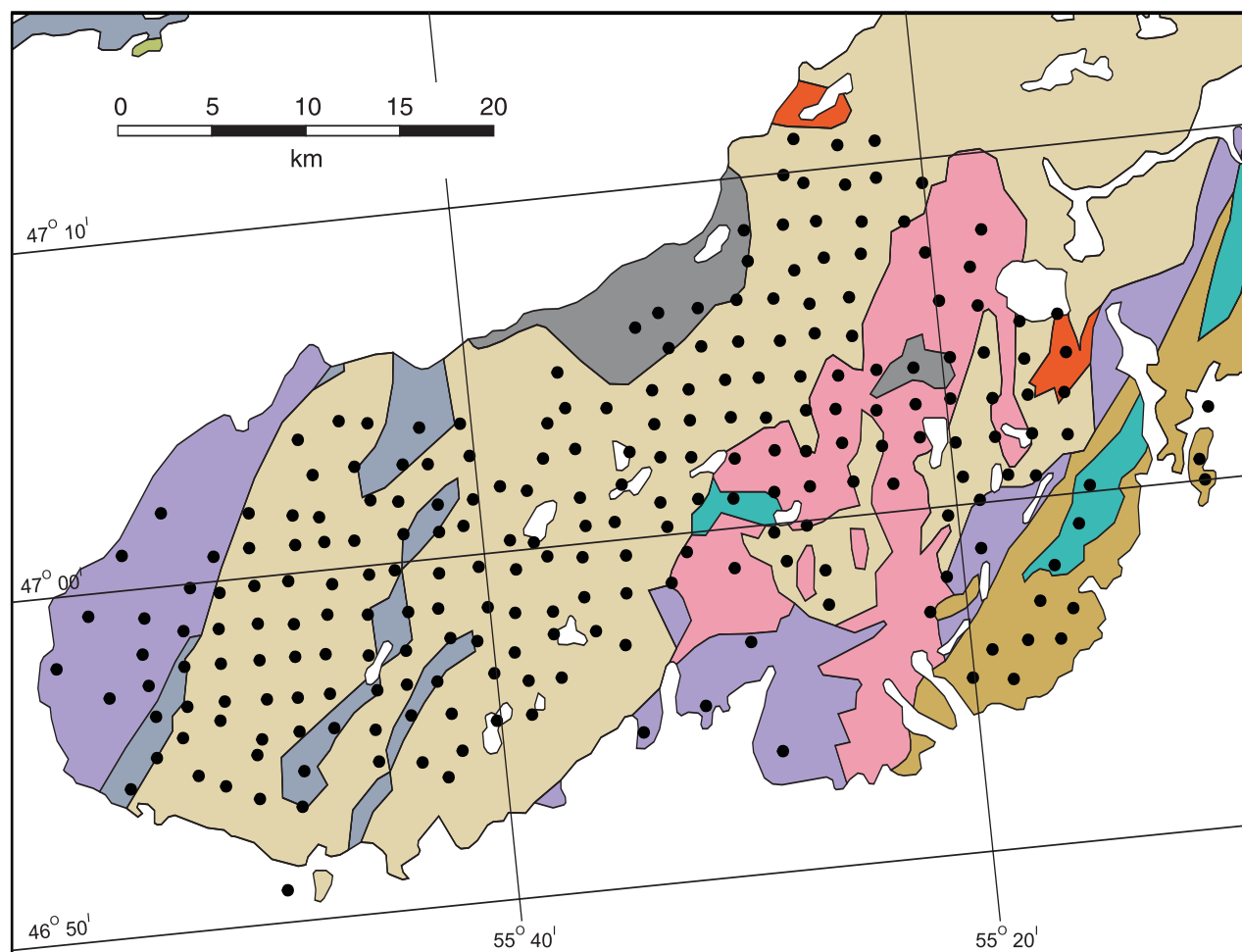


Plate 3. View of the interior of the Cape St. Mary's Peninsula. The area is characterized by extensive areas of bog, dissected till blankets and occasional bedrock outcrop.

partly a reflection of their exposure to the ocean. The Placentia Bay side of the peninsula is characterized by steep bedrock coastal cliffs and deeply incised valleys hosting Little Barachois River and Cuslett Brook, and un-named rivers flowing into Patrick's Cove, Gooseberry Cove, Ship Cove, and Great Barasway. In contrast, the St. Mary's Bay side of the peninsula generally has gentler gradients, and normally graded river valleys.

