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REGIONAL TILL GEOCHEMISTRY AND SURFICIAL GEOLOGY OF THE CENTRAL AVALON AND BAY DE VERDE PENINSULAS

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ABSTRACT

A regional till-geochemistry survey was completed in the central Avalon Peninsula, and the northern half of the Bay de Verde Peninsula. In addition, ice-flow indicators were mapped to reconstruct the regional paleo ice-flow history. Till was sampled using a sample density ranging from 1 sample per 1 km^2 in areas of good access to 1 sample per 4 km^2, where helicopter support was required; 985 samples were collected during the survey.

The entire survey area was ice covered during the last, late Wisconsinan glacial period. The survey area is subdivided into two, reflecting the two different sources of ice flow. The central Avalon Peninsula and the southern Bay de Verde Peninsula were covered by generally northward-flowing ice from the main Avalon dispersal centre at the head of St. Mary's Bay. This ice flow produced an extensive Rogen moraine field that extends as far north as Makinsons. The central and northern parts of the Bay de Verde Peninsula maintained an independent ice centre during the late Wisconsinan, likely deflecting St. Mary's Bay ice into Trinity and Conception bays. Dispersal distances over much of the Bay de Verde Peninsula are likely short (less than 5 km).

Areas of glaciofluvial sediment indicate the paths of meltwater during glacial retreat. The effect of regional isostatic rebound was to produce raised marine features around much of the coastline, ranging from about 16 m above modern sea level on the east side of Placentia Bay to about 7 m on the northeast shore of Trinity Bay. Drift-exploration programs in these areas should be conducted with caution to ensure that the appropriate sample media is collected, otherwise the results, while not erroneous could be misleading.

INTRODUCTION

This report describes the progress of an eastern Newfoundland regional mapping and till-geochemistry project that commenced on the Bonavista Peninsula (Batterson and Taylor, 2001a, b) and continued onto the western Avalon Peninsula and Isthmus (Batterson and Taylor, 2003a, b). Similar projects have been completed in the Grand Falls–Mount Peyton (Batterson *et al.*, 1998), Hodges Hill (Liverman *et al.*, 2000), Roberts Arm (Liverman *et al.*, 1996), and in southern Labrador (McCuaig, 2002) areas. Open-file releases of the till-geochemistry data from these projects have been successful in generating exploration activity, e.g., 2357 new claims having a value of $140 520 following the Grand Falls release in 1998, and 1045 new claims having a value of $62 300 following the Bonavista Peninsula release in 2001.

These projects combine surficial mapping (a combination of aerial photograph analysis and field verification), paleo ice-flow mapping and sampling of till to be analyzed for geochemistry. The latter two components are complete for this project, although further surficial geology mapping is required. Field work in 2003 completed coverage on the Bay de Verde Peninsula and extended sampling into the central Avalon Peninsula. The emphasis of 2003 field program was on sampling for till geochemistry. Surficial mapping will be a focus of subsequent field seasons, and thus descriptions of the surficial geology in this report relies heavily on that of Batterson and Taylor (2003a).

LOCATION AND ACCESS

The Avalon Peninsula of Newfoundland is located in the eastern part of the province, comprising an area of about 9700 km^2, and contains a population of about 300 000 (over 60 percent of the total population of the province). The Avalon Peninsula is connected to the rest of the island by an Isthmus that is only 6.3 km across at its narrowest point.

This project covered all, or parts of, six 1:50 000 NTS map sheets extending from the central Avalon Peninsula,

