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INVESTIGATION OF FOUR TILL ANOMALIES, NEWFOUNDLAND

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ABSTRACT

A detailed study of four geochemical till anomalies has been carried out in an attempt to determine their origin. On the Avalon, in the Bay de Verde Peninsula, the Hearts Content and Carbonear anomalies are characterized by anomalous values of a variety of rare-earth elements that may be derived from the Neoproterozoic Drook and Big Head formations. In central Newfoundland, the Henry Waters anomaly is dominated by europium and phosphorus. The anomaly's source appears to be a penecontemporaneous dioritic or monzonitic sill that intrudes a Cambrian volcanosedimentary sequence. In the same region, the polymetallic Michaels Pond anomaly is dominated by molybdenum and underlain by a thin but complexly refolded Ordovician black shale unit (Lawrence Harbour formation) within a larger unit of volcanogenic sandstone and siltstone (Stanley Waters formation).

Bulk till samples were collected within the bounds of these four anomalies during fieldwork in 2010. The coarsest fraction of the till samples was separated for pebble counts, and the finest fraction was separated for extraction of panned concentrates using a 'Goldhound' rotary panner. The processing of the samples is expected to be completed in early 2011.

INTRODUCTION

A number of unexplained anomalies are present within the till database of the Geoscience Atlas of the Government of Newfoundland and Labrador. This study seeks to investigate the bedrock source of four of these anomalies by further examination of existing data and the re-sampling of selected anomalous sites. Other similar anomalies will be investigated in the future.

Three of the anomalies are characterized by enrichment in rare-earth elements (REE). Two are located over Neoproterozoic sedimentary rocks in the Bay de Verde Peninsula. The third is situated in central Newfoundland, over a supracrustal sequence of Cambro-Ordovician age, southwest of Red Indian Lake. The fourth anomaly, although most strongly manifested by molybdenum, is polymetallic and occurs over Ordovician sedimentary rocks to the south of Millertown, also in central Newfoundland.

In this report, the available information about each of the anomalies is presented, followed by a description of the sampling and sample-processing methods used.

DEFINITIONS

Frequent use will be made of the terms anomalous, elevated and background in identifying and describing areas where the analyzed content of till or lake-sediment samples justifies further investigation. These terms are defined in Table 1.

Table 1. Definition of terms used in the report

Anomalous	indicates that the sample's content exceeds the 97.5 percentile in a particular population of samples of the element in question.
Elevated	indicates that the sample's content is less than or equal to the 97.5 percentile but exceeds the 90 percentile in a particular population of samples of the element in question.
Background	refers to all values less than or equal to the 90 percentile in a particular population of samples of the element in question.

The population of analytical values from which the percentiles are derived may be 'global' in scope (*e.g.*, all samples from the Island of Newfoundland), or more 'local' (*e.g.*, all the samples collected over a particular rock type, a particular tectonic domain, or within certain geographic or project limits).

In any geochemical population whose frequency distribution approximates some permutation of the 'Gaussian' or 'Normal' distribution, there will always be values that are defined as 'anomalous' or 'elevated', whether or not they are either statistically, or geochemically, anomalous, and whether, or not, they have any spatial or genetic relationship with enrichment of that element in bedrock. Nevertheless, this method of anomaly identification has the advantage of being rapid and the significance of the anomalies can be assessed by examining their relationship to known geology, or to the behaviour of other elements.

AVALON PENINSULA

Anomalous values of various REE form several conspicuous groupings in tills and lake sediments over the Avalon Peninsula (Figures 1A to C). These anomalies show a conspicuous spatial association with two mapped geological units of Neoproterozoic age (King, 1988): the older Drook Formation of the Conception Group (CHD: green siliceous siltstone and sandstone, silicified tuff) and the younger Big Head Formation of the Musgravetown Group (MHBI; wavy bedded, siliceous siltstone and arkose). Figure 1A and B indicate the occurrence of anomalous and elevated values of lanthanum (La) in lake sediments and tills over most of the Avalon, as well as the mapped and inferred contacts of the Big Head and Drook formations. Most other REEs behave similarly, although certain individual anomalies may be better defined by elements other than La.

There is a good deal of similarity in the distribution patterns displayed by La in the till and lake-sediment samples. This is particularly so in the Bay de Verde Peninsula, where anomalous La values were returned for most of the lake-sediment samples collected over the extensive outcrop of the Big Head Formation in the north, whereas anomalous till samples are concentrated on the periphery of the map unit; that is, at its stratigraphic base. The lake-sediment anomaly, associated with an inlier of Drook Formation west of Carbonear, also has a greater areal extent than the corresponding till anomaly; however, the till anomaly is better expressed by other elements, such as Dy2 (Figure 2). A conspicuous lake-sediment REE anomaly over Drook Formation rocks, centred on Middle Gull Lake (NTS map area 01N/06), is not spatially associated with a corresponding till anomaly in La. However, other REE (*e.g.*, Dy and Lu; not shown here) are anomalous in tills at this locality.

There is no till geochemistry coverage east of the NTS map area 01N/06. Consequently, it is unknown whether there is a till anomaly corresponding to the strong La anomaly in lake sediments, centred on Winsor Lake, about 10 km west-northwest of St. John's, and spatially associated with Drook Formation rocks (Figure 1A).

Another concentration of anomalous La values in lake sediments is located over Big Head Formation rocks in the northwest of the Avalon Peninsula, north of Long Harbour. The tills in the vicinity of this lake-sediment anomaly are elevated in La, and anomalous in other REE.

Monazite, with formula (Ce, La, Pr, Nd, Th, Y)PO_4, is the REE host mineral that is most likely, in its detrital or diagenetic form, to be encountered in these rocks and the phosphorus (P) content of the tills is shown in Figure 1C. Most of the anomalous and elevated P values are from till samples collected directly over Drook Formation rocks between Brigus Bay in the north, and Salmonier Arm in the south. Anomalous and elevated P values are also concentrated over Big Head Formation rocks north of Long Harbour where the direct spatial association with certain REE is high. However, in the Bay de Verde Peninsula the association of anomalous and elevated P with the Big Head and Drook formations is minor.

Monazite is reported to occur in nodular form in lower Paleozoic sedimentary rocks in Wales and Variscan (late Paleozoic) rocks in southwest England (Cooper *et al*., 1983; Read *et al*., 1987; Smith *et al*., 1994). The reported tuffaceous component of the Drook Formation may also be significant; the enrichment of rare earths in Jamaican bauxites has been ascribed to ash falls originating from Miocene volcanoes in Central America (Grant *et al*., 2005).

BAY DE VERDE PENINSULA

On the Bay de Verde Peninsula, located between Hearts Content in the west and Carbonear in the east, two REE till anomalies have a spatial relationship with Neoproterozoic rocks (Figure 2): the Hearts Content anomaly is associated with the southern, possibly basal, contact of an extensive outcrop of the Big Head Formation; and the Carbonear anomaly shows a similar relationship to an inlier of the Drook Formation in the core of the Victoria Anticline (King, 1988). The distribution pattern of anomalous and elevated dysprosium (Dy2) values, shown in Figure 2, is representative of the occurrence of most of the REE in the area.

Till in the Bay de Verde Peninsula commonly occurs as a veneer over bedrock. The sampled material consists entirely of matrix-supported diamicton till having a silty-sand matrix, 10–15% fines, and medium concentrations (30–60%) of clasts of maximum size ranging from 25–45 cm. Most clasts are locally derived, with dispersal distances less than 5 km (Batterson and Taylor, 2003, 2004). The REE anomalies in the tills are likely related to westward glacial transportation from the nearby Hearts Content Barrens Ice Dispersal Centre (Figure 3). To the north of the Hearts Content anomaly, ice-movement directions are generally eastward. However, to the southwest of the anomaly, southeastward to northwestward ice-movement directions are reported. Ice-movement striations (measurements) within the bounds of the anomaly are scarce.

