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OPEN FILE 2454

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A COMPILATION OF CANADIAN RELATIVE SEA-LEVEL DATA FOR USE IN CONSTRAINING GLACIAL ISOSTATIC ADJUSTMENT MODELS

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ABSTRACT

Because of the large mass of the Laurentide Ice Sheet, Canada has experienced and continues to experience the largest postglacial vertical motion in the world. As relative sea-level histories record the motion, it was deemed desirable to collect together a large number of Canadian relative sea-level histories in a single source. In all, 115 sites at which relative sea-level data have been collected are compiled in this work. Radiocarbon techniques and geological evidence for relict shorelines are briefly reviewed.

RÉSUMÉ

En raison de la masse considérable de l'Inlandsis laurentidien, le Canada a connu dans le passé et présente encore aujourd'hui les mouvements verticaux postglaciaires les plus importants du globe. Puisque l'évolution du niveau marin relatif rend compte de ces mouvements, il est apparu utile de regrouper en une seule source un grand nombre de données permettant de reconstituer l'évolution du niveau marin relatif en différents points du Canada. Les données se rapportant au niveau marin relatif de 115 sites ont été regroupées dans la présente étude. Les techniques de datation au radiocarbone et les données géologiques se rapportant aux lignes de rivage reliques sont brièvement passées en revue.

INTRODUCTION

Secular variations in sea level are usually measured with respect to the land and so the phrase "relative sea level" has been widely adopted (abbreviated here as RSL). The collection of RSL data is a primary research objective in itself, but the data are also the raw material for subsequent analysis by geologists, geophysicists, oceanographers, climatologists, archaeologists, and many others. Sea-level variations are caused by many different mechanisms which operate over various timescales (e.g., Fairbridge and Krebs 1962). Earthquakes occur over extremely short timescales and, if the right conditions are present, they can change the relative sea level in a localized area. On somewhat longer timescales, meteorological and astronomical effects also induce substantial changes in sea level. The El Niño-Southern Oscillation phenomenon can effect sea level over periods of years (e.g., Quinn et al. 1987). As the average temperature of the oceans has increased over the last century (e.g., Jones et al. 1986), the oceans have expanded and sea level risen during this period (Gornitz et al. 1982). Over timescales of several thousand years, glacial isostatic adjustment and meltwater redistribution are the dominant mechanisms (e.g., Tushingham and Peltier 1991) and cause large variations in global sea level (>100 m). It is these latter mechanisms on which this work is focused.

GEOLOGICAL EVIDENCE OF VARIATIONS IN SEA LEVEL

Because Canada was covered by the large Laurentide Ice Sheet, the extent and magnitude of postglacial adjustment is larger over Canada than anywhere else in the world. To measure this adjustment, RSL data have been collected from many sites across Canada. The RSL data from each site was inferred from geological samples collected in the field, usually shells or other datable material found in or near relict shorelines located at various elevations above or below present-day sea level.

Wave action, marine deposition, and terrestrial deposition are the three different processes which form features that may indicate a relict shoreline. Strandlines (or beach lines) are an example of a wave-action feature and are usually considered good indicators of relict shorelines. One of the most striking examples of a flight of strandlines is found near Cape Storm on southernmost Ellesmere Island (Blake 1975). Related to strandlines, pumice lines are invaluable in constructing a regional pattern of sea-level change. Pumice from a single volcanic event can often be mapped over a wide spatial area and its age can be estimated by dating material found immediately above and below the pumice layer. Pumice distribution in the Queen Elizabeth Islands was employed by Blake (1970) to aid in constructing an uplift map for this region. Another feature is wave-cut terraces such as those found on Broughton Island, near Baffin Island (England and Andrews 1973). Unfortunately terraces are difficult, if not impossible, to date accurately. The presence of boulder barricades allow an upper estimate of relict shoreline positions, but are also difficult to date. Complications such as rock falls, sea-ice movement, and the fact that a few boulder barricades are found below sea level lead to further uncertainties in the sea level estimate. Marine depositional features include deltas, water-sorted muds, and rolled cobbles. Deltas are usually good indicators of sea level if they can be identified as marine deltas and if they do not subside when exposed. Such a delta was employed in the determination of the RSL history of Thores River, northernmost Ellesmere Island (Tushingham 1991). Land deposits and features, which include submerged river channels, perched boulders, submerged eolian sand, and unsorted ground moraines, are commonly only used to estimate the marine limit in such areas due to the difficulty in establishing an age for the feature. Submerged fluvial features were used by Forbes (1980) in his study of the RSL history of the southern Beaufort Sea. Some land deposits, such as submerged peat and stumps of salt-killed trees, are more useful as they can be easily dated. For example, Grant (1970) used both of these type of deposits in his reconstruction of the RSL history of the Bay of Fundy.