Access to the margins of the study area is good along a paved road that roughly follows the coast, with side roads to the community of Point Lance and Cape St. Mary's Ecological Reserve. Access into the interior of the peninsula is generally poor, and restricted to ATV trails, most of which are not provincially approved.

**Devonian and Carboniferous**

Non-marine sedimentary and volcanic rocks; latter includes Grand Beach complex, and Rocky Ridge Formation on the Burin Peninsula

Devonian

Granite; includes Ackley granite (buff to pink, coarse-grained biotite granite), Red Island granite (pink, fine- to medium-grained, biotite granite), Bar Haven granite (pink, buff and grey, medium-grained granite), Ragged Islands Intrusive Suite (pink, medium-grained granite) and St. Lawrence granite (pink to red, medium- to fine-grained riebeckite-aegirine granite)

Silurian

Posttectonic gabbro-syenite-granite-peralkaline granite suites and minor unseparated volcanic rocks

DUNNAGE ZONE**Cambrian to Middle Ordovician**

Marine siliclastic submarine rocks, including shale, argillite, sandstone with minor volcanic rocks

Submarine mafic, intermediate and felsic volcanic rocks, including rocks from ophiolite complexes

GANDER ZONE**Cambrian (?) and Ordovician**

Quartzite, psammite, semipelite and pelite, including minor black shale, conglomerate, limestone, mafic and felsic volcanic rocks

AVALON ZONE**INTRUSIVE ROCKS****Neoproterozoic to Cambrian**

Mafic intrusions; includes Cross Hills Intrusive Suite (medium-grained, hornblende-biotite granodiorite and biotite granite, some peralkaline granite), Wandsworth Gabbro (Burin Group) and Grole Intrusive Suite (diorite and gabbro)

STRATIFIED ROCKS**Neoproterozoic to Middle Cambrian**

Shallow-marine, mainly fine-grained, siliclastic sedimentary rocks, including minor unseparated limestone and volcanic rocks; includes Random Formation, Chapel Island Formation

Neoproterozoic

Fluviatile and shallow-marine siliclastic sedimentary rocks, including minor unseparated limestone and bimodal volcanic rocks (Musgravetown Group)

Bimodal, mainly subaerial volcanic rocks, including unseparated siliclastic sedimentary rocks (Long Harbour Group and equivalents; Tickle Point Formation and related rocks of the Connaigre Peninsula)

Sandstone and shale turbidites (Musgravetown Group)

Bimodal, submarine to subaerial volcanic rocks, including minor siliclastic sedimentary rocks (Marystown Group)

Pillow lavas and related mafic volcanic rocks; limestone breccia (Burin Group)

Figure 2. Sample locations on the southern Burin Peninsula overlain on a regional bedrock geology map (modified from Colman-Sadd et al., 1990).