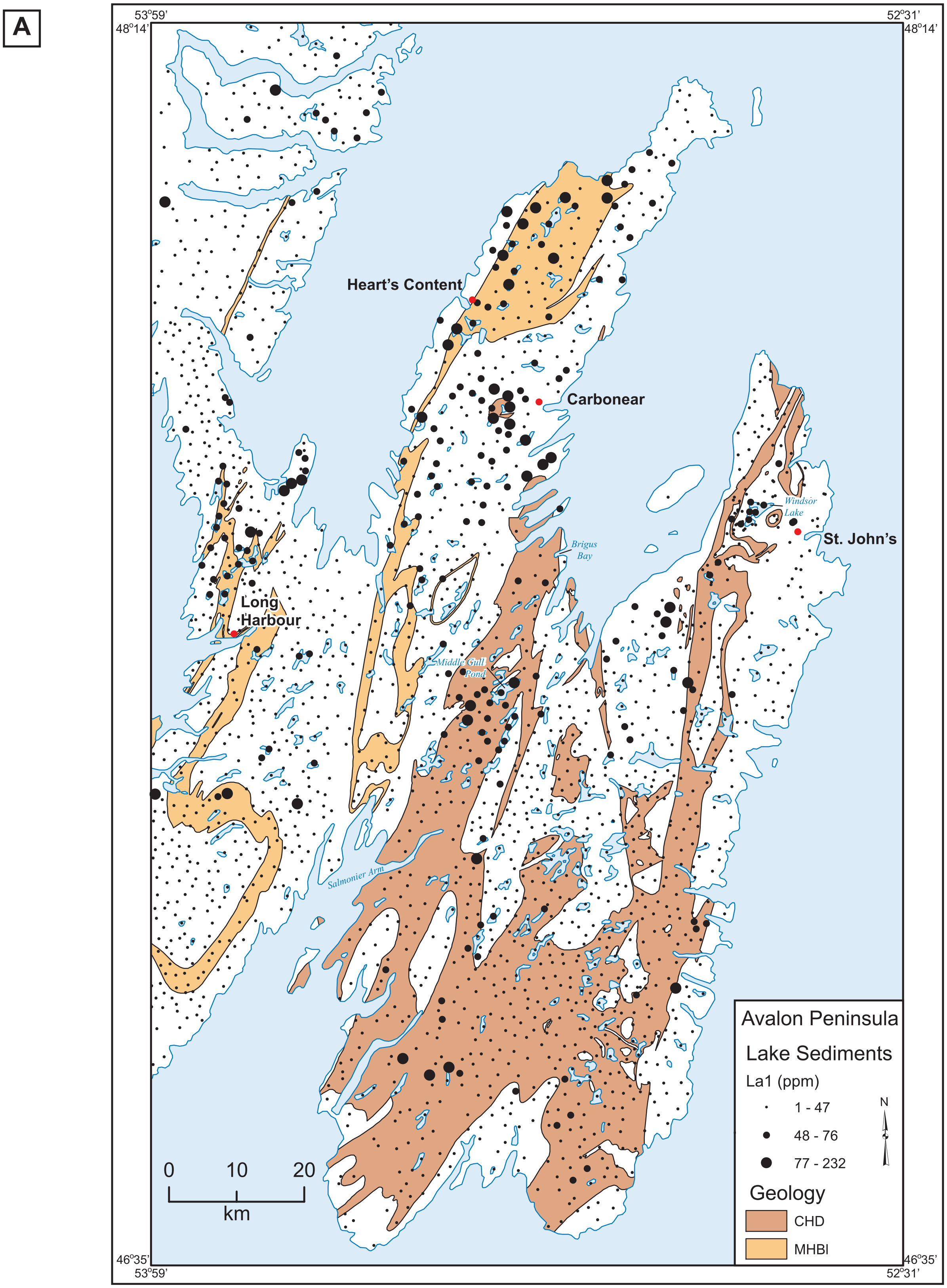

Figure 1A. *Distribution of elevated and anomalous values of* La_1 *in lake sediments, Avalon Peninsula. Buff shading: mapped occurrence of Big Head Formation (MHBI); brown shading: mapped occurrence of Drook Formation (CHD); geology from King (1988).*

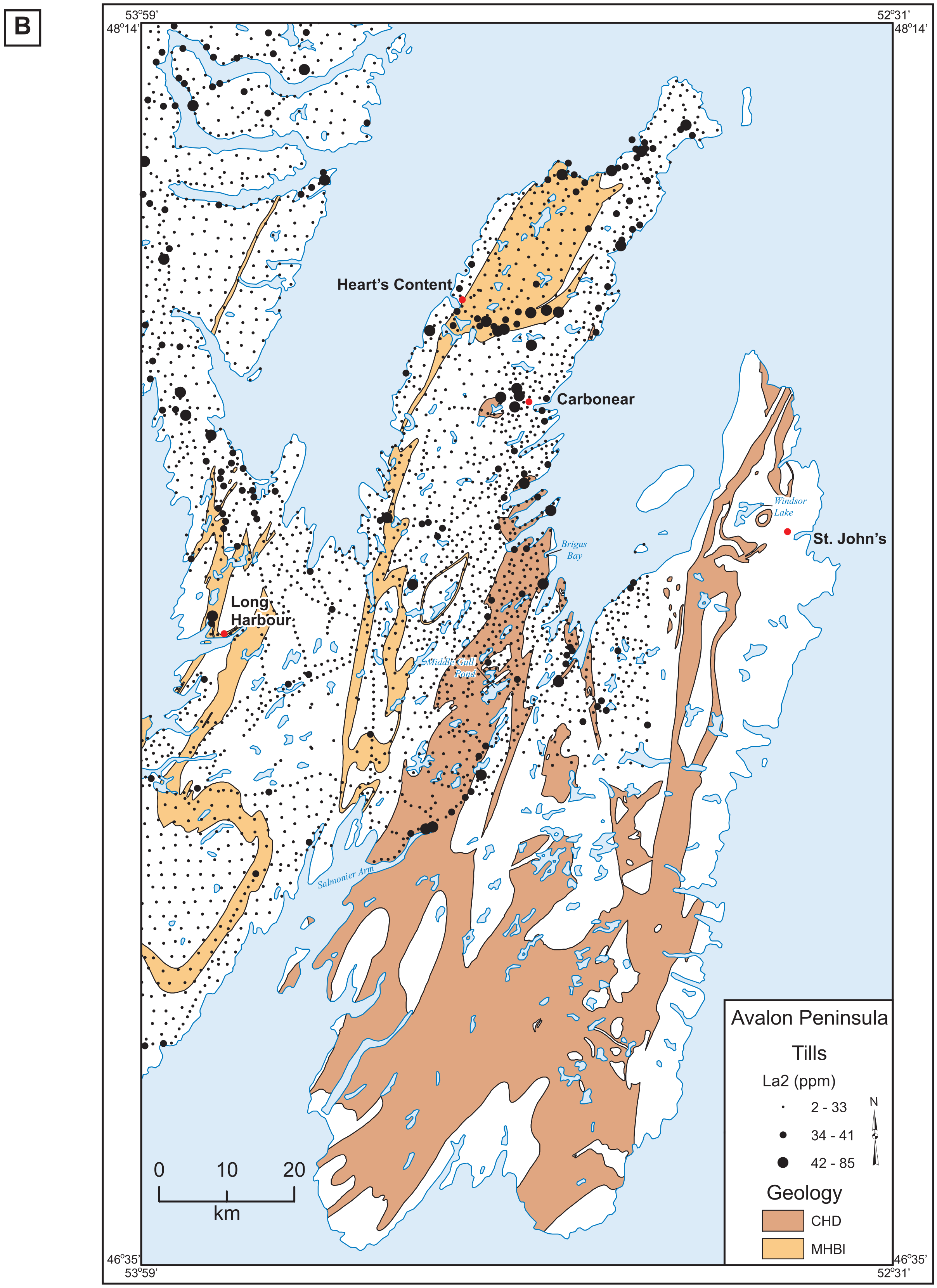

Figure 1B. *Distribution of elevated and anomalous values of* La_2 *in tills, Avalon Peninsula. Buff shading: mapped occurrence of Big Head Formation (MHBI); brown shading: mapped occurrence of Drook Formation (CHD); geology from King (1988).*

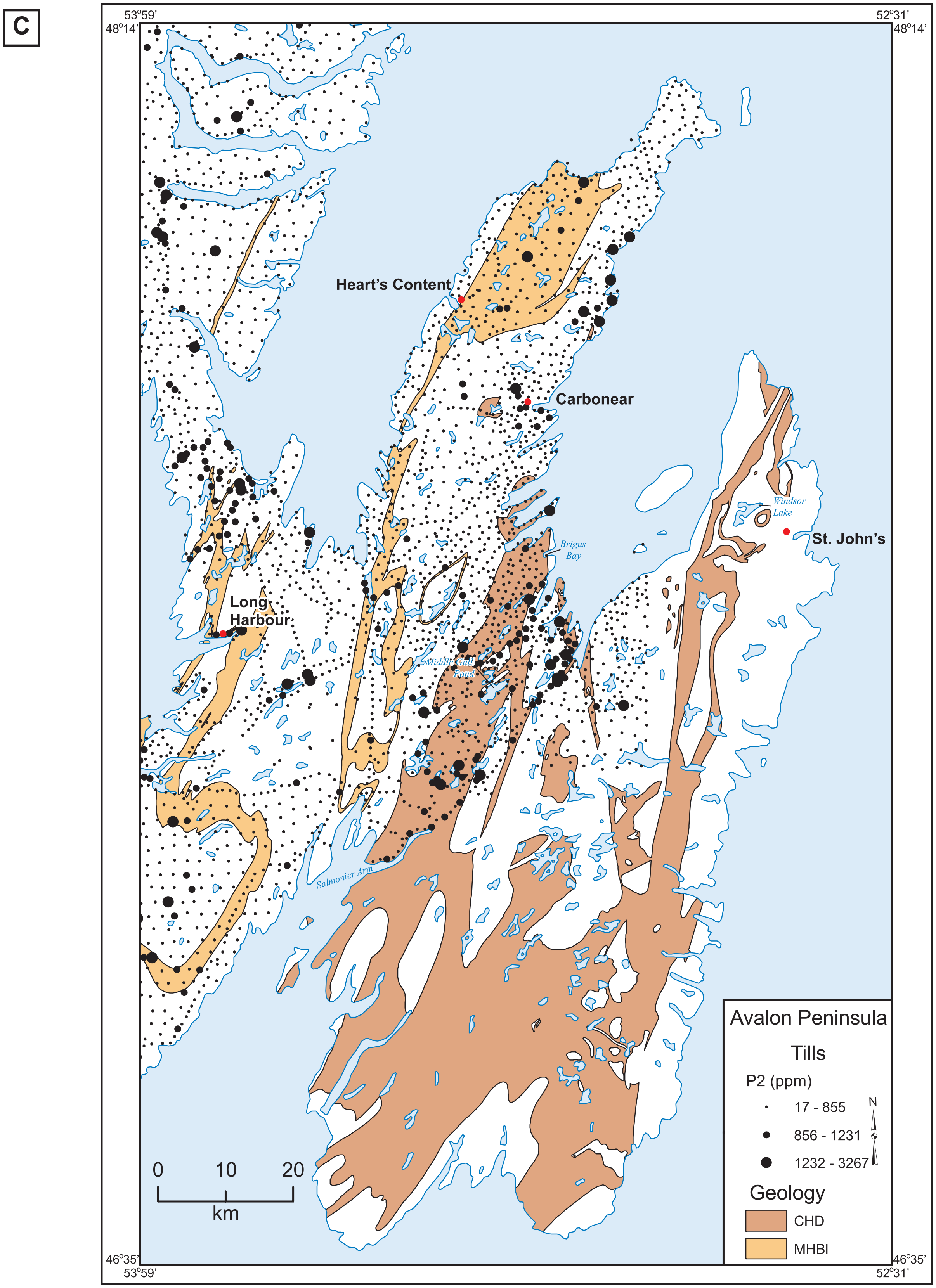

Figure 1C. *Distribution of elevated and anomalous values of P_2 in tills, Avalon Peninsula. Buff shading: mapped occurrence of Big Head Formation (MHBI); brown shading: mapped occurrence of Drook Formation (CHD); geology from King (1988).*