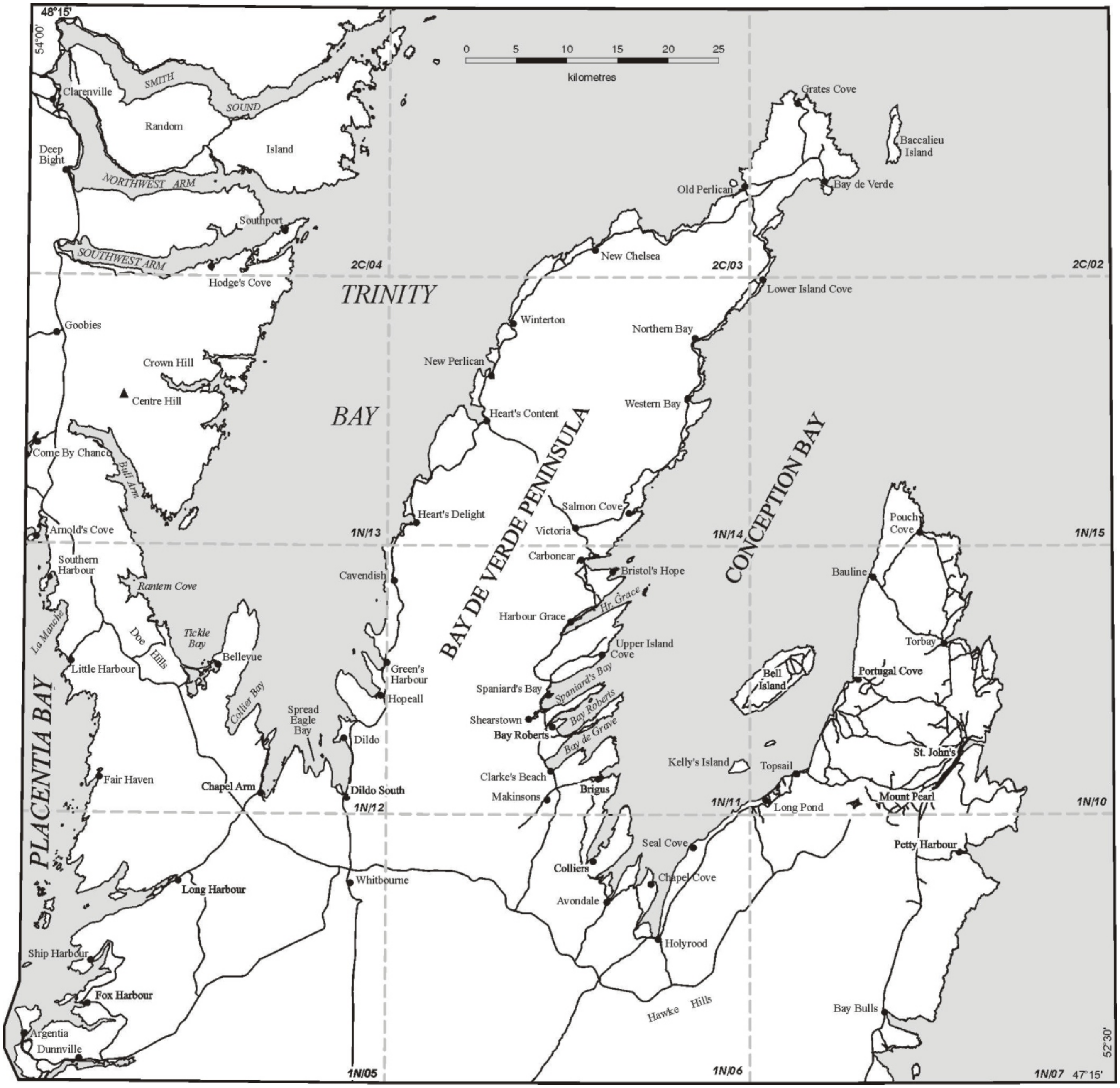

Figure 1. *Location of study area, and places mentioned in text.*

northward along the Bay de Verde Peninsula, completing the till sampling started in 2002. Map areas completed were NTS 1N/5 (Argentia), 1N/6 (Holyrood), 1N/11 (Harbour Grace), 1N/14 (Heart's Content), 2C/2 (Bay de Verde) and 2C/3 (Old Perlican) (Figure 1).

Access to the area was generally good via a network of paved and gravel roads. The decommissioned Newfoundland railway track also provided access to some areas on the Bay de Verde Peninsula. Parts of the study area, however, were only accessible via helicopter. These included parts of the Bay de Verde Peninsula, the northern part of the Avalon Wilderness area, and small areas in the central Avalon Peninsula.

Much of the study area has subdued relief (Figure 2). The highest peaks are over the Heart's Content barrens, rising to 301 m asl. This is in contrast to the study area south of the Trans-Canada Highway, which is generally less than 100 m asl.