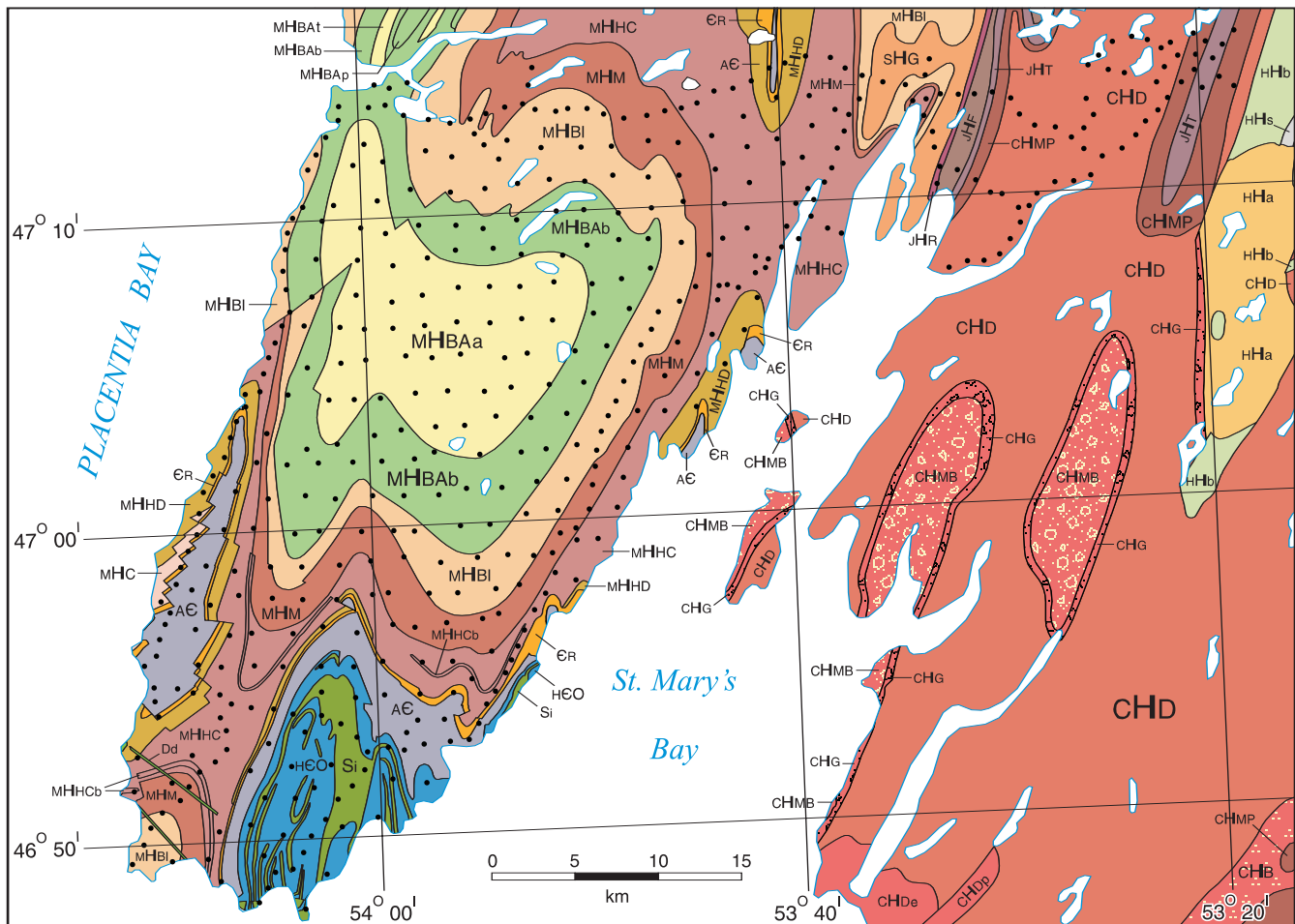


Figure 3. Sample locations on the Cape St. Mary's Peninsula overlain on a regional bedrock geology map (after King, 1988).

BEDROCK GEOLOGY

The study area lies entirely within the Avalon (tectonostratigraphic) Zone. The bedrock consists of Late Precambrian volcanic and sedimentary rocks overlain by Palaeozoic shallow-marine and terrestrial sedimentary and minor volcanic rocks (O'Brien *et al.*, 1983; King, 1988; O'Brien and King, 2002; Fletcher, 2006; Figure 3). Rocks are folded into several anticlines–synclines, including the Cape St. Mary's anticline, which extends along the west side of the peninsula, and the Branch anticline along the east side, separated by the Point Lance syncline (King, 1988).

The oldest rocks in the area are sedimentary and volcanic rocks of the Hadrynian Conception Group (Drook Formation and Mistaken Point Formation), which outcrop in the eastern part of the study area. These are overlain by sediments of the St. John's Group (Fermeuse Formation), and sediments and associated volcanic rocks of the Signal Hill Group (Gibbett Hill Formation). These rocks are roughly equivalent in age to rocks of the Musgravetown Group, which underlie most of the Cape St. Mary's Peninsula. The

base of the Musgravetown Group are felsic to mafic volcanic flows and associated clastic sedimentary rocks of the Bull Arm Formation. These are overlain by sandstone, siltstone, conglomerate and shale of the Maturin Point, Heart's Content, Heart's Desire, Trinny Cove and Crown Hill formations. Exposed along the Placentia Bay and St. Mary's Bay coast and in the southern part of the Placentia subpeninsula, the Musgravetown Group rocks are unconformably overlain by orthoquartzite of the Early Cambrian Random Formation, which, in turn, is unconformably overlain by the Early Cambrian Adeytown Group. This group consists of mostly shale and slate, and limestone of the Smith Point Formation (not seen on Figure 3). The Adeytown Group is overlain by Upper Cambrian Harcourt Group shale and minor siltstone. The Harcourt Group is intruded by Silurian gabbro, diabase and diorite that are well exposed in the southern part of the peninsula.