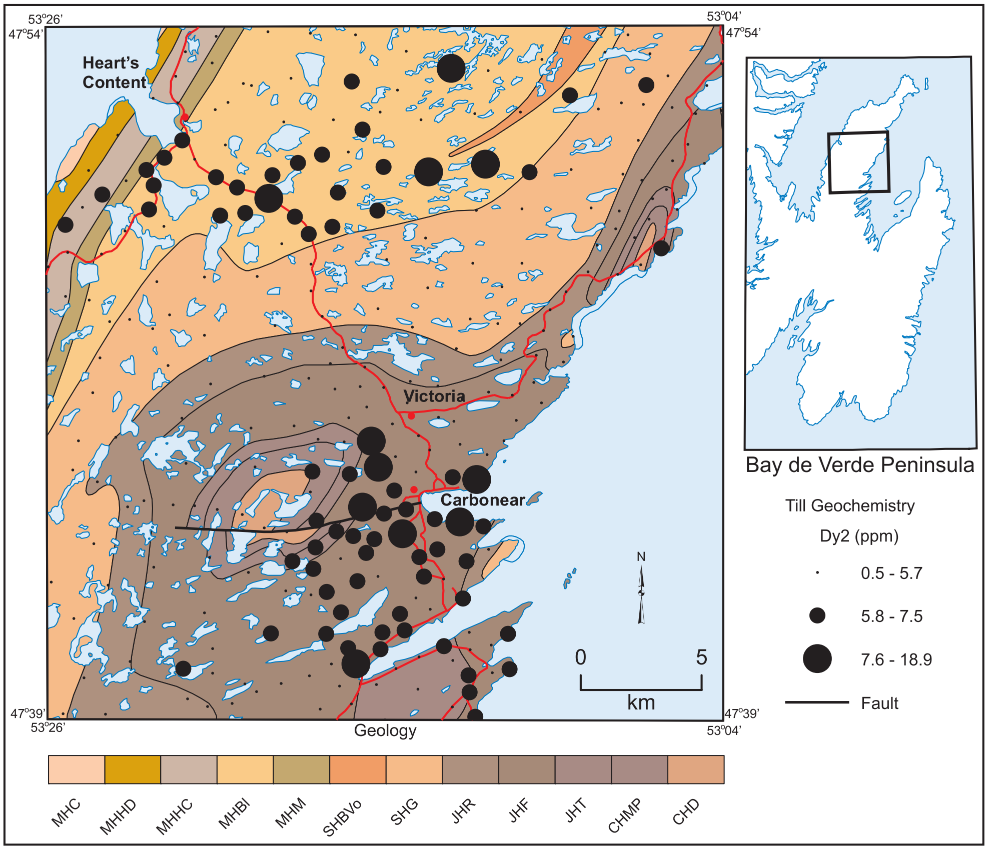

Figure 2. *Areal distribution of Dy in tills, Bay de Verde Peninsula study area. MHC: Crown Hill Formation; MHHD: Heart's Desire formation; MHHC: Heart's Content formation; MHBI: Big Head Formation; MHM: Maturin Ponds Formation; SHBVO: Bay de Verde formation; SHG: Gibbett Hill Formation; JHR: Renews Head Formation; JHF: Fermeuse Formation; JHT: Trepassey Formation; CHMP: Mistaken Point Formation; CHD: Drook Formation; geology from King (1988).*

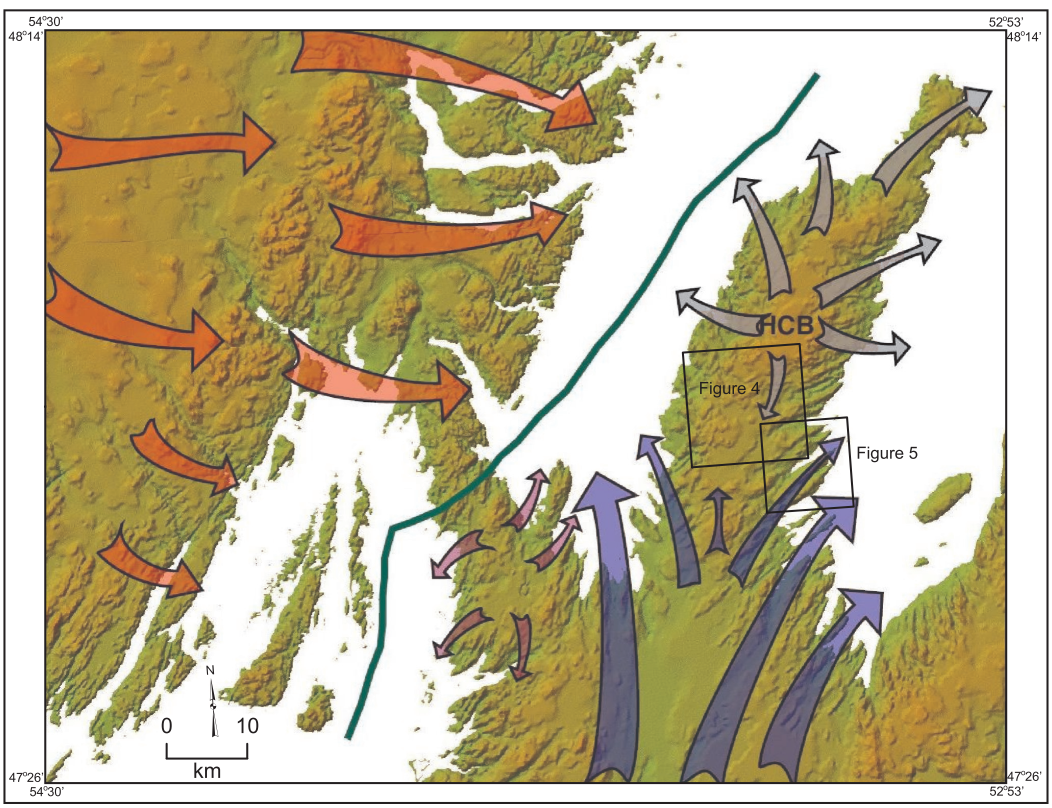

Figure 3. *Caption on opposite page.*

Table 2. Component till samples of Hearts Content anomaly, with analyses of rare earths and associated elements (data from Batterson and Taylor, 2004); all values in ppm except Au (ppb); the numeric suffix '1' indicates analysis by Instrumental Neutron Activation Analysis (INAA) and '2' indicates Induction-Coupled Plasma Emission Spectrometry (ICP-ES) after 'total' (HF-$HClO_4$-HNO_3) digestion; red text indicate 'anomalous' values exceeding 97.5-percentile for till samples collected over Avalon Tectonic Domain; blue text indicate 'elevated' values exceeding 90-percentile for the same population

NTS Sheet	Sample No.	Longitude (º west)	Latitude (º north)	Ce2	Dy2	Eu1	La2	Lu1	Nd1	Sm1	Tb1	Th1	U1	Y2	Yb1	Au1
01N/14	1032	53.2061	47.8800	53	5.7	1.4	30	0.63	**29**	**6.9**	**1.5**	9.4	2.1	**34**	3.9	1
01N/14	1042	53.2554	47.8593	52	**6.1**	1.2	**38**	**0.82**	**33**	**8.3**	1.0	**11.5**	**3.2**	**39**	**5.2**	1
01N/14	4711	53.3767	47.8601	79	**7.4**	**2.0**	**38**	**0.79**	**29**	**8.3**	**1.5**	9.0	2.5	**40**	**5.2**	3
01N/14	4712	53.3862	47.8555	78	**5.8**	1.6	29	**0.77**	25	6.3	**1.2**	9.6	**3.2**	**35**	**5.1**	2
01N/14	4721	53.4097	47.8238	68	5.2	1.7	29	0.61	28	6.3	**1.3**	8.8	2.9	31	4.0	**6**
01N/14	4728	53.4299	47.8341	**91**	**6.8**	**2.9**	**44**	**0.76**	**48**	**12.0**	**1.8**	8.7	**3.7**	**40**	**5.1**	**9**
01N/14	4731	53.3477	47.8536	70	**6.1**	1.3	29	**0.69**	23	5.3	**1.3**	9.5	2.3	**38**	**4.6**	5
01N/14	4732	53.3359	47.8500	**89**	**7.1**	1.6	**37**	**0.80**	**29**	6.7	**1.6**	**12.0**	**4.4**	**41**	**5.2**	**16**
01N/14	4733	53.3182	47.8462	**96**	**8.3**	**1.8**	**51**	**0.76**	**38**	**8.2**	1.1	**11.0**	2.4	**46**	**5.1**	1
01N/14	4734	53.3035	47.8399	64	**7.3**	1.4	**37**	**0.78**	26	6.8	**1.3**	**12.0**	2.5	**42**	**5.2**	1
01N/14	4736	53.2827	47.8364	71	**6.4**	1.7	**43**	0.62	**35**	7.6	**1.2**	**11.0**	2.5	**42**	4.2	**8**
01N/14	4737	53.2956	47.8334	82	**6.8**	**2.0**	**46**	**0.67**	**40**	**8.8**	**1.3**	10.0	**3.5**	**43**	**4.5**	**14**
01N/14	4749	53.2197	47.8965	64	**7.6**	1.6	**39**	**0.68**	28	**7.8**	**1.4**	9.1	2.5	**44**	**4.4**	**9**
01N/14	4758	53.2304	47.8578	71	**7.7**	1.6	**42**	**0.82**	**34**	**8.6**	**1.6**	**11.5**	2.1	**48**	**5.4**	1
01N/14	4759	53.1993	47.8614	75	**7.7**	1.5	**42**	**0.79**	**32**	**8.3**	**1.2**	10.5	2.9	**47**	**5.2**	**14**
01N/14	4763	53.1748	47.8590	**113**	**6.6**	**2.1**	**50**	**0.71**	**39**	**9.8**	**1.5**	9.7	2.7	**37**	4.2	4
01N/14	4766	53.2581	47.8429	60	**6.6**	1.4	**34**	**0.69**	27	**7.4**	**1.3**	**12.0**	2.5	**40**	**4.5**	3
01N/14	4842	53.3449	47.8393	54	**6.4**	**1.8**	31	0.55	**30**	6.7	1.1	**11.0**	2.6	**35**	4.0	<1
01N/14	4843	53.3310	47.8407	59	**6.8**	1.5	**35**	0.57	25	6.1	1.1	9.6	2.8	**40**	3.7	5