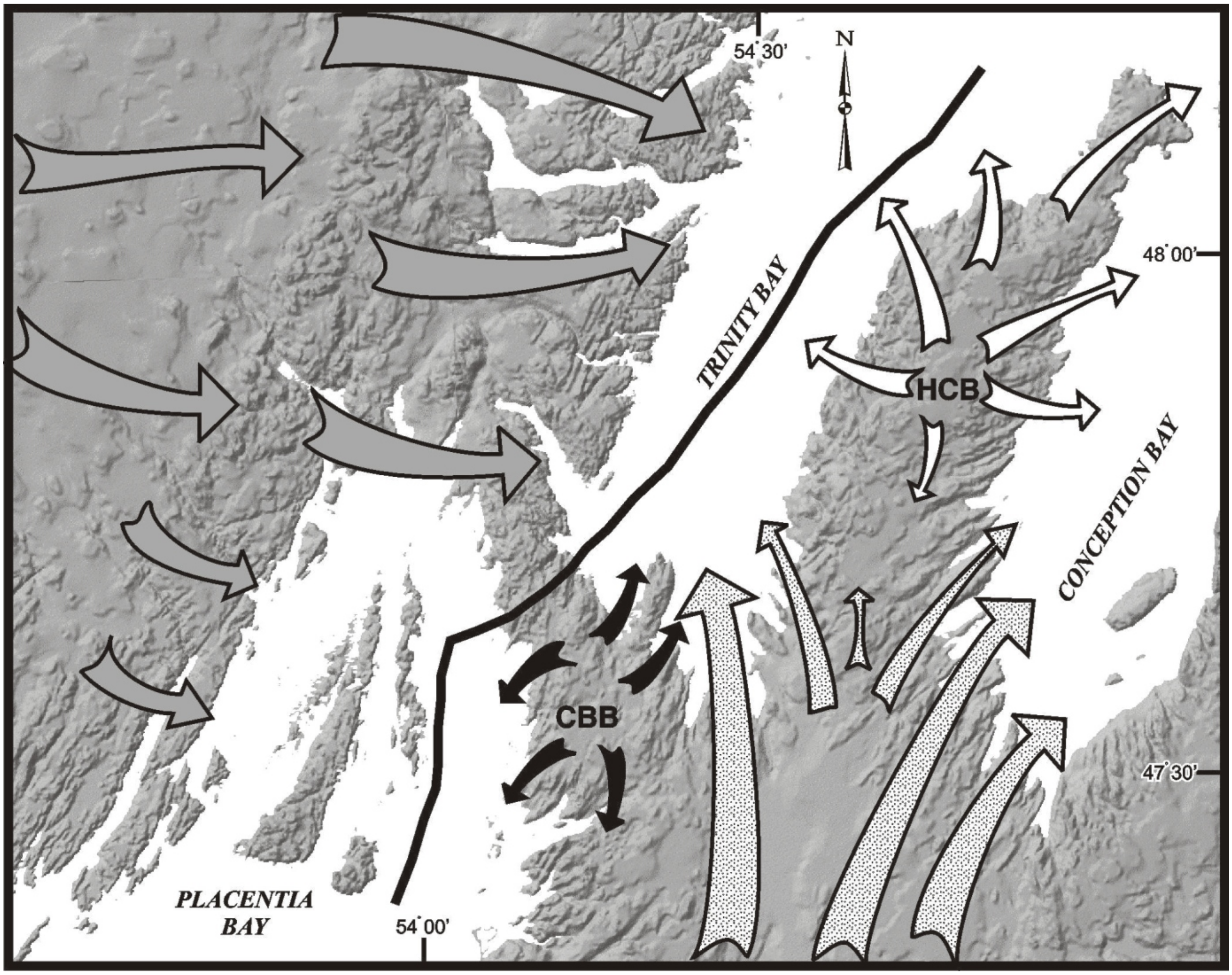

Figure 2. *Shaded relief map and patterns of ice flow at the late Wisconsinan maximum (modified from Catto, 1998). The western part of the Avalon Peninsula was covered by ice from the main Newfoundland ice dispersal centre (grey arrows), likely on Middle Ridge. In contrast, the Avalon Peninsula was covered by radially flowing ice from a number of small dispersal centres located on the spine of the peninsulas. In the study area, ice flow was from dispersal centres at the head of St. Mary's Bay (stippled arrows), and Heart's Content barrens (HCB). (CBB=Collier Bay Brook ice centre).*

BEDROCK GEOLOGY AND MINERAL POTENTIAL

The study area lies entirely within the Avalon tectonostratigraphic zone (Colman-Sadd *et al*., 1990). The bedrock consists of late Precambrian igneous and sedimentary rocks overlain by Paleozoic shallow-marine and terrestrial sedimentary and minor volcanic rocks (O'Brien *et al*., 1983; King, 1988; O'Brien and King, 2002; Figure 3).

The oldest rocks in the area are Hadrynian volcanic and igneous rocks of the Harbour Main Group and Holyrood Intrusive Suite, which crop out in the eastern part of the study area. Rocks of the Harbour Main Group consist of felsic volcanic, rhyolite, and basaltic flows, and pyroclastic rocks. They are intruded by the Holyrood Horst, a 620-Ma intrusion (Krogh *et al*., 1983) that is mostly composed of medium-grained, massive, pink to grey granite, and lesser amounts of quartz monzonite. Hadrynian sedimentary sequences of shallow-marine to fluvial rocks underlie most of the remainder of the study area. The oldest of these are shallow-marine platformal rocks of the Conception Group found on the western shore of Conception Bay, which are overlain by deltaic sedimentary rocks of the St. John's Group. The Connecting Point Group consists of early Hadrynian shallow-marine sediments of similar age to the Signal Hill and Conception groups and is found in the west of the study area. These are overlain by fluvial sediments of the Signal Hill Group in the east, and the Musgravetown