The Cape St. Mary's Peninsula contains numerous mineral showings, mostly around the coast of Placentia and St. Mary's bays. There are relatively few showings in the interior of the peninsula in similar rock types to those exposed

DEVONIAN/SILURIAN

Dd	<i>Diabase and diorite dykes containing euhedral plagioclase phenocrysts</i>
Si	<i>Diabase, diorite and gabbro sills</i>

MIDDLE CAMBRIAN TO LOWER ORDOVICIAN**HARCOURT GROUP**

HCO	<i>Grey, green to black, silty, micaceous shale, slate and siltstone; limestone concretions</i>
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ADEYTON GROUP

AE	<i>Red, pink and green shale or slate and thin limestone beds; basal conglomerate where formation rests directly on Precambrian rocks</i>
ER	<i>Random Formation: white orthoquartzite interbedded with green, grey and red arkose and siltstone; local basal conglomerate</i>

HADRYNIAN**MUSGRAVETOWN GROUP** (not listed in stratigraphic order)

MHC	<i>Crown Hill Formation: red pebble conglomerate and sandstone; locally, red siltstone at base; minor green conglomerate</i>
MHHD	<i>Heart's Desire Formation: olive-green sandstone</i>
MHHC	<i>Heart's Content Formation: grey to black shale containing wispy sandstone laminae</i>
MHHCb	<i>Bellevue Beach Member: grey pebble conglomerate</i>
MHM	<i>Maturin Ponds Formation: red sandstone and mudstone exhibiting distinctive wavy bedding; minor conglomerate</i>
MHBI	<i>Big Head Formation: wavy bedded, grey to green tuffaceous siltstone and arkose</i>

BULL ARM FORMATION

MHBAA	<i>Felsic flows and tuffs, and clastic sedimentary rocks</i>
MHBAb	<i>Mafic flows; includes minor felsic flows and clastic sedimentary rocks</i>
MHBAt	<i>Predominantly crystal and lithic tuffs, commonly reworked</i>
MHBAP	<i>Mafic to felsic variegated flows, and pyroclastic and clastic sedimentary rocks</i>

SIGNAL HILL GROUP

SHG	<i>Gibbit Hill Formation: Thickly bedded, light-grey sandstone; locally thinly bedded, greenish-grey to red sandstone, siltstone, tuff and conglomerate</i>
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HADRYNIAN**ST. JOHN'S GROUP**

JHR	<i>Renews Head Formation: Thin, lenticular bedded, dark-grey sandstone and minor shale</i>
JHF	<i>Fermeuse Formation: 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>
JHT	<i>Trepassey Formation: medium to thinly bedded, graded, grey sandstone and shale; minor tuffaceous rocks</i>

CONCEPTION GROUP

CHMP	<i>Mistaken Point Formation (Upper part): red and green tuffaceous siltstone and sandstone (Lower part): medium bedded, grey to pink sandstone and green to purple and red shale; minor thin tuff horizons; fossiliferous near top</i>
CHB	<i>Briscal Formation: Thickly bedded, coarse grained, grey sandstone, olive to grey argillite, red arkosic sandstone; local units of thinly bedded grey siltstone and shale</i>

DROOK FORMATION (not listed in stratigraphic order)

CHD	<i>Green siliceous siltstone and sandstone; silicified tuff</i>
CHDP	<i>Peter's River Member: grey, coarse grained sandstone</i>
CHDe	<i>Cape English Member: grey to pale-red, thickly bedded sandstone</i>
CHDr	<i>Broad Cove River Member: thickly bedded chert and sandstone</i>
CHG	<i>Gaskiers Formation: Grey mixtite (tillite); red mixtite overlain by red mudstone at top</i>
CHMB	<i>Mall Bay Formation: Green siliceous siltstone, argillite and tuff; thickly bedded quartzose sandstone</i>