HEARTS CONTENT ANOMALY

Component samples of the Hearts Content anomaly are listed in Table 2 along with analytical values for REEs and associated elements. Anomalous and elevated values are highlighted. The anomaly is defined most strongly by Dy and La, and several samples are also anomalous or elevated in gold. During the 2010 fieldwork, the sites of eleven component samples of the Hearts Content anomaly were re-sampled. The locations of these samples are shown in Figure 4.

Most of the anomaly is underlain by the grey to green tuffaceous siltstone and arkose of the Big Head Formation (MHBI; King, 1988). A few anomalous samples lie west of this unit's outcrop, near the coast.

CARBONEAR ANOMALY

Component samples of the Carbonear anomaly are listed, with their anomalous and elevated associated elements, in Table 3. The geology underlying the anomaly, and the locations of samples collected in 2010, are shown in Figure 5.

This anomaly is defined most strongly by Dy, Sm and Tb. Several elements besides the REE show anomalous or elevated responses, including Li, Nb, P and Ta. There are also strong responses in Pb and Zn within the bounds of the anomaly, but these responses are associated with the adjacent Fermeuse Formation elsewhere in eastern Newfoundland and their source is, therefore, probably not the same as that of the REE.

Anomalous sample sites are mostly underlain by shales of the Fermeuse Formation (JHF), St. John's Group. One sample was collected from till over clastic sedimentary rocks of the Mistaken Point Formation (CHMP), Conception Group. Based on bedrock and till relationships observed elsewhere on the Avalon Peninsula, and local ice-flow history, it is reasonable to postulate that the REE anomalies in till are derived from the Drook Formation (CHD), which

Figure 3. (opposite page) *Patterns of ice flow at the late Wisconsinan maximum. Adapted from Batterson and Taylor (2004); Catto (1998). HCB = Hearts Content Barrens Ice Dispersal Centre.*

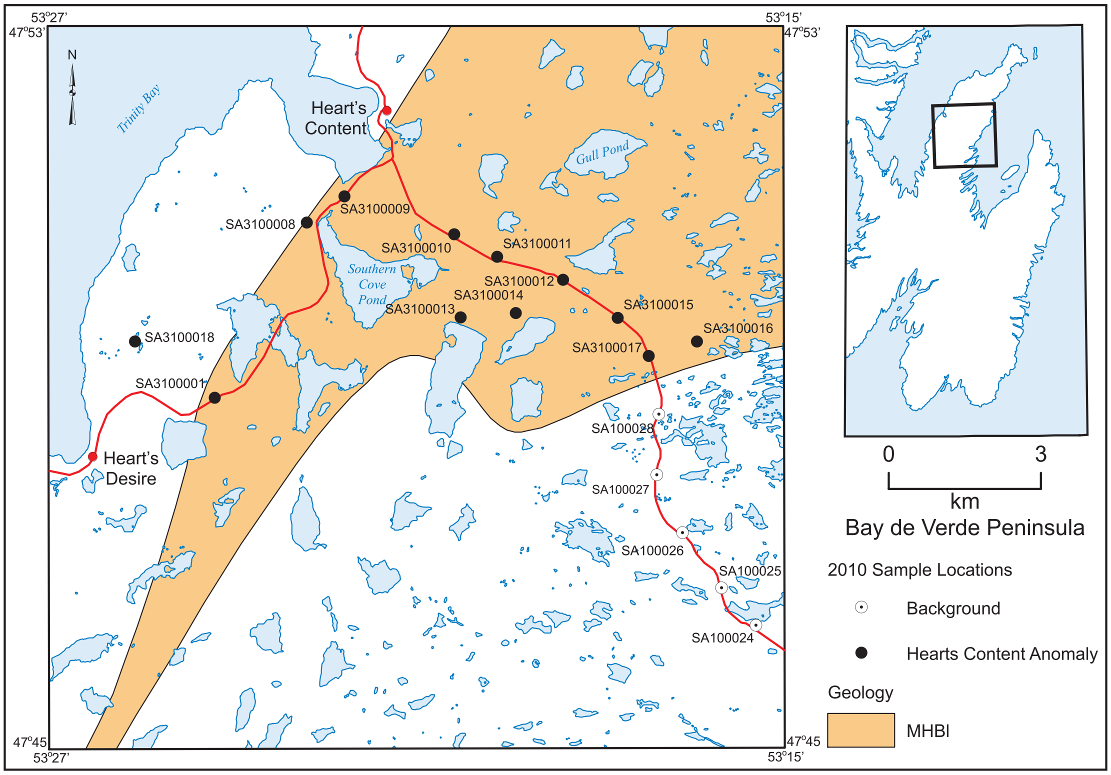

Figure 4. *Locations of 2010 till samples collected over the Hearts Content anomaly, and of background samples. Outcrop of Big Head Formation (MHBI) is shaded buff; geology from King (1988).*

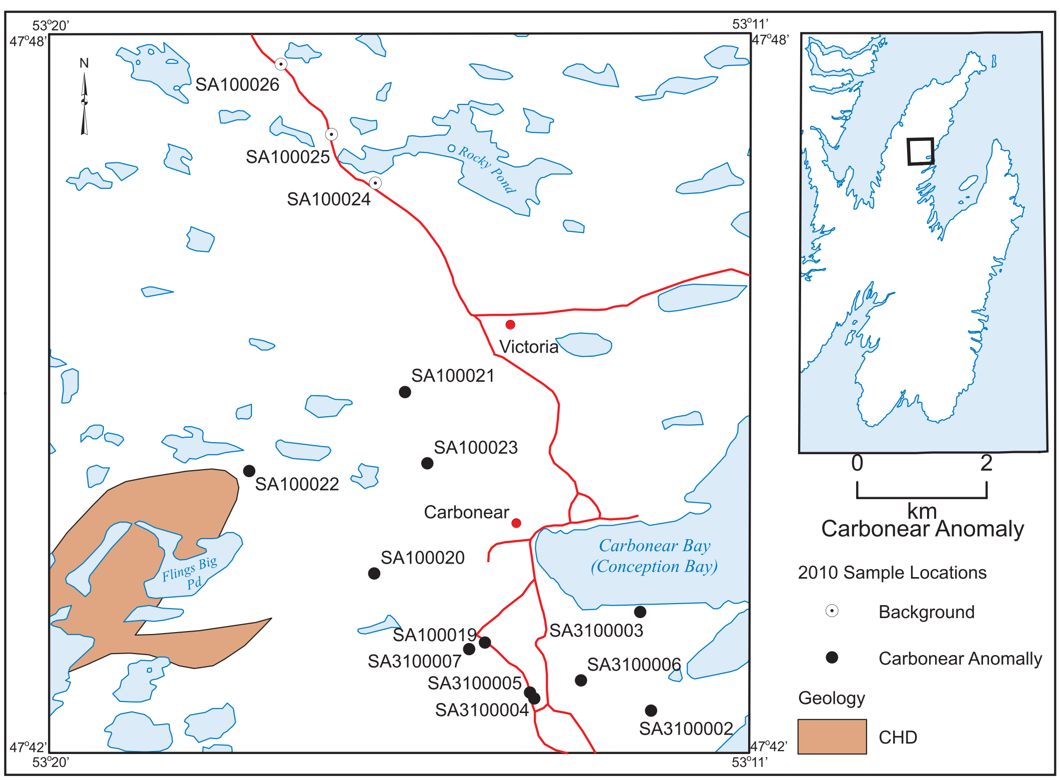

Figure 5. *Locations of 2010 till samples collected over the Hearts Content anomaly and adjacent background samples. Outcrop of Drook Formation (CHD) is shaded light brown; geology from King (1988).*

Table 3. Component till samples of Carbonear anomaly, with analyses of rare earths and associated elements (data from Batterson and Taylor, 2004); all values in ppm; the numeric suffix '1' indicates analysis by Instrumental Neutron Activation Analysis (INAA) and '2' indicates Induction-Coupled Plasma Emission Spectrometry (ICP-ES) after 'total' (HF-HClO$_4$-HNO$_3$) digestion; red text indicate 'anomalous' values exceeding 97.5-percentile for till samples collected over Avalon Tectonic Domain; blue text indicate 'elevated' values exceeding 90-percentile for the same population