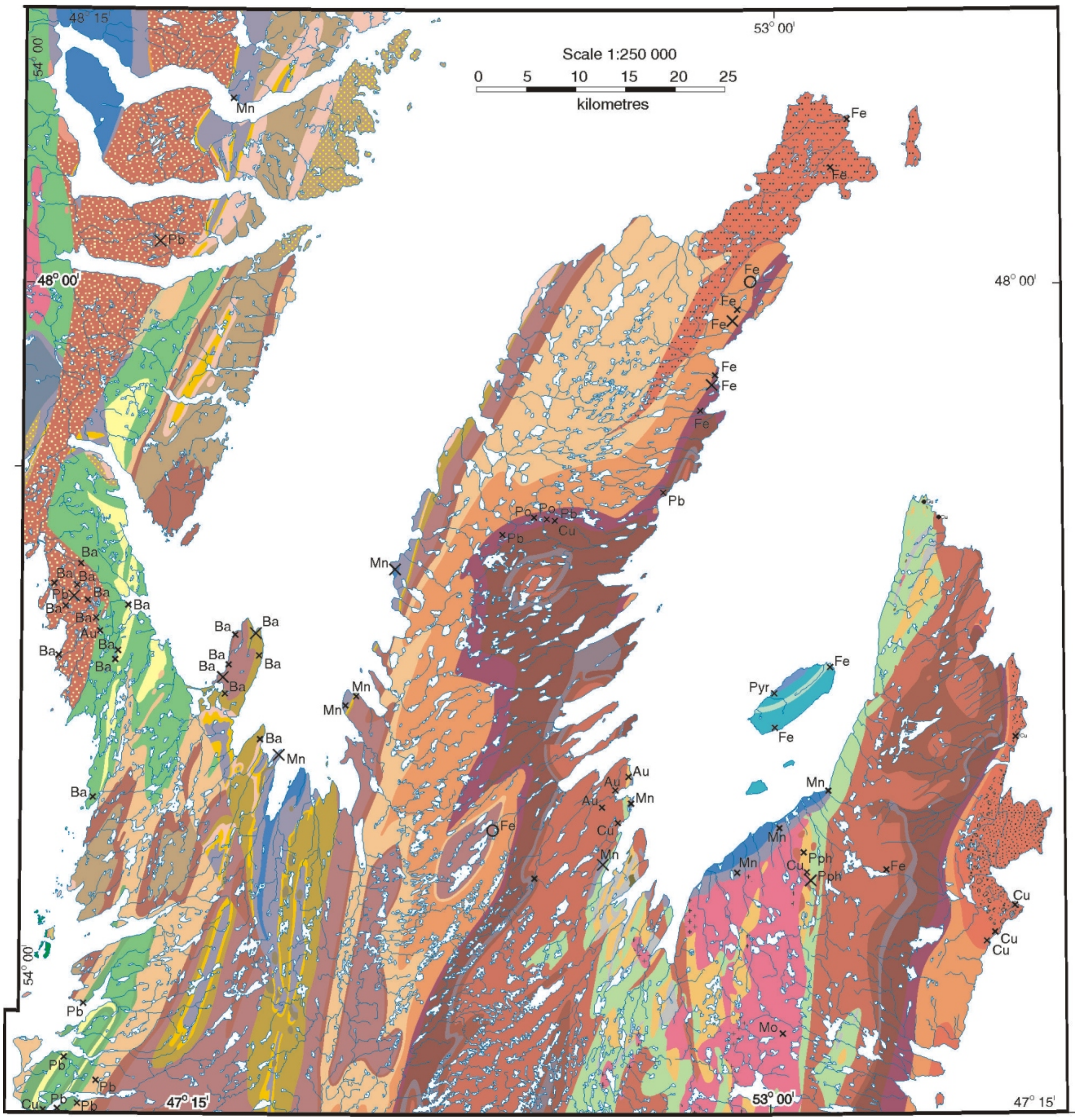

Figure 3. *Bedrock geology of the study area (after King, 1988).*

Group in the west. The Musgravetown Group contains felsic and mafic volcanic flows and tuffs found within the Bull Arm Formation, which is also intruded by the Hadrynian pink to grey, medium-grained Swift Current granite.

Much of the remainder of the Avalon Peninsula and Isthmus is underlain by areas of younger rocks, the largest of which are shale and limestone of the Early Cambrian to Middle Ordovician Adeytown Group. These rocks are found along the eastern shores of Trinity and Conception bays where they unconformably overlie rocks of the Holyrood horst. Adeytown Group rocks are stratigraphically overlain by dark shale and quartzose sandstone of the Kellys Island Formation of the Bell Island Group, and these represent the youngest rocks within the study area.

The Avalon Peninsula has a long history of mining. The abandoned lead mine in Conception Group rocks at LaManche, on the shore of Placentia Bay (Figure 1), is one of the oldest mines in Newfoundland, operating from 1855

LEGEND (Figure 3)

DEVONIAN OR EARLIER

CLARENVILLE GRANITE: *Pink to red, medium grained biotite granite*

POWDER HORN INTRUSIVE SUITE: *Fine to medium grained diorite, gabbro and minor granite*

LOWER CAMBRIAN

HARCOURT GROUP: Grey to black, micaceous shale; minor siltstone and limestone

ADEYTOWN GROUP: Green and red shale and slate; thin limestone beds

HADRYNIAN

MUSGRAVETOWN GROUP

Undivided sedimentary rocks

CROWN HILL FORMATION: Red pebble conglomerate and sandstone

TRINNY COVE FORMATION: Olive-green and red sandstone, siltstone and conglomerate

HEART'S DESIRE FORMATION: Olive-green sandstone

HEART'S CONTENT FORMATION: Grey to black shale; contains beds of wispy sandstone

BULL ARM FORMATION:

Mafic to felsic variegated flows, and pyroclastic and sedimentary rocks

Felsic flows and tuffs, and clastic sedimentary rocks

BIG HEAD FORMATION: Wavy bedded, grey to green tuffaceous siltstone and arkose

SWIFT CURRENT GRANITE: Pink to grey, medium grained granite to granodiorite

SIGNAL HILL GROUP

BAY DE VERDE FORMATION: Red and grey, white-weathering sandstone, siltstone and red mudstone

GIBBET HILL FORMATION: Thickly bedded, light grey sandstone; minor sandstone, siltstone and tuff

ST. JOHN'S GROUP

RENEWS HEAD FORMATION: Thin, lenticular bedded, dark grey sandstone and minor shale

FERMEUSE FORMATION: Grey to black shale, with lenses of buff-weathering sandstone and siltstone

TREPASSEY FORMATION: Medium to thinly bedded, grey sandstone and shale; minor tuff

CONNECTING POINT GROUP

Green, grey and black shale, siliceous siltstone and sandstone; minor conglomerate; numerous mafic dykes and sills

CONCEPTION GROUP

DROOK FORMATION: Green siliceous siltstone and sandstone; silicified tuff

MISTAKEN POINT FORMATION: Red and green tuffaceous siltstone and sandstone in upper; sandstone and shale, with minor tuff and fossiliferous near top in lower part.

HARBOUR MAIN GROUP

Green to purple basaltic flows and pyroclastic rocks

Pink to grey felsic tuff and agglomerate

Past Producing Mine

Mineral Showing

Element List

Au	Gold
Ba	Barium
Cu	Copper
Mn	Manganese
Pb	Lead

to late 1878 (Martin, 1983). In 1856, the Turk's Head and English Ridge copper deposits were discovered near Marysvale, and mined briefly until 1860. The Silver Cliff lead mine near Argentia operated sporadically between 1883 and 1887, with other ill-fated attempts continuing until 1925. More recently, the open-pit mine at Collier Point (Figure 1) extracted barite for the offshore oil industry. Other mineral occurrences include several manganese showings within the Adeytown Group, pyrrhotite found within St. John's Group rocks in the central Bay de Verde Peninsula; and copper exposed on the Heart's Content barrens within the St. John's Group. Recent exploration efforts have focussed on the potential for sediment-hosted or volcanic redbed copper deposits within the Musgravetown Group (O'Brien and King, 2002). Cornerstone Resources Limited discovered copper mineralization within the Crown Hill Formation on the northern Bonavista Peninsula, and in volcanic rocks of the Bull Arm Formation. This has prompted exploration activity on the Isthmus and Avalon Peninsula, in areas underlain by Crown Hill and Bull Arm formation rocks. Small copper and gold showings are known near Triangle Pond in an area underlain by volcanic rocks of the Harbour Main Group.

ICE-FLOW HISTORY

PREVIOUS WORK

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), although MacClintock and Twenhofel (*op. cit.*) argued that the Avalon Peninsula maintained an independent ice cap during deglaciation. There is speculative evidence of ice invading from the west, mostly based on clast provenance, e.g., Summers (1949) notes the presence of serpentinite clasts near St. John's. This may be derived from west of the Avalon Peninsula, although D. Bragg (personal communication, 1999) reported serpentinite-rich veins in the Cochrane Pond area. There is no erosional evidence (e.g., striations) for ice invasion from the west.