HARBOUR MAIN GROUP (not listed in stratigraphic order)

HHs	<i>Red sandstone, conglomerate, slate; green tuffaceous siltstone and sandstone; includes minor felsic and mafic volcanic rocks</i>
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>
HHb	<i>Green to purple basaltic flows and pyroclastic rocks; includes minor felsic volcanic rocks, clastic sedimentary rocks and gabbro</i>

Legend for Figure 3

along the coast, perhaps being an indication of the lack of mineral exploration in this area. Barium showings are found at Cross Point (near St. Bride's), North Branch Head and Branch, all within rocks of the Adeytown Group; and at Cuslett Cove and Cape St. Mary's within the Musgravetown Group. Rocks of the Musgravetown Group also host several base-metal showings. Copper and lead were found along the river that flows into Point Verde within rocks of the Bull Arm Formation, and a lead showing was identified at Black Point within the Big Head Formation. A short-lived copper

mine existed at Stoney House on Placentia Bay within the Hearts Desire Formation (King, 1988). The mine operated in 1860 and only managed to produce 25 tons of ore before the adit was abandoned (Martin, 1983).

REGIONAL TILL-GEOCHEMISTRY PROGRAM

Sediment sampling was on a rough grid of 1 sample per 1 km² where access was good and a spacing of 1 sample per 4 km² where helicopter support was required (Figure 3).



Plate 4. *Rogen moraine ridges formed by northward-moving ice from the St. Mary's Bay ice centre are common in the Whitbourne area.*

Sampling in parts of the Cape St. Mary's Peninsula, particularly the southern portion, was hampered by thick bog cover. Samples were usually taken of the C- or BC-soil horizon, at a depth of about 0.5 m from hand-dug test pits or 0.5 to 1.0 m in roadcuts, quarries, and natural exposures along coasts or rivers. Sediment matrix samples (~1 kg) were collected in kraft-paper bags and submitted to the Geological Survey laboratory for geochemical analysis, including a suite of elements determined from AA and ICP techniques. Samples will be sent for external analysis for other elements, including gold, by INAA techniques. A total of 439 samples (including duplicates) were collected during this initial phase using a combination of road (truck and ATV) and helicopter-supported sampling. Results from this analyses will be released when they become available.

QUATERNARY HISTORY OVERVIEW

Much of the early 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 (Taylor, 2001), 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 dome was likely at the head of St. Mary's Bay (Henderson, 1972; Catto, 1998), with ice flowing radially into Placentia Bay in the west, southward 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 (Plate 4) formed during this northward ice flow (Marich *et al.*, 2005). The radial flow from St. Mary's Bay had little

effect on outlying peninsulas, which likely maintained their own ice caps (Summers, 1949; Catto, 1998). This is supported by striations and the provenance of clasts in till (Catto, 1998).

Ice flow on the Cape St. Mary's Peninsula was described by Catto (1998) based on the orientation of striations and streamlined glacial landforms. Catto (1998) suggested that the area maintained an ice centre in the northern part of the peninsula, which he termed the 'Castle Ridge' ice centre (Figure 4). Ice flow was radial from this centre, being drawn into Placentia and St. Mary's bays. On the northeastern side of the peninsula southward ice flow was recorded from the 'White Hearts Pond' ice centre (Figure 4). During the late Wisconsinan maximum, the St. Mary's Bay ice centre developed west of Great Colinet Island in central St. Mary's Bay. Ice flow was radial from this centre, directed northwestward in the northern part of the Cape St. Mary's Peninsula and southwestward in the southern part. During deglaciation, the collapse of the St. Mary's Bay ice centre led to the development of a series of smaller remnant ice centres, and large areas of stagnant ice. On the Cape St. Mary's Peninsula, small ice centres existed near Branch in the south from which eastward ice flow was recorded (Catto, 1998), and at Little Salmonier River in the north, where southward flow was recorded (Catto, 1998). The remainder of the area was covered by stagnant ice.