Archaeological evidence can also be employed to estimate sea level, as it was in the Bay of Fundy. Grant (1970) used the elevation of shell heaps of abandoned Indian encampments on the southwest coast of Nova Scotia to supplement his geological evidence of sea-level change. The elevation of Eskimo camps were employed in a comprehensive study of Arctic sea level by Andrews et al. (1971). Even fortifications built in historical times, such as Fortress Louisbourg on Cape Breton Island (Grant 1970), reveal a change in relative sea level. Archaeological features may be modified by a later civilization and careful consideration must be given to the interpretation of the structure's function.

RADIOCARBON ANALYSIS

Regardless of the geological feature being examined, a method of estimating its age is clearly required in order to use the feature to constrain the RSL history. Early methods such as varve chronology and pollen analysis (palynology) have been superceded by radiocarbon analysis. To obtain a radiocarbon estimate of the age of the RSL indicator feature, any datable material found in or near the feature (such as a marine shell, a piece of driftwood, a drowned tree stump, a whale bone or peat) is collected and analysed. It is essential that the material can be stratigraphically associated with the RSL indicator feature, and in such a way that the timing of the deposition of the material corresponds to the time of the formation of the feature. In the field, this is often difficult to ascertain.

Radiocarbon analysis is concerned with the decay of the radioactive isotope ^{14}C. When cosmic rays strike the Earth's upper atmosphere, neutrons are created and soon collide with nitrogen molecules producing ^{14}C. The ^{14}C is oxidized to CO_2, which can become incorporated in living matter until the organism dies. The radioactive ^{14}C undergoes beta decay, and conventional radiocarbon dating techniques involve counting the number of beta decays in a given time interval. All radiocarbon dates were obtained in this manner from 1946 to 1977. The conventional method has however a serious limitation: the observed beta-ray counting rate from contemporary carbon of biological origin is only about 15 decays per minute per gram (Libby 1955), which means that during the usual three-day analysis only one-millionth of the total ^{14}C in the sample has been counted (Stuiver 1978). For beta-counting to be practical, gram-sized samples must be analysed over two to three days. Routinely after pretreatment, sample size is between 5 and 20 g (W. Blake, Jr., personal communication, 1990), which represents a fairly large sample that can be expensive to obtain or, more likely, just not available. Commonly, many samples from a single site must be collected to have enough material for the conventional method to analyse, but this means that any age estimate is only the age of the aggregate sample which of course may be misleading.

A recent development has allowed the actual number of ^{14}C atoms to be counted using a process called accelerator mass spectrometry (e.g., Litherland 1980). This new method has important advantages over conventional beta-counting in that it can date much smaller samples with less uncertainty and in a shorter time. The improvement in dating smaller samples is primarily due to the fact that a far greater fraction of the carbon atoms in the sample are counted, not just those which decay during the period of analysis. The major implication for RSL studies is that many individual samples from a particular site can now be dated, thus allowing more certainty in the age of the relict sea-level feature. Furthermore, RSL histories can now be developed for sites with sparse datable material.