NTS Sheet	Sample No.	Longitude	Latitude	Ce2	Dy2	Eu1	La2	Lu1	Nd1	Sm	Tb1	Y2	Yb1	Li2	Nb2	P2	Pb2	Ta1	Th1	U1	Zn2
01N/11	4568	-53.2391	47.7229	91	8.8	2.1	23	0.76	22	8.8	1.6	43	5.1	44.8	25	797	25	0.1	8.3	1.3	101
01N/11	4624	-53.2294	47.7146	141	7.5	2.1	20	0.55	27	7.9	1.3	38	3.7	43.7	21	719	36	2.2	9	2.3	95
01N/11	4636	-53.2617	47.7324	130	9.3	3.8	85	0.75	91	17	2.3	50	5	48.6	19	753	49	1.4	9.6	3.5	158
01N/11	4669	-53.2034	47.7136	77	6.2	2.3	41	0.65	48	9.5	1.7	34	4.3	53.2	17	630	44	2.5	8	2.9	142
01N/11	4672	-53.2076	47.7280	95	7.8	2.5	35	0.72	40	10	1.3	40	4.8	45.2	20	1022	37	2.2	8.9	2.2	152
01N/11	4674	-53.2196	47.7177	115	6.7	2.2	30	0.57	34	8.1	1.6	36	3.8	50.9	21	704	99	2.9	8.8	1.8	182
01N/14	4752	-53.2577	47.7570	287	7.9	2.4	43	0.52	41	12	1.4	29	3.5	39.9	12	1410	114	1.5	13	1.5	164
01N/11	4757	-53.2898	47.7453	65	6.3	2	55	0.62	46	8.5	1.3	42	4.1	46.2	15	682	38	0.1	7.9	2.7	118
01N/11	4839	-53.2535	47.7475	250	14.1	5.3	63	0.71	70	20	3.3	52	4.7	66.5	13	892	216	0.1	12	2.2	308

outcrops in the core of the Victoria Anticline a few kilometres to the west.

BAY DE VERDE PENINSULA BACKGROUND SAMPLES

Samples were also collected from sites where REE are not enriched in tills, based upon results from the earlier sampling programs. This was done, so that the mineralogical and lithological characteristics, which are not unique to till samples collected within the identified anomalies, can be eliminated as putative sources for the REE. An interval of the highway between the Hearts Content and Carbonear anomalies is characterized by a sequence of five background till samples, whose locations are shown in Figure 4. The sample sites are underlain, from east to west, by arenites of the Gibbet Hill (SHG) and Renews (JHR) formations and pelite of the Fermeuse Formation (JHF). The sites were re-sampled, and the samples processed, in the same manner as the anomalous sites.

CENTRAL NEWFOUNDLAND

Two till anomalies were investigated over early Paleozoic rocks south and southwest of Red Indian Lake (Figures 6 and 7, respectively): the Henry Waters anomaly, which appears to be associated with a dioritic or monzonitic unit (Roebucks intrusive suite) intrusive into a Cambrian volcanosedimentary sequence (Tulks Group); and the Michaels Pond anomaly, which occurs over Ordovician black shales of the Lawrence Harbour formation, and volcanogenic sandstone and siltstone of the Stanley Waters formation. The Lawrence Harbour and Stanley Waters formations are part of the Noel Pauls Brook group.

Surficial deposits in the area include till, glaciofluvial sand and gravel, glaciolacustrine silt and clay, and organics, varying in thickness from 1 to 50 m (Smith *et al.*, 2009). The earliest ice-flow direction recorded is a south to southeastward flow (Phase 1; red arrows in Figure 9). This was followed by the development of an interpreted ice divide between Harbour Round Lake and Costigan Lake (Phase 2) when ice flowed to the northeast (blue arrows) and southwest (yellow arrows; Smith *et al.*, 2009).

HENRY WATERS ANOMALY

The component samples of the Henry Waters anomaly are listed, with their anomalous and elevated elements, in Table 4. In the 2010 study, 13 sites within the area of the anomaly were re-sampled (Figures 6 and 8). Based on previous work, the anomaly is primarily characterized by anomalous and elevated values of Eu, Dy, La, P and Y. Other elements including Na and Zr also show enrichment.

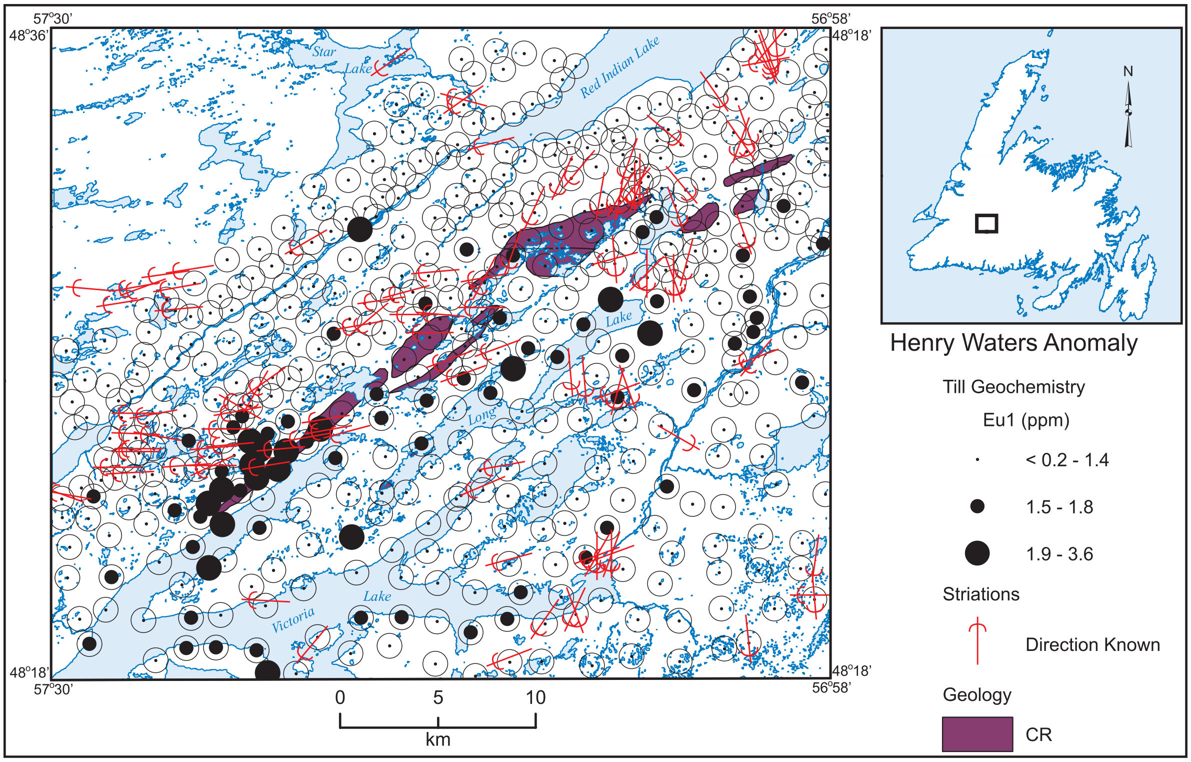

Figure 6. *Europium in tills (from Smith* et al., *2009) shown in relation to outcrop of the Roebucks intrusive suite (CR; purple shading); from Lissenberg* et al. *(2005), Rogers* et al. *(2005) and van Staal* et al. *(2005). Glacial striations shown in red, from Taylor (2001).*

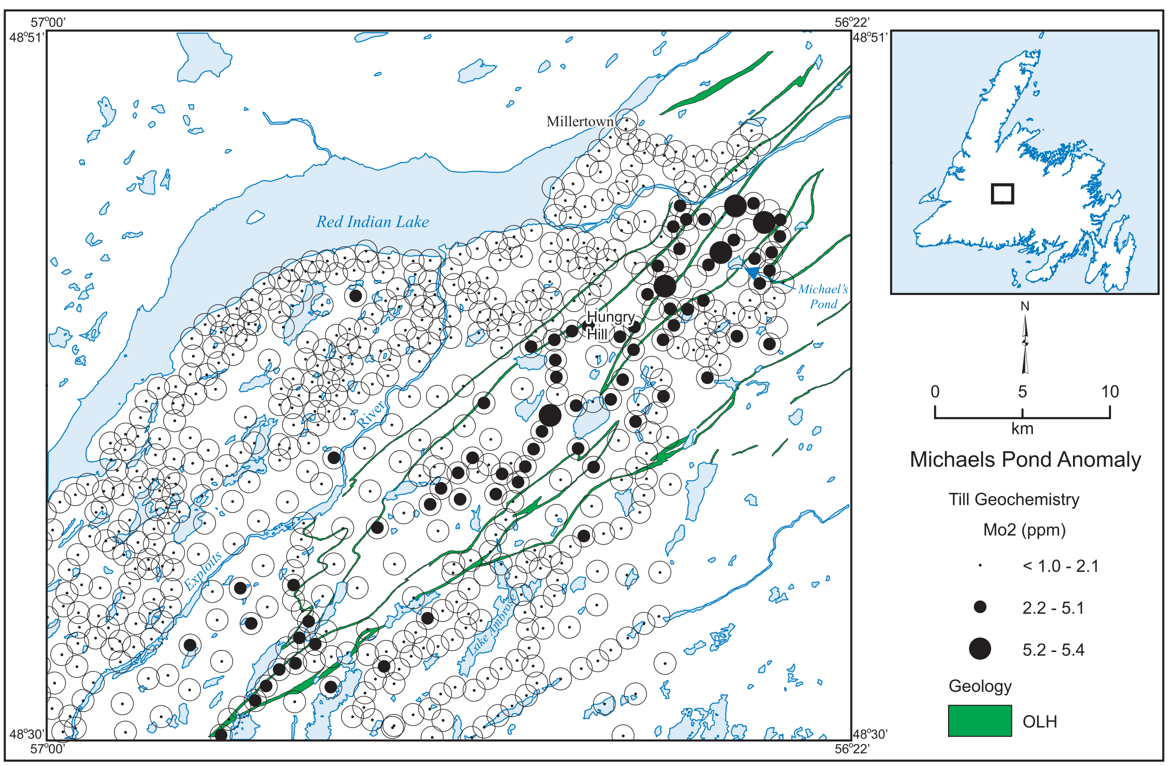

Figure 7. *Relationship between outcrop of Lawrence Harbour formation (OLH) and molybdenum in tills. Geology from Rogers* et al. *(2005a, b, c); geochemical data from Smith* et al. *(2009).*