ICE-FLOW PATTERNS

Striation Record

Ice-flow indicators (mostly striations) were recorded from bedrock outcrops. These data supplemented previous measurements in the area, and indicate that the area was affected by two major ice-flow directions, both of which are tentatively assigned a late Wisconsinan age based on their fresh, unweathered appearance. The earliest flow was generally southward along the axis of St. Mary's Bay from a source north of the bay (White Hills Pond ice centre?), and along the east side of Placentia Bay. The source of the Placentia Bay ice is uncertain, but may have been from a source on the Isthmus or from the White Hills Pond ice centre (Catto, 1998). There are few striated bedrock outcrops in the central part of the Cape St. Mary's Peninsula and none were found to confirm the radial flow from the Castle Ridge ice centre. The early ice flow was followed by a regional westward to southwestward ice flow that crossed the entire peninsula into Placentia Bay. This flow pattern is consistent with ice flow from the St. Mary's Bay ice centre (Catto, 1998). The regional ice flow was confluent with southward flowing ice, in Placentia Bay, from the main Newfoundland ice centre (Brushett *et al.*, 2007).

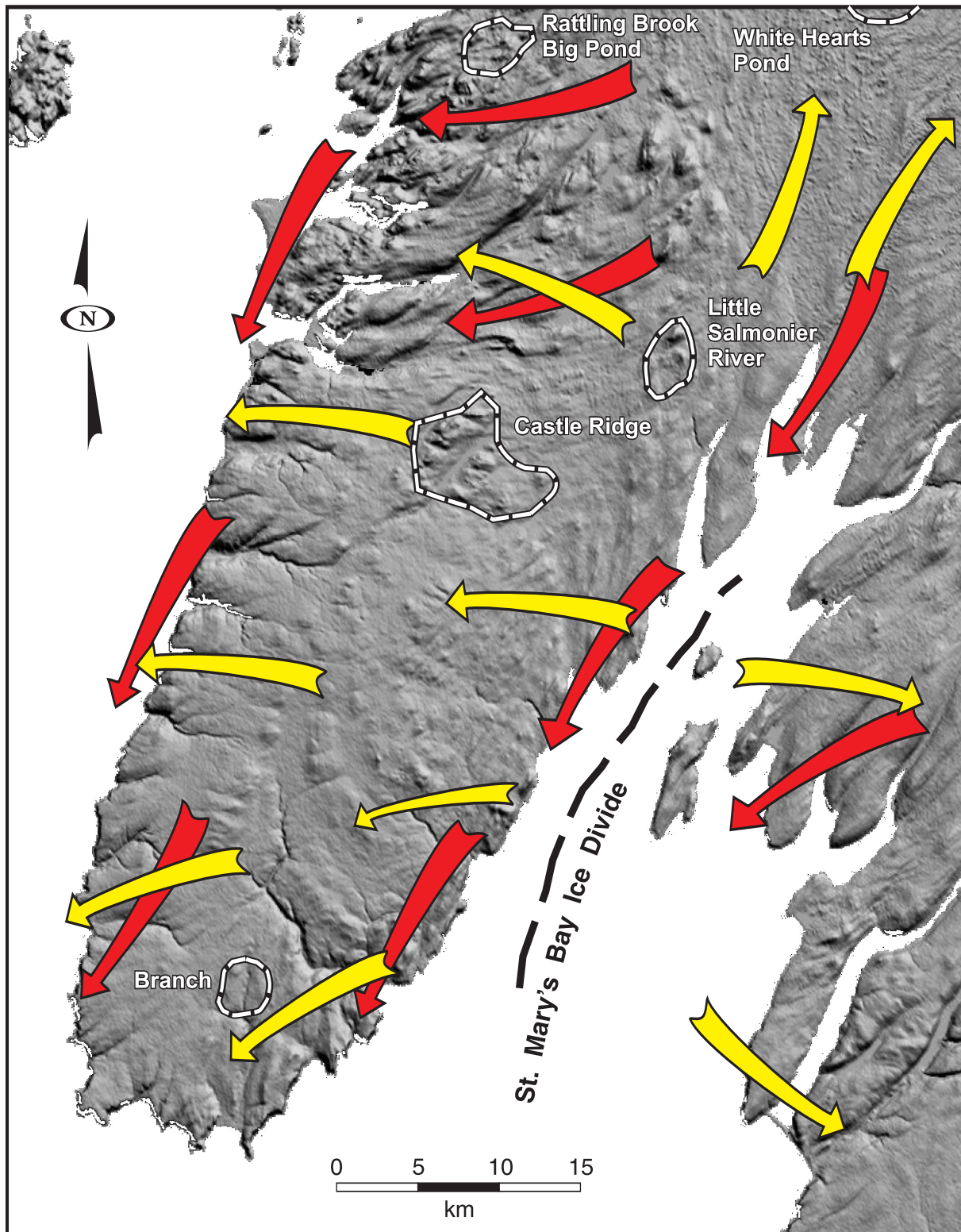


Figure 4. Ice-flow patterns across the Cape St. Mary's Peninsula overlain on the SRTM image. An early southward flow (red arrows) from various sources was crossed by a westward to southwestward flow over most of the peninsula (yellow arrows), from a source in St. Mary's Bay. The SRTM image shows lineated features in the north produced by active ice. Over most of the peninsula drainage channels are pronounced, suggesting that the area was covered by stagnating ice during regional deglaciation. The ice centres interpreted by Catto (1998) are also shown (white dashed line).