The erosional data available to date suggest that the Avalon Peninsula maintained an independent ice cap during the late Wisconsinan. Chamberlin (1895) was the first to suggest this and subsequently the idea has been well accepted (e.g., 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 the ice flowing radially, although preferentially over the low cols to the north and northwest into the Trinity and Conception bay watersheds. Rogen moraines found south of Whitbourne formed during this northward flow. 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 conclusion is supported by the striation data collected and the provenance of clasts found in till.

ICE-FLOW MAPPING

The most successful method used for delineating ice flow in Newfoundland and Labrador is by mapping striations (Batterson and Liverman, 2001). Striations are excellent indicators of ice flow because they are formed by the direct action of moving ice on bedrock. Nevertheless, data derived from individual striations should be treated with care, as ice-flow patterns can show considerable local variation where ice flow was deflected by local topography (Liverman and St. Croix, 1989). Regional flow patterns can only be determined after examining numerous striated outcrops. The orientation of ice flow can be discerned from a striation by measuring its azimuth. Determination of the direction of flow can be made by observing the striation pattern over the outcrop; where areas in the lee of ice flow may not be striated; by the presence of such features as “nail-head” striations, and miniature crag and tails (rat-tails), and by the morphology of the bedrock surface, which may show the effects of sculpturing by ice (Iverson, 1991). At many sites, the direction of ice flow is unclear, and only the orientation of ice flow (e.g., north or south) can be deduced. Where striations representing separate flow events are found, the age relationships are based on crosscutting of striation sets, and preservation of older striations in the lee of younger striations.

Striation data for Newfoundland and Labrador are compiled in a web-accessible database (Taylor, 2001), which currently contains over 10 700 observations. Ice flow is interpreted from striations, with additional data from large-scale landforms; either erosional rôche moutonée features or depositional features such as Rogen moraines. Clast provenance also helped confirm glacial source areas.

RESULTS

Paleo ice-flow history was determined from 716 striation observations from across the study area, of which 16 were collected during this project. Striations were fresh, and unweathered. Where two or more sets of striations were found at a site, the older striations showed no evidence (e.g., iron staining) of survival through a non-glacial period. Therefore, all striations were considered to have been produced during the late Wisconsinan period. The present data are summarized on Figure 2, and are interpreted to generally conform with the detailed ice reconstruction of Catto (1998).

Within the study area, the striation patterns and the presence of clasts derived from local bedrock suggest that the ice flowed from two separate sources covered the study area during the late Wisconsinan. 1) The southern parts of the Bay de Verde Peninsula, Trinity Bay and Conception Bay were covered by northward-flowing ice from the main Avalon ice centre at the head of St. Mary’s Bay. 2) The Bay de Verde Peninsula maintained its own ice cap, centred on the barrens to the east of Heart’s Content (Catto, 1998), and from which ice flow was radial. Within this area, clasts found in till are consistently locally derived. On the Bay de Verde Peninsula, topography had a profound influence on the ice-flow patterns, in particular the configuration of bays and inlets. Ice-flow indicators are consistently oriented parallel with major, bedrock-controlled embayments, e.g., Harbour Grace, Bay Roberts, Bay de Grave.

SURFICIAL GEOLOGY

The surficial geology of much of the study area was mapped by Catto and Taylor (1998a-d). These maps will be revised based on field work from this study and descriptions of sections of Quaternary exposures will be completed in subsequent years. The following discussion is mostly based on the work of Catto and Taylor (*op. cit.*), supplemented by recent observations.

The surficial geology of the study area is summarized in Figure 4. It is subdivided into 5 main categories; bedrock, till, glaciofluvial, raised marine and Holocene sediments.

BEDROCK

Bedrock outcrop is found over much of the study area, although large expanses of bedrock-dominated terrain are restricted to the northern parts of the Bay de Verde Peninsula, and the west side of Conception Bay. Bedrock exposed at the surface is commonly streamlined. However, within the Rogen moraine field that covers the lowland of the central Avalon Peninsula, bedrock outcrop is rare.

TILL

Till of varying thickness and composition is by far the most extensive surficial cover on the Avalon Peninsula. It commonly occurs as a veneer over bedrock (particularly on the Bay de Verde Peninsula; Plate 1), interspersed with bedrock outcrop. Examination of the tills show that they exhibit consistent characteristics over a wide area. On the Bay de Verde Peninsula, tills are commonly poorly consolidated, very poorly sorted to unsorted and have a silty sand matrix. Clast content varies from 30 to 60 percent by volume, and the clasts are derived mainly locally from the underlying bedrock. Fine-grained rocks are commonly striated. Exotic clasts were rare or absent. In contrast, till exposed on the east side of Conception Bay has a sandy matrix and is dominated by granite clasts from the Holyrood horst (Plate 2). Till that forms the Rogen moraine has not been examined in detail. Brief observations show they commonly are structureless, matrix-supported sediments having a silty sand matrix and 40 to 60 percent clast content (by volume) and the clasts being subangular and of local provenance (*see* Catto, 1998).

Till mostly forms either a veneer or blanket over bedrock, rather than any constructional features. The exception is the southern part of the Bay de Verde Peninsula and the central Avalon lowland that contains part of the central Avalon Rogen moraine field (Plate 3). The moraines are commonly crescent-shaped, and curved in the direction of glacial movement, which was northward from the St. Mary's Bay ice-dispersal centre. The Rogen moraines are up to 30 m high, and are spaced 200 to 400 m apart. They are mostly till, although some sorted sand and gravel are present and are commonly found adjacent to small ponds. The mode of formation of these features has been the subject of substantive debate. Lundqvist (1969) argues for squeezing of sediment into subglacial cavities; Boulton (1987) suggests complete deformation of subglacial sediment; a melt-out hypothesis is favoured by Bouchard (1989) and Aylsworth and Shilts (1989); and formation by subglacial meltwater is proposed by Fisher and Shaw (1992), based on their work on the Avalon moraines.