Whereas pollen analysis and varve chronology produce age estimates in sidereal (or calendar) years, the radiocarbon methods do not. Due to solar fluctuations the radiocarbon timescale is not the same as the sidereal timescale, so depending on the nature of the research a radiocarbon conversion curve may be required. The curve presented in Figure 1 from the present back to 10 000 ^{14}C yr BP is based on tree-ring studies of Irish Oaks by Pearson et al. (1986) and Becker et al. (1991) and a model of ^{14}C trends of Stuiver et al. (1986). A recent study of Barbadian corals by Bard et al. (1990) has extended the curve back to 19 000 ^{14}C yr BP. They compared radiocarbon dates of corals to dates obtained from Uranium-Thorium analysis and found the correction from radiocarbon years to sidereal years grew larger as the dates became older. The implication of this phenomenon on the chronology of sea-level changes has been discussed by Tushingham and Peltier (1992a).

CANADIAN RELATIVE SEA-LEVEL DATA

Early work in constructing Canadian RSL histories using radiocarbon-dated relict shorelines was undertaken in the early 1960s by Frankel and Crowl (1961) on Prince Edward Island, Blake (1963) in Bathurst Inlet and Henoch (1964) on Melville Island. Since then, and especially over the last decade, the quantity and quality of Canadian RSL data have increased dramatically.

The first step in compiling data for Canadian RSL histories began by examining three general references (Walcott 1972; Bloom 1977; Newman 1986), and from these references the original sources of individual radiocarbon-controlled RSL histories were reviewed. Many additional references not cited in these general references were also examined and their data extracted. Tushingham (1989) compiled RSL data from 392 sites from around the world of which 86 were located in Canada. This global data set is available on microfiche (Tushingham and Peltier 1992b). The review process has continued and an additional 29 Canadian sites with RSL data have been compiled and several previous sites have been revised. The 115 sites constituting this expanded Canadian data set have been grouped into their respective Provinces and Territories (listed from west to east and south to north). Elevations for these ancient sea levels and their associated *uncorrected* radiocarbon ages are listed in Appendix A, with the references for the sites provided in Appendix B. The excellent distribution of sites is illustrated in Figure 2. Data from six sites, each with a predicted RSL curve based on the deglaciation model ICE-3G (Tushingham and Peltier 1991), are presented in Figure 3 in order to show the variety of shapes of curves in Canada. Most of the data presented here aided in the glacial isostatic adjustment modelling process that developed ICE-3G.

When dealing with such a large amount of data obtained from numerous sources, it was necessary to ensure overall consistency and homogeneity of the compilation. To this end, elevations were always taken in metres above high tide and ages in radiocarbon years before present. If the data were scattered over a small area (e.g., Keewatin and Northwestern Newfoundland) the geographical centre of the area was chosen as the site location. At some locations the quantity of data was sufficient that only elevations at thousand-year intervals were reported (e.g., Cape Storm and Cornwallis Island). It was also necessary to be consistent in handling the uncertainties in the sample ages and elevations. Upon reviewing Newman (1986) and Litherland et al. (1980), the accuracy of conventional radiocarbon dating was taken to be ±3%. Accelerator mass spectrometry is often used to an accuracy of approximately ±0.3% (Beukens et al. 1986), but as yet only a few samples have been dated by this method. To incorporate uncertainties in the radiocarbon conversion curve, the uncertainty in the ages was increased to ±4% with a minimum uncertainty of ±200 yr. Uncertainty in the elevation may be due to the direct error in the measuring of the altitude of the sample, the position of high tide, or more importantly the potential uncertainty in geological interpretation. From the twenty-eight Canadian RSL curves compiled by Walcott (1972), the range of uncertainty in elevation was estimated to be ±15%, with a minimum error of ±1 m assigned due to wave action and instrument error. If the original reference cited larger uncertainties in either the age or the elevation, those values were reported. The uncertainty assigned to the elevation of the sample will, hopefully, include the effect of any minor tectonic uplift or subsidence. To minimize these uncertainties, extreme care must be made in selecting samples and inferring associated sea levels. It is now possible with the advent of accelerator mass spectrometry to date individual samples from a single deposit instead of estimating the age of an aggregate sample, and this may allow anomalous samples to be immediately omitted from the average age of the deposit.

It is hoped that this compilation of Canadian relative sea-level data will help to focus attention on regions in Canada where more work is needed to establish well-defined relative sea-level histories.