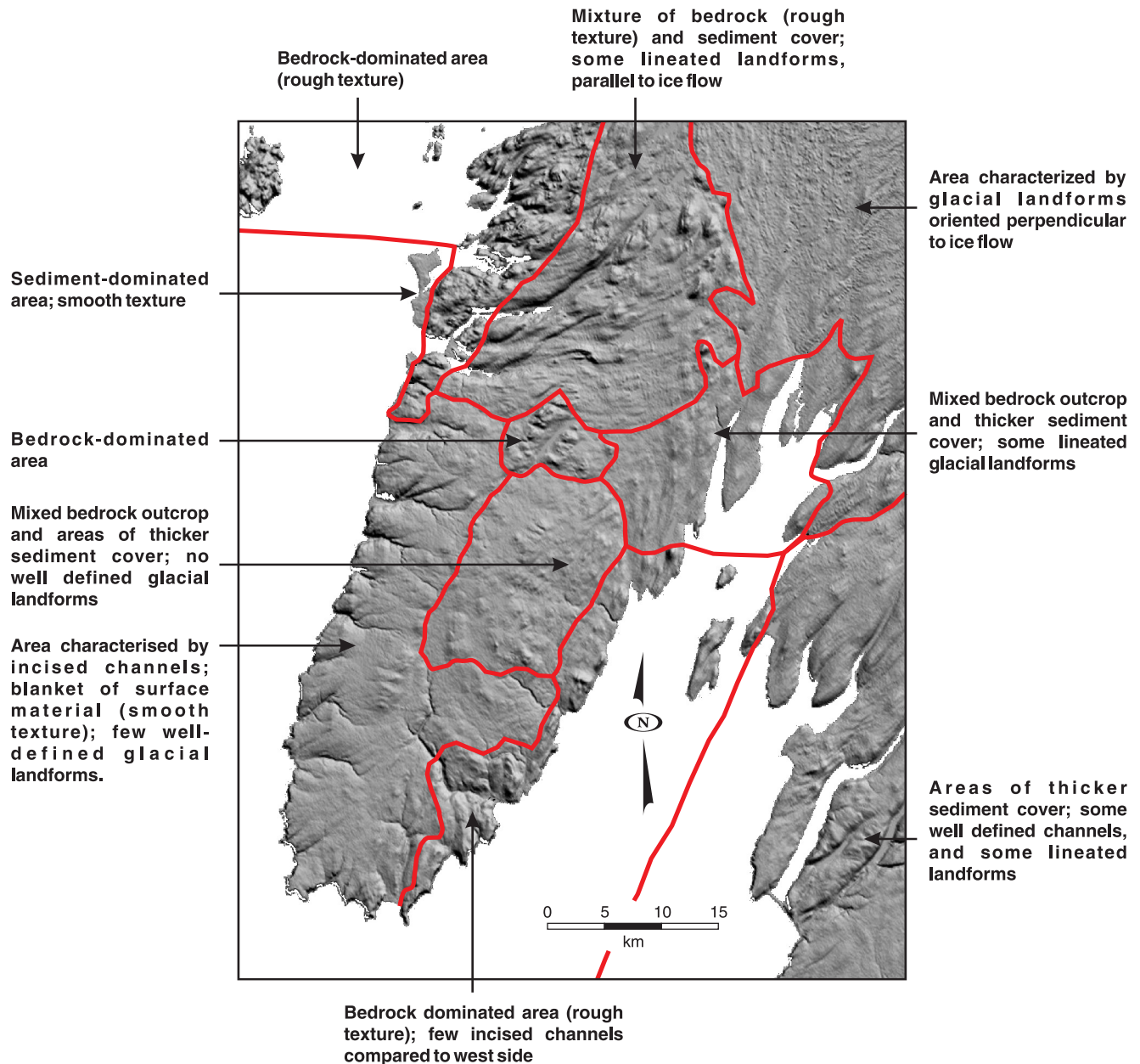


Figure 5. SRTM image of the Cape St. Mary's Peninsula. A preliminary interpretation of the image is provided.

SRTM Image

The SRTM image provides corroborative evidence of the sequence of events just described. In the northern part of the Cape St. Mary's Peninsula, streamlined landforms are consistent with ice movement into Placentia Bay through Southeast Arm, whereas southward ice movement into St. Mary's Bay is also evident (Figure 5). These streamlined features were also interpreted from aerial photographs (Catto and Taylor, 1998a-d). In addition, D. Liverman (personal communication, 2007) interprets small, randomly oriented moraines throughout most of the area from the SRTM image.

Numerous, deeply incised valleys are obvious on the SRTM image. These extend coastward from the interior, and are interpreted as glaciofluvial meltwater channels from waning ice in the centre of the peninsula and are consistent with the interpretation of Catto (1998). The distribution of meltwater channels suggests that stagnant ice occupied the central part of the peninsula south of the Castle Ridge area. The moraine ridges described by D. Liverman (personal communication, 2007) are therefore interpreted as poorly oriented hummocky moraine, consistent with deposition in areas of stagnating ice.

SUMMARY OF QUATERNARY HISTORY

Only an initial preliminary interpretation of the sequence of glacial events can be presented. There is no absolute chronology for the area due to a lack of radiocarbon dateable material, and the glacial stratigraphy that is exposed at places around the Cape St. Mary's Peninsula has not been investigated in detail. In particular, thick exposures of glacial sediment at Branch, near St. Bride's and in Brierly Cove (north of Cape St. Mary's) require further attention.