GLACIOFLUVIAL

Small areas of glaciofluvial sand and gravel are exposed on the southern part of the Bay de Verde Peninsula, all of which are currently being exploited for granular-aggregate production. Both ice-contact (at Makinsons) and ice-distal (near Shearstown) glaciofluvial deposits were briefly described by Batterson and Taylor (2003a). Extensive proglacial glaciofluvial sand and gravel are also exposed along the Northeast River, east of Dunville. Several eskers have been identified by Ricketts (2002) between Sparrows Pond and Fitzgerald Pond.

RAISED MARINE SEDIMENTS

The paleo sea-level history of the Avalon Peninsula is poorly understood. Grant (1987) suggested that the 0 m isopleth crosses the Avalon Peninsula approximately between Long Harbour and Chapel Arm, extending northward along the western shore of the Bay de Verde Peninsula. The area to the west of this line therefore has a Type B (Quinlan and Beaumont, 1981) paleo sea-level history having a period of raised sea level following deglaciation and a subsequent fall to a lowstand position from which sea level has gradually recovered to the present. To the east, the paleo sea-level history is characterized as being always below modern levels and no raised marine features occurring anywhere. However, this hypothesis was challenged by Catto and Taylor (1998a-d) who mapped raised marine sediments in the Argentia area and at the head of St. Mary's Bay. Catto *et al.* (2000) argue for recent sea-level rise on the west side of Conception Bay at rates on 2 to 3 mm/a, based on dated tree stumps from the harbour at Port de Grave.

Within the study area, raised marine deposits were found along the shore of Placentia Bay and on the Bay de Verde Peninsula. In Placentia Bay, a raised beach having a surface elevation of 13 m asl was noted at Southern Harbour, and a raised marine platform (~10 m asl) formed part of the now-abandoned US Airforce base at Argentia. On Bonavista Bay, raised marine terraces were noted at Heart's Delight (11 to 12 m asl) and Heart's Content (9 m asl), and a delta was noted at New Chelsea (~7 m asl). The age of these surfaces remains speculative, as no marine shells were found within Quaternary deposits in the study area.

HOLOCENE SEDIMENTS

Holocene sediments include fluvial sand, gravel and silt (alluvium) found adjacent to modern streams, colluvium at the base of steep hills, modern marine deposits such as beaches and tidal flats, and aeolian deposits. These sediment types are found in small areas across the study area. The most extensive modern fluvial deposits are found in the Northwest River valley that flows into Northwest Arm, east of Placentia. Fluvial sediments in this area are likely reworked glaciofluvial sediments. Other thin veneers of alluvium were identified by Catto and Taylor (1998a-d), including those along the Salmon Cove River, Spout Cove Brook (Plate 4) and Western Bay Brook valleys draining into Conception Bay, and the Great Brook and New Perlican River valleys draining into Trinity Bay. Many other small, unnamed stream valleys also contain thin fluvial deposits over bedrock.

Colluvium is found at the base of steep hills, particularly on the western side of the Bay de Verde Peninsula, north of Heart's Content, and between Spaniard's Bay and Carbonear on the east side of the peninsula. Several of these areas have formed at the base of active slopes within communities, including that at Bay de Verde, which has been the site of rock falls.

Much of the coastline in the study area is steep and bedrock-dominated. Beaches are commonly restricted to small, gravel-dominated, high-energy, pocket beaches. Barachois beaches occur at several localities, including Argentia, near Fox Harbour, and near Ship Harbour on Pla-