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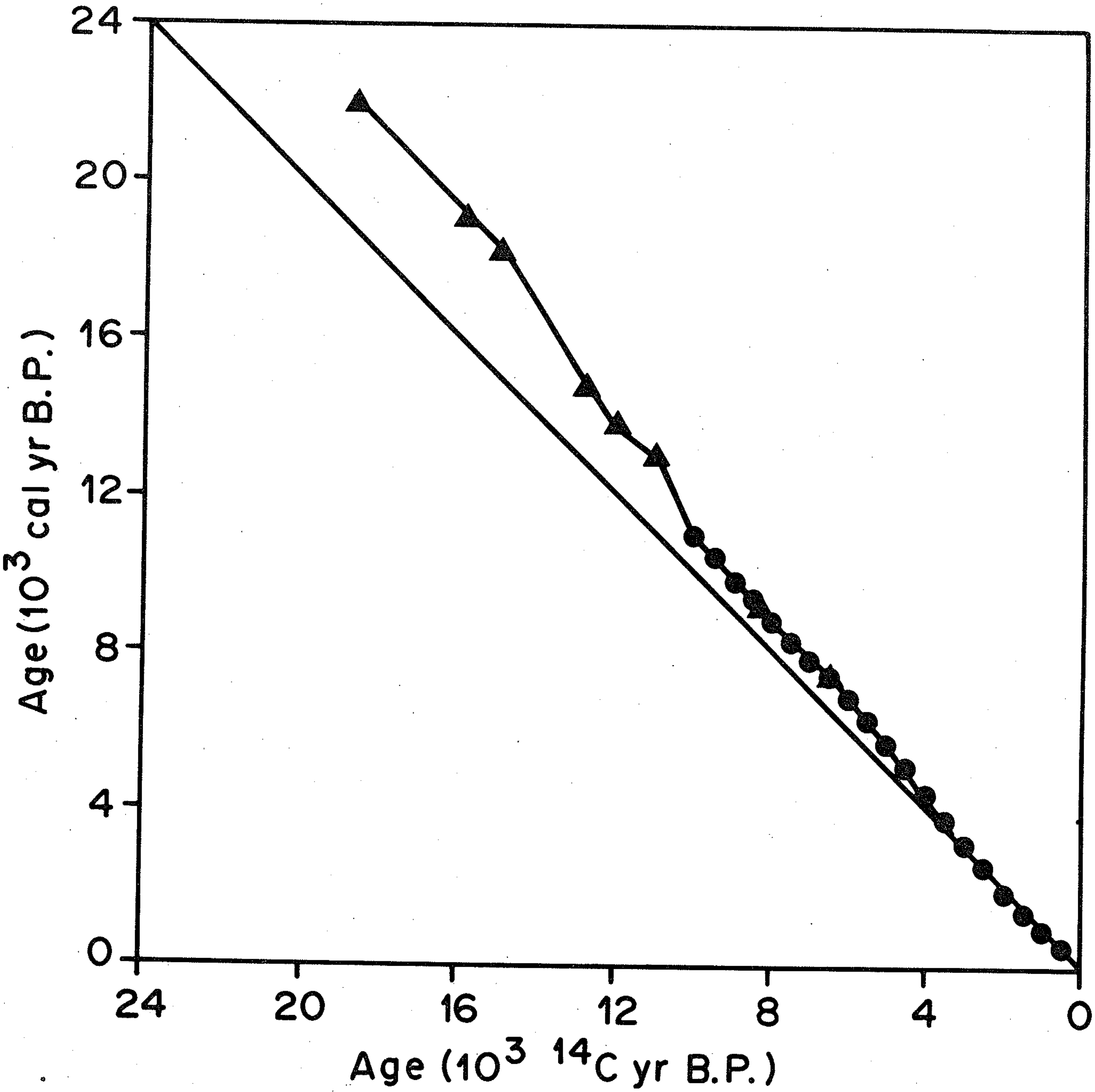

Figure 1. Radiocarbon conversion curve. This curve, which converts radiocarbon years to sidereal years, was based on tree-ring studies (shown as dots) (Pearson et al. 1986; Becker et al. 1991) and a model of ^{14}C trends (Stuiver et al. 1986). An extension to 19 000 ^{14}C yr BP was obtained from the U-Th analysis of Barbadian corals (shown as triangles) by Bard et al. (1990).