The earliest recorded ice flow was generally southward along the margins of the Cape St. Mary's Peninsula. The source of ice on the east coast is uncertain, but likely originated from the White Hills Pond ice centre (Catto, 1998) to the north. This interpretation is supported by the orientation of striations and flutes along St. Mary's Bay and southward-directed striations. Southward-flowing ice along the Placentia Bay coastline was either from a source on the Isthmus, the White Hills Pond centre or main Newfoundland ice flowing into Placentia Bay. The extent of southward-flowing ice over the central part of the peninsula is unclear. There are no glacial landforms consistent with this flow direction, and no southward striations were recorded from bedrock outcrops examined. This early flow was followed by a regionally extensive westward to southwestward ice flow from the St. Mary's Bay ice centre, consistent with the reconstruction of Catto (1998). There is landform evidence consistent with westward flow in the northern part of the peninsula, but none elsewhere. The westward ice flow is recorded in the striation record.

During deglaciation, regional stagnation produced the ridges noted by D. Liverman (personal communication, 2007). Meltwater drainage was primarily westward into Placentia Bay, perhaps because St. Mary's Bay was still occupied by ice. During the Holocene a period of paludification produced the extensive bogs characteristic of this area.

ACKNOWLEDGMENTS

The authors acknowledge the contribution of the following to this project. Gerry Hickey provided his usual competent logistical support. Tony Paltanavage prepared the final figures, and Dave Liverman provided a critical review of the manuscript. Ron Whiffen and Universal Helicopters provided the air support for work on the Avalon Peninsula, and Baxter Slade and Newfoundland Helicopters provided helicopter support on the Burin. Tragically, the 206L used in our surveys crashed at Postville in October 2007 killing the pilot, Ken Steele; our sympathies are extended to his family and friends.

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