Table 4. Component till samples of Henry Waters anomaly, with analyses of rare earths and associated elements (data from Smith *et al*., 2009); the numeric suffix '1' indicates analysis by Instrumental Neutron Activation Analysis (INAA) and '2' indicates Induction-Coupled Plasma Emission Spectrometry (ICP-ES) after 'total' ($HF-HClO_4-HNO_3$) digestion; red text indicate 'anomalous' values exceeding 97.5-percentile for Red Indian Lake till data set only (Smith *et al*., 2009); blue text indicate 'elevated' values exceeding 90-percentile for the same population

NTS	Sample	Latitude	Longitude	Ce2	Dy2	Eu1	La2	Lu1	Nd1	P2	Sm1	Tb1	Th1	U1	Y2	Yb1	Na2	Zr2
12A/06	78161	48.39902	-57.38369	**72**	**5.5**	**1.8**	**30**	**0.67**	26	**1198**	**6.4**	0.8	7.2	2.9	**28**	**4.5**	**3.2**	**77**
12A/06	78162	48.39086	-57.3839	**72**	**5.2**	**2**	**28**	0.63	25	**1169**	**6.5**	1	9.3	3.1	**26**	**4.4**	**2.9**	**77**
12A/06	78163	48.38439	-57.39273	**63**	**5.8**	**1.9**	**25**	**0.65**	26	**893**	**6.4**	1.2	8.4	3.6	**27**	4.2	**2.7**	**76**
12A/06	78164	48.37825	-57.39837	49	**4.4**	**1.6**	**23**	0.54	19	**971**	5.1	<0.5	7.5	2.4	**25**	3.8	**3.2**	62
12A/06	78166	48.40244	-57.36291	**66**	**4.8**	**1.9**	**29**	0.59	22	**1305**	6.2	1.2	8.6	**4.8**	**26**	4.2	**3.1**	70
12A/06	78167	48.39041	-57.37109	50	**4.7**	**1.6**	**24**	0.61	17	645	5.4	0.9	7.3	2.5	**26**	4.3	**3.3**	68
12A/06	78168	48.39634	-57.3597	**70**	**8.8**	**2.9**	**27**	**0.81**	30	**2574**	**8.8**	1.2	6.1	2.5	**47**	**5.8**	2.5	**74**
12A/06	78169	48.40023	-57.34485	**69**	**4.1**	**1.9**	**25**	**0.67**	24	639	6.2	1	8.9	2	**24**	**4.5**	**3.4**	**78**
12A/06	78170	48.41309	-57.36418	**64**	**4.3**	**2**	18	0.62	24	**1046**	6.2	1	8.6	2.5	20	4.2	**2.8**	63
12A/06	78171	48.4091	-57.35789	**61**	**4.7**	**1.9**	**26**	**0.67**	23	**1062**	6.2	1.1	9.4	2.4	**24**	4.2	**2.6**	**82**
12A/06	78172	48.41644	-57.35229	**64**	3.5	**1.6**	22	0.52	20	741	4.6	<0.5	8.5	<0.5	20	3.1	**2.9**	60
12A/06	78173	48.42218	-57.33847	58	**4.4**	**1.6**	**27**	0.53	22	**930**	5.5	0.9	9	2.8	**24**	3.8	**3.1**	65
12A/06	78174	48.40861	-57.33935	**66**	**5.3**	**2**	**30**	0.63	25	**1395**	**6.3**	1	**10.3**	2.7	**28**	4.2	**3.2**	**73**
12A/06	78175	48.41887	-57.31578	**67**	**4.5**	**1.9**	**33**	0.48	21	**1661**	5.6	0.7	**10.4**	2.7	**25**	3	**2.8**	60
12A/06	78176	48.41284	-57.32541	52	**4.6**	**1.6**	**24**	0.57	19	694	5.1	0.8	9.7	2.1	**25**	3.7	**3**	65
12A/06	78177	48.41933	-57.37587	31	3.5	**1.7**	14	0.61	15	722	4.6	0.8	6.1	2.7	18	4	**3.9**	62
12A/06	78178	48.42443	-57.37002	24	1.7	**1.5**	8	0.4	16	620	4.2	<0.5	3.3	<0.5	8	2.5	2	39
12A/06	78289	48.36442	-57.40352	**66**	**4.4**	**1.7**	20	**0.75**	20	860	5	<0.5	**11**	3.3	**25**	**4.5**	**2.9**	**74**
12A/06	78539	48.38126	-57.41627	**71**	**4.3**	**1.5**	**23**	**0.69**	<5	602	4.4	<0.5	**12.2**	3.4	**24**	**4.6**	**3.1**	70
12A/06	78540	48.37499	-57.38309	**64**	**4.3**	**1.9**	**27**	**0.81**	21	**897**	5.3	1	**18.4**	**6.8**	**26**	4.1	**2.7**	**97**
12A/06	78542	48.40552	-57.30555	39	3.5	**1.5**	17	**0.74**	3	649	4	<0.5	6.7	<0.5	**23**	**4.4**	**3.4**	69

The Henry Waters anomaly is mainly underlain by the following Middle to Upper Cambrian intrusive, volcanic and sedimentary rocks: felsic volcanics (CCL) and minor clastic sediments (CCLS) of the Costigan Lake formation; basalt and andesite of the Harmsworth Steady formation (CHS); felsic volcanic and volcaniclastic rocks of the Jacks Lake formation (CJP) and mafic volcanics of the Bobbys Pond formation (CBPbe); and bimodal volcanic breccias (COPP) and pillow basalt (COPPmv) of the Pats Pond formation. The Jacks Pond formation is intruded by quartz monzonite, diorite and/or gabbro of the Roebucks intrusive suite (CR). Ordovician rocks of the Victoria Lake supergroup, which outcrop to the northwest, include pillow basalt of the Victoria River Mouth formation (ORM), Sutherlands Pond group; and basalt (ODPmv) and felsic pyroclastics (ODP) of the Dragon Pond formation, Wigwam Brook group.

The postulated ice-flow directions (*see* above) assume greater importance in the formation of the Henry Waters anomaly, which is centred about 1.5 km to the northwest of the Roebucks intrusive suite. If the Roebucks intrusive suite is the source of europium, this may provide evidence for Phase 2 transportation. On the other hand, a more diffuse Eu anomaly to the east of the Henry Waters anomaly, centred on the northeast arm of Long Lake, is 4.5 km south of the Roebucks intrusive suite and appears to display the effects of Phase 1 transportation (Figures 6 and 9).

The Henry Waters (Eu–Dy) anomaly lies within the Messina Minerals Inc. Tulks South base-metal property. The Boomerang massive sulphide deposit was discovered by Messina on the property in 2005. Since that time, two adjacent massive sulphide zones, Boomerang and Domino, have been outlined by drilling and approximately 1.4 million

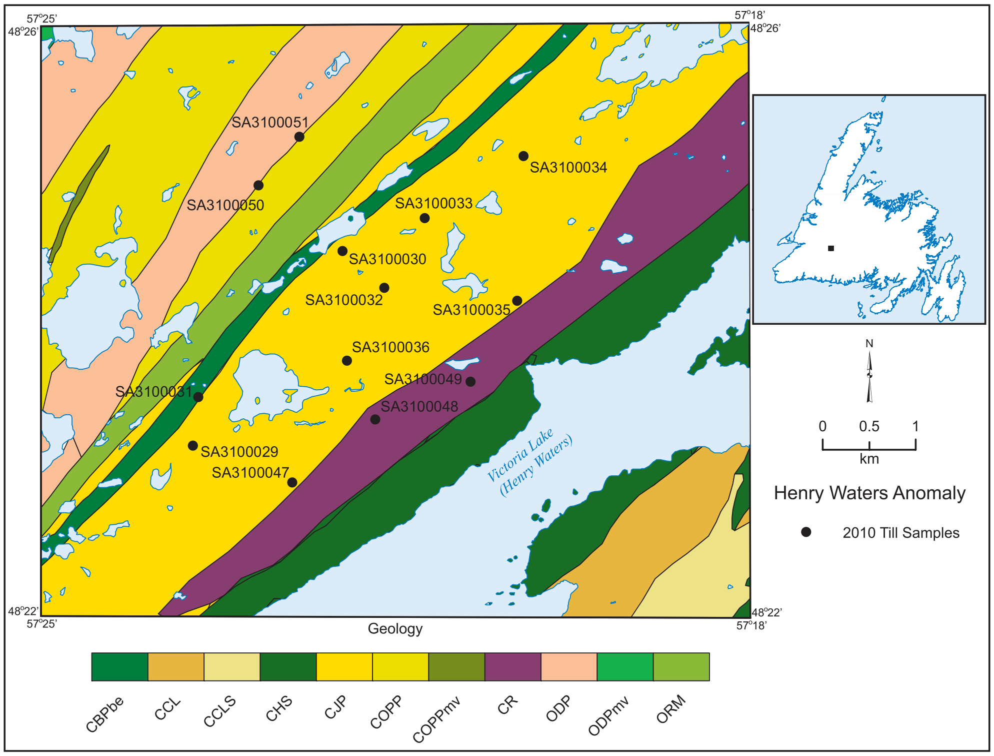

Figure 8. *Bedrock geology of the Henry Waters anomaly (digitized from van Staal* et al.*, 2005). CBPbe: Bobbys Pond formation; CCL: Costigan Lake formation felsic volcanic rocks; CCLS: Costigan Lake formation clastic sediments; CHS: Harmsworth Steady formation; CJP: Jack's Lake formation; COPP: Pat's Pond formation volcanic breccia; COPPmv: Pat's Pond formation pillow basalt; CR: Roebucks intrusive suite; ODP: Dragon Pond formation felsic volcanics; ODPmv: Dragon Pond formation basalt; ORM: Victoria River mouth formation. Locations of 2010 samples over Henry Waters anomaly are indicated.*