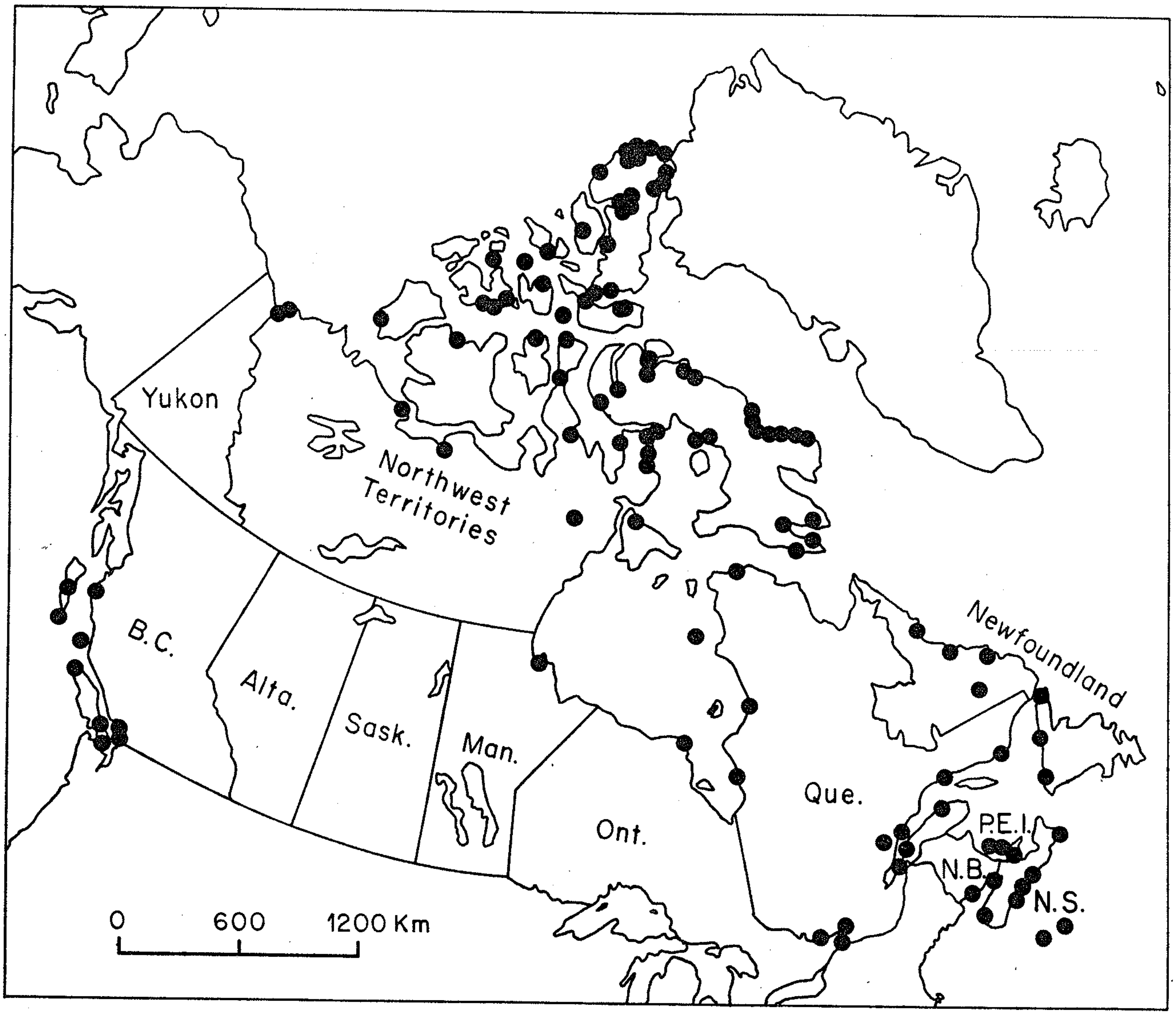

Figure 2. The locations of sites across Canada at which relative sea-level histories have been constructed.