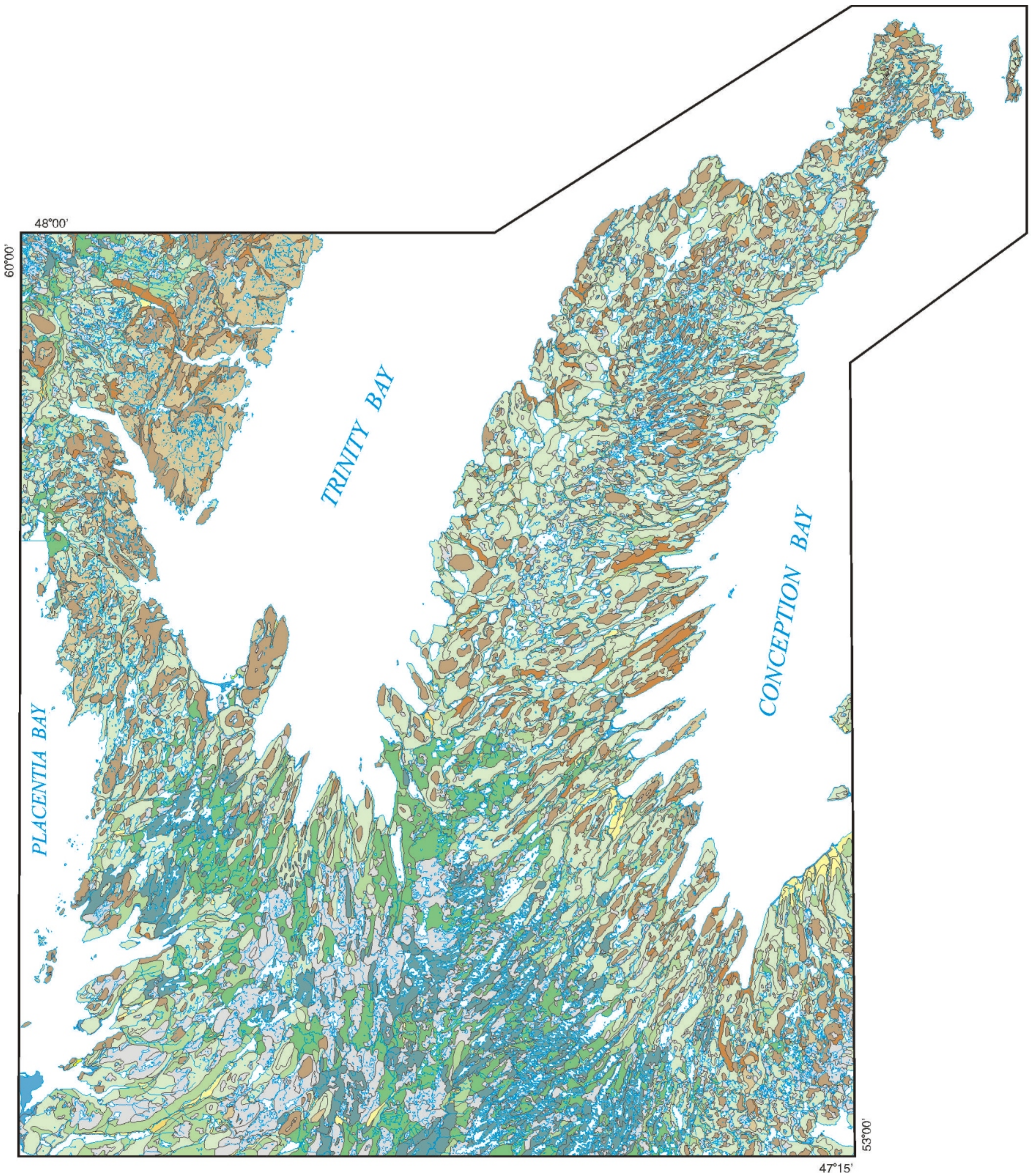

Figure 4. *Surficial geology of the study area (after Catto and Taylor, 1998a-f), mostly based on aerial photographic interpretation with some ground verification of surficial units.*

LEGEND (for Figure 4)

- ***Bog:*** Accumulations of degraded organic matter deposited in poorly drained low lying areas
- ***Colluvium:*** Accumulations of poorly sorted detritus around the base of steep hills derived from the slopes above
- ***Fluvial:*** Moderate to well sorted gravel, sand, silt and clay deposited in modern river systems
- ***Marine:*** Moderately to well sorted gravel, sand and mud. Mostly exposed in marine terraces
- ***Glaciofluvial:*** Poorly to well sorted sand and gravel, 1.5 to 50 m thick
- ***Till veneer:*** Thin (less than 1.5 m) discontinuous sheet of till overlying bedrock. Patches of exposed bedrock and thicker sediment common. Relief and topography variable
- ***Till blanket:*** Continuous till cover thicker than 1.5 m. Includes areas of eroded till
- ***Hummocky till:*** A blanket of till having an irregular hummocky topography and relief of 2 to 10 m. Hummocks mostly till, but may contain sand and gravel
- ***Ridged till:*** Blanket of till having topography consisting of ridges oriented parallel or perpendicular to ice flow
- ***Concealed bedrock:*** Mainly bedrock, concealed by vegetation with patches of till, sand, gravel, bog, and exposed bedrock
- ***Exposed bedrock:*** Areas of bedrock with little or no surface sediment

Plate 1. *Typical coastal exposure of diamicton on the Bay de Verde Peninsula. Diamictons are commonly thin, but continuous over much of the coastal fringes. Central parts of the peninsula, close to the ice-dispersal centre contain more surface bedrock exposures.*

Plate 2. *A granite-dominated diamicton along the Conception Bay South coastline. The granites are derived from the Holyrood horst, which is located to the south. The dispersal of granite clasts clearly shows northward paleo ice flow in this part of the Avalon Peninsula.*

Plate 3. *Rogen moraine south of Whitbourne. These features are oriented perpendicular to ice flow and are formed in a subglacial environment. The Rogen moraines on the Avalon Peninsula were formed either by northward flowing ice, or subglacial water from a dispersal centre at the head of St. Mary's Bay.*

centia Bay; Freshwater and Salmon Cove on the east shore of Conception Bay; and Chapel Cove, Holyrood, Seal Cove and Long Pond on the south shore of Conception Bay (Figure 1). All are gravel-dominated, commonly less than 500 m long, and have a variety of structures, including small- and large-scale cuspate features, and beach berms, with back-beach areas commonly exhibiting overwash fans. Sand surfaces commonly exhibit wave ripples. The largest barachois beach is at Indian Pond near Holyrood, which is over 1 km long. Rare sand beaches are found at Northern Bay and Salmon Cove.

A small area of aeolian sediments was located at Salmon Cove, where active sand dunes are present in the backbeach area. Areas of organic accumulation are common across the entire area and most are less than 50 cm thick, although pockets of bog are deeper than 3 m.

Plate 4. *Well-developed, graded fluvial terrace at the mouth of Spout Cove Brook, Conception Bay. Coastal retreat is common along many stretches of the Conception Bay coast, as shown in this photograph, and eroded material from cliffs feeds small pocket beaches at their base. No evidence of raised marine features has been found along the east side of the Bay de Verde Peninsula.*

REGIONAL TILL SAMPLING

A regional till-sampling program was conducted using the surficial geology of Catto and Taylor (1998a-d) as a guide. Glaciofluvial, fluvial, marine, and aeolian sediments were excluded as sampling media. Most samples were from the C- or BC-soil horizons, taken from about 0.5 m below surface from test pits, or 0.5 to 1.0 m depth from quarries or road-cuts. In rare instances, the lack of surface sediment necessitated the sampling of bedrock detritus. Sample spacing was controlled by access, as well as surficial geology. In areas of good access, the sample density was about 1 sample per 1 km^2, increasing to about 1 sample per 4 km^2, in areas where helicopter support was required. Samples were sieved through a 5-mm mesh sieve, and about 1 kg of sediment was collected.