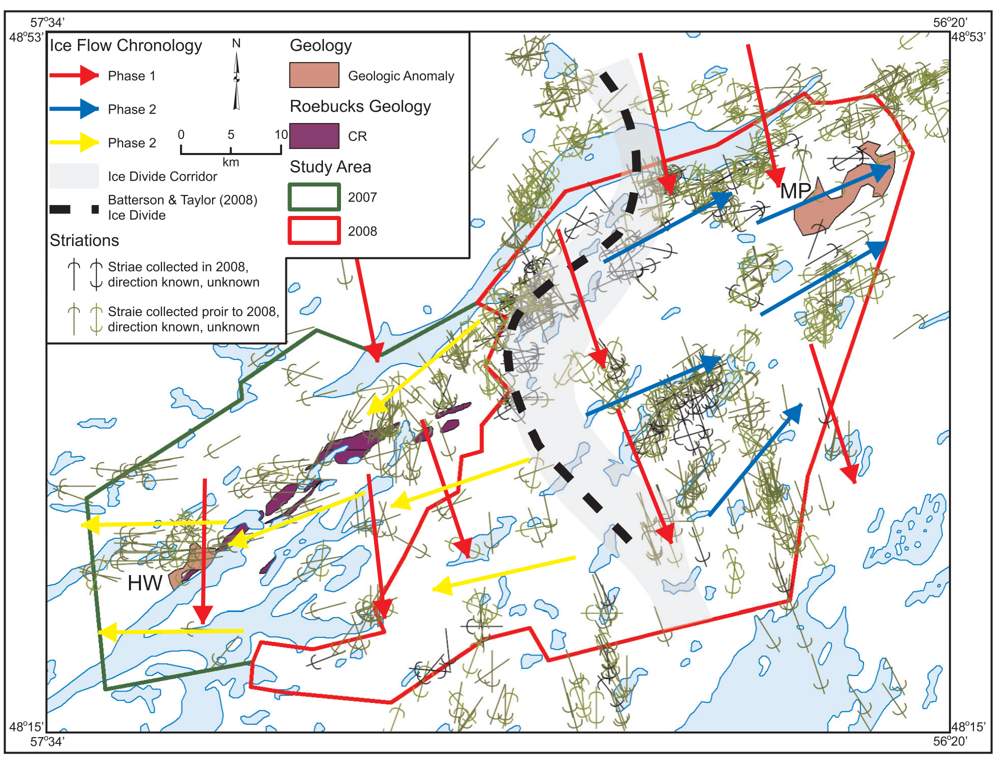

Figure 9. *Ice-flow directions south of Red Indian Lake (from Smith* et al.*, 2009). Henry Waters (HW; in the west) and Michaels Pond anomalies (MP; in the east) are shaded brown; outcrop of Roebucks intrusive suite in purple (from Lissenberg* et al.*, 2005, Rogers* et al.*, 2005a,b,c and van Staal* et al.*, 2005).*

Table 5. Component samples of Michaels Pond anomaly, with strongly anomalous element analyses (data from Smith *et al*., 2009); all values in ppm; the numeric suffix '1' indicates analysis by Instrumental Neutron Activation Analysis (INAA) and '2' indicates Induction-Coupled Plasma Emission Spectrometry (ICP-ES) after 'total' ($HF-HClO_4-HNO_3$) digestion; red text indicate 'anomalous' values exceeding 97.5-percentile for Red Indian Lake till data set only (Smith *et al*., 2009); blue text indicate 'elevated' values exceeding 90-percentile for the same population

NTS	Sample	Latitude	Longitude	Mo2	U1	Cs1	P2	Rb2	K2	Pb2	Fe1	Li2
12A/10	85456	48.69818	-56.53406	4.0	2.9	2.3	633	52	1.07	22	4.9	19.8
12A/10	85457	48.70475	-56.54425	5.0	4.9	3.1	963	67	1.54	31	5.9	22.1
12A/10	85458	48.70749	-56.55744	5.9	5.2	5.1	965	101	2.16	32	6.0	29.0
12A/10	85507	48.71918	-56.51844	8.6	5.1	3.3	1343	63	1.16	56	6.9	21.7
12A/10	85508	48.71908	-56.50529	4.7	3.9	3.8	935	88	1.78	33	5.6	22.0
12A/10	85509	48.73096	-56.50932	5.4	4.5	3.0	1006	71	1.49	38	5.6	18.8
12A/10	85510	48.73748	-56.52633	8.6	5.2	4.0	1029	74	1.49	36	6.8	20.6
12A/10	85511	48.72671	-56.52288	4.3	4.5	2.5	865	54	1.23	29	5.8	16.5
12A/10	85512	48.74132	-56.51475	4.5	6.2	3.4	791	69	1.43	31	5.5	20.9
12A/16	85528	48.77192	-56.45375	5.4	3.6	2.8	966	62	0.93	29	7.0	18.9
12A/16	85530	48.75706	-56.49099	7.2	3.4	3.2	1381	73	0.99	44	6.7	25.4
12A/09	85531	48.74998	-56.49763	4.1	3.7	3.5	800	88	1.35	16	4.6	24.5
12A/10	85532	48.74397	-56.50778	5.9	4.5	2.9	844	69	1.43	35	5.7	18.7
12A/10	85533	48.73504	-56.50773	6.0	5.1	3.1	723	73	1.45	37	5.7	19.1
12A/09	85534	48.73059	-56.49725	7.4	4.6	4.3	953	85	1.52	37	6.5	22.6
12A/10	85537	48.71065	-56.50229	3.7	3.7	2.9	801	69	1.38	19	5.4	21.9
12A/10	85538	48.70304	-56.51120	3.4	3.6	3.3	934	75	1.61	26	5.5	22.5
12A/16	85558	48.76333	-56.43153	5.2	6.1	5.7	759	84	1.76	23	5.9	34.2
12A/16	85559	48.75966	-56.44481	6.0	5.9	4.0	733	84	1.87	27	5.2	26.9
12A/16	85560	48.75423	-56.45542	4.4	4.5	4.2	767	88	1.99	30	5.5	24.8
12A/09	85562	48.74793	-56.46529	5.3	4.7	3.4	942	78	1.70	34	6.2	20.8
12A/09	85563	48.74168	-56.47536	4.4	4.8	4.0	852	73	1.52	36	6.2	27.0
12A/09	85564	48.73578	-56.48520	8.3	4.3	4.0	1218	84	1.89	43	6.7	23.2
12A/16	85565	48.76462	-56.41878	3.9	5.1	4.0	902	83	1.80	27	5.7	24.5
12A/16	85566	48.75607	-56.41948	4.9	5.2	3.5	1190	78	1.55	32	6.5	24.3
12A/09	85568	48.74452	-56.43925	4.6	4.0	3.2	1183	66	0.72	22	7.0	35.7
12A/09	85569	48.73848	-56.42774	3.6	2.8	2.0	759	44	0.78	17	5.8	22.5
12A/09	85571	48.73591	-56.45216	9.3	3.3	3.2	1034	62	0.80	19	6.4	37.5
12A/15	85619	48.76144	-56.50220	4.9	4.2	4.3	905	88	1.36	21	6.4	38.9
12A/16	85621	48.76939	-56.42775	6.4	5.0	4.0	1256					

tonnes of mineralization, with indicated resources of 7.1% Zn, 3.0% Pb, 0.5% Cu, 110 g/t Ag and 1.7 g/t Au, identified (Messina Minerals Inc., Press Release, June 21, 2007). These deposits are hosted in Ordovician rocks.

MICHAELS POND ANOMALY

Table 5 lists the component samples of the Michaels Pond anomaly. The element association (Mo, U, Cs, P, Rb, K, Pb, Fe, Li) is not immediately suggestive of a documented deposit type, particularly in the apparent absence of intrusive igneous rocks.

The geology of the anomaly is shown in Figures 7 and 10. It is underlain by a thin but complexly folded black shale unit of Ordovician age (the Lawrence Harbour formation; OLH) within a larger unit of volcanogenic sandstone and siltstone (the Stanley Waters formation; OSW). These rocks are intruded by Ordovician gabbro of the Harpoon suite (OH) and flanked to the southeast by Cambrian felsic volcanic and volcaniclastic rocks of the Bindons Pond formation (CB) and mafic volcanic rocks of the Lake Ambrose Formation (CLA); and to the northwest by Cambrian felsic volcanic and volcaniclastic rocks of the Costigan Lake formation (CCL) and Ordovician felsic volcanics and derived sediments of the Wigwam Brook group (OWB), black shale of the Perriers Pond formation (OPP), felsic pyroclastics of the Healy Bay formation (OHB) and calc-alkaline basalt of the Harbour Round Formation (OHRmv2). The outcrop of the Lawrence Harbour formation is shown on a more regional scale with molybdenum in till superimposed (Figure 7). There appears to be a connection between anomalous till geochemistry and the occurrence of this unit, beyond the bounds of the Michaels Pond anomaly itself. The size and intensity of the Michaels Pond anomaly may be due to the complex folding and subsequent concentration of source material in that area. To the northeast, the Lawrence Harbour formation outcrops in a roadcut of the Trans-Canada Highway between Grand Falls-Windsor and Badger, where it has given rise to a significant 'sulphide burn.'

A considerable amount of prospecting has taken place in the past, most recently by Crosshair Exploration, who drilled 16 diamond-drill holes into the same package of rocks that underlies the Michaels Pond anomaly. A composite quartz vein system up to 5 m wide was intersected over a strike length of 230 m, with eleven holes that encountered anomalous Au mineralization. Over the anomaly itself, prior to release of the GSNL's till geochemical data, Crosshair obtained Au assays of up to 796 ppb from a previously unmapped sulphide-bearing gabbro cut by quartz veins. An extensive trenching program was initially postponed due to heavy logging activity in the area and then cancelled prior to the claims being dropped (Morgan *et al*., 2006).

During 2010, the sites of 28 component samples of the Michaels Pond anomaly were revisited and large samples collected. Their locations are shown in Figure 10.

RED INDIAN LAKE BACKGROUND SAMPLES

As a control, re-sampling was carried out at eight sites where the original samples did not return anomalous or elevated REE analyses, although in a region underlain by several volcanosedimentary sequences it proved impossible to identify a group of samples that showed no enrichment in chalcophile base metals. The samples were collected from till overlying a sequence of Upper Cambrian felsic volcanic and volcaniclastic rocks of the Jacks Pond formation (CJP) interspersed with thin units of tholeiitic basalt and andesite of the Bobbys Pond formation (CBPbe and CBPba). The felsic volcanic and volcaniclastic rocks of the Jacks Pond formation are flanked to the south by Middle to Upper Cambrian basalt of the Harmsworth Steady formation (OHS) and to the north by Ordovician Victoria River Mouth formation basalt (ORM) and volcanic and volcaniclastic rocks from the Weasel Pond formation (OWP) that host the sub-economic Jacks Pond volcanogenic massive sulphide deposit.

Sample locations and local geology are shown in Figure 11.

SAMPLING METHOD

The method of sample collection and processing was essentially the same for the entire study area. With the aid of a GPS, the new samples were collected as close as possible to the sites of the original samples but no extra effort was made to locate the previous sample pit. One 20-litre pail of material was collected at each site.

The first stage of the processing was to pass the sampled till through a series of sieves, with the coarsest material (greater than 25 mm) being retained for pebble counting and the finest (less than 1 mm) being panned. As most REE and base-metal sulphide minerals have densities in excess of 4.5 it is to be expected that the panning process will concentrate these minerals and facilitate analysis.

Panning was carried out with a 'Goldhound' rotary panner (Plate 1), powered by a 12 volt battery and augmented by a battery-powered water pump. The former device consists of an inclined, rotating metal cylinder with a spiral groove in the base. As the cylinder rotates, heavy minerals assisted by a steady flow of water sink to the bottom of the slurry and are drawn along the spiral groove, to the centre of the cylinder where they fall into a small holding pail. The lighter minerals are gradually removed, in suspension, over the edge of the cylinder. The panner was set up in a plastic wading pool, to which the panning water was drained and from which the water was drawn by a battery-powered pump, in a closed system. This minimized the clay-laden water that was discarded when the work was complete.

The efficiency of the Goldhound in concentrating the heavy minerals from the tills has yet to be evaluated. Certainly, when tills associated with volcanic rocks from study areas in central Newfoundland were being processed, it was possible to observe fine-grained magnetite being removed in suspension with the light minerals. For this reason, samples of both heavies and lights have been retained, and also for the purpose of comparison. After drying and sieving these samples to remove adhered clay particles, the heavy- and light-mineral fractions will be split and one half submitted for neutron-activation analysis. Prompted by the results of the latter, selected splits will be examined for their mineral content.

CONCLUSIONS

A program of till sampling was completed as follow-up to four till anomalies identified during earlier programs by the GSNL. In all cases, the anomalies can be tentatively ascribed to a specific mapped unit but this requires confirmation, and the exact mode of occurrence within each host unit will need to be identified to evaluate the economic potential of anomaly sources.

Bulk samples of till were processed to generate coarse fractions, and panned concentrates were prepared from the

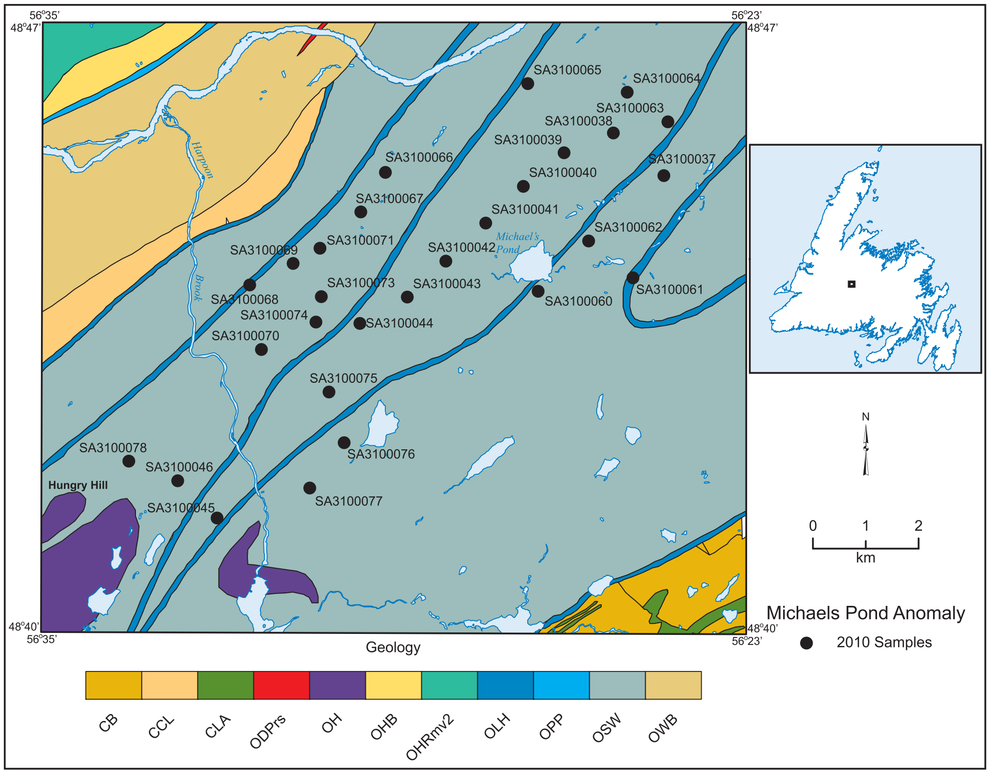

Figure 10. *Geology of Michaels Pond anomaly. CB: Bindon's Pond formation; CCL: Costigan Lake formation; CLA: Lake Ambrose formation; ODPrs: Dragon Pond formation; OH: Harpoon Suite; OHB: Healy Bay formation; OHRmv2: Harbour Round Formation; OLH: Lawrence Harbour formation; OPP: Perrier's Pond formation; OSW: Stanley Waters formation; OWB: Wigwam Brook group. Geology digitized from Rogers* et al. *(2005a, b, c). Locations of 2010 samples over Michaels Pond anomaly are indicated.*

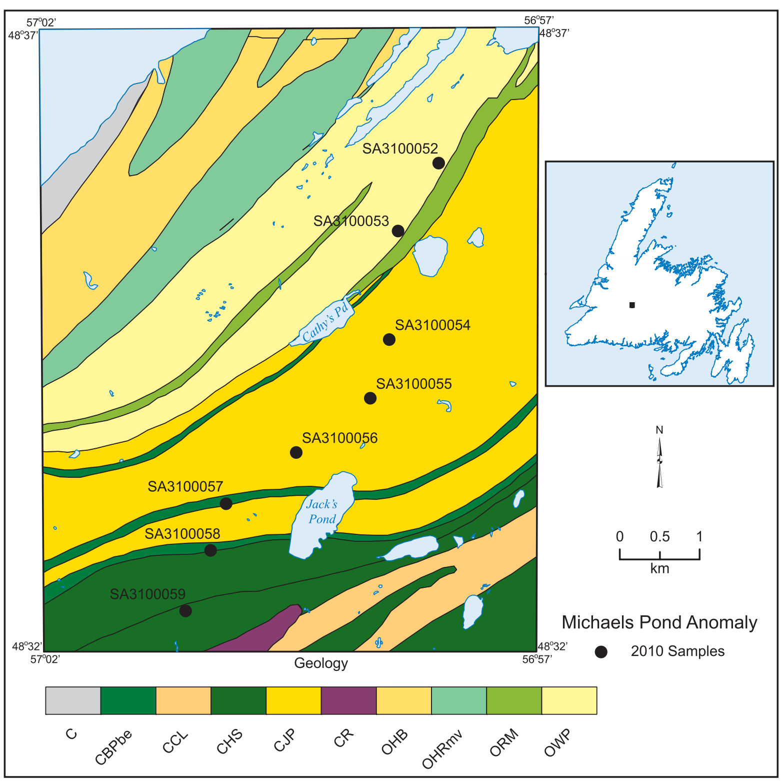

Figure 11. *Red Indian Lake background sample locations. C: Shanadithit formation; CBPbe: Bobby's Pond formation; CCL: Costigan Lake formation; CHS: Harmsworth Steady formation; CJP: Jack's Lake formation; CR: Roebucks intrusive suite; OHB: Healy Bay formation; OHRmv: Harbour Round Formation; ORM: Victoria River mouth formation; OWP: Weasel Pond formation.*

Plate 1. *Panning a till sample using the Goldhound. The panned concentrate falls through the centre of the panner and accumulates in the small plastic pail. Light minerals are washed over the edge of the panner into the large pail along with water, which returns to the holding pool. Panning water is continually recycled by an electric pump.*

fine fractions. Work in early 2011 will involve pebble counting of the coarse fractions, and geochemical analysis and mineral concentrate examination of the fine fractions.

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