A total of 985 samples were collected (Figure 5) and submitted to the Geological Survey's geochemical laboratory in St. John's for analysis, either internally by atomic absorption spectrophotometry (AAS), gravimetric analysis, and inductively coupled plasma emission spectrometry (ICP) using an *aqua regia* digestion; or externally, by commercial laboratories 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 (analytical precision only), and standard reference materials. In all cases, the silt/clay fraction (less than 0.063 mm) is analyzed. Data release is anticipated before summer 2004.

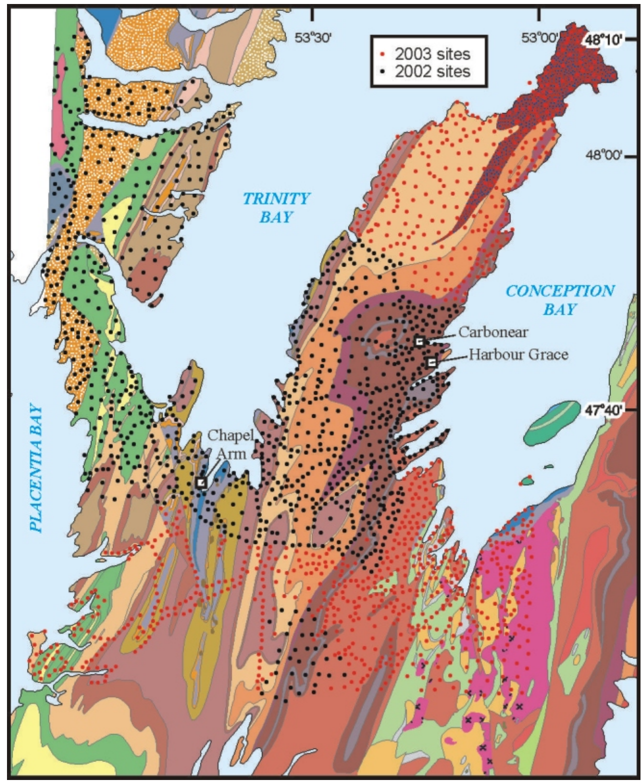

Figure 5. *Location of till samples for which geochemistry will be completed. Sites are overlain on a simplified bedrock-geology base taken from King (1988). See Figure 3 for legend.*

IMPLICATIONS FOR MINERAL EXPLORATION

The adoption of a multi-faceted approach to the collection of geochemical data has proven useful in defining glacial dispersion patterns in Newfoundland and Labrador (Batterson and Liverman, 2001). A combination of clast identification, striation mapping, surficial mapping and till geochemistry are recommended for drift-prospecting programs. Clast lithology analysis rarely focuses on mineralized material, but instead uses visually distinctive rock types that have a discrete source area to define general patterns of dispersal. Surficial geological mapping is essential in guiding sampling for geochemistry, and to the interpretation of geochemical data. Striation mapping also provides exploration companies with ice-flow data that should be used when sampling till and interpreting results.

For the purposes of discussion, the study area is divided into 2 areas: southern Bay de Verde Peninsula and central Avalon Peninsula; and central and northern Bay de Verde Peninsula.

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

Method	Elements Analyzed
Atomic aabsorption spectrophotometry (AAS)	Ag
Gravimetric analysis	LOI
Inductively coupled plasma emission spectrometry (ICP)	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 and Yb

Southern Bay de Verde Peninsula and Central Avalon Peninsula

Ice from the St. Mary's Bay dispersal centre covered much of the central region of the Avalon Peninsula and southern part of the Bay de Verde Peninsula. The influence of topography is noted by the movement of ice into Trinity Bay on the west, and Conception Bay on the east side of the peninsula. Ice flow commonly was parallel to the orientation of the major bays on both coasts. Northward-flowing St. Mary's Bay ice produced the Rogen moraines that characterize the central Avalon Peninsula. The mode of formation of these moraines may be unimportant to prospecting in the area. If formed of diamicton during active subglacial ice flow by a compressive flow regime, these features may reflect local derivation. If however, they were formed by erosion during a subglacial flood event, they are likely also composed of locally derived material, although partially transported in a glaciofluvial system. Therefore, dispersal distances are considered to be short (less than 5 km). Further work on these features is required to determine their mode of formation.

Central and Northern Bay de Verde Peninsulas

The central part of the Bay de Verde Peninsula maintained its own ice cap during the late Wisconsinan and the paleo ice-flow from this centre was radial. Diamictons characteristically contain clasts from the underlying bedrock and erratics are absent from this area. Therefore, dispersal distances are considered to be similarly short (less than 5 km).

Areas of glaciofluvial sedimentation are well defined on published surficial maps, and should be treated separately from diamictons in a regional-till geochemistry program. Much of the coastline shows evidence of having being raised, following deglaciation, to about 15 m above modern sea level in the south to about 7 m in the north. Marine sediments, due to the uncertainty in source directions and distances of transport (e.g., possibly iceberg derived), should be avoided in exploration programs. Colluvium is derived from the overlying slopes and therefore provides point-source geochemical data.

PROJECT DEVELOPMENT

This is the third year of a multi-year Quaternary mapping and till-geochemistry project in eastern Newfoundland, continuing on from the work of Batterson and Taylor (2001a,b, 2003a-h). Revised surficial geology maps of the areas to the north and west have been released (Batterson and Taylor, 2003c-h; Batterson *et al.*, 2003a, b), as have open-file releases of regional till geochemistry (Batterson and Taylor, 2001a, b, 2003b). Till-geochemistry data from this part of the project will be released by summer 2004. Subsequent work will focus on completing mapping and sampling the remainder of the Avalon Peninsula, and the northern Burin Peninsula.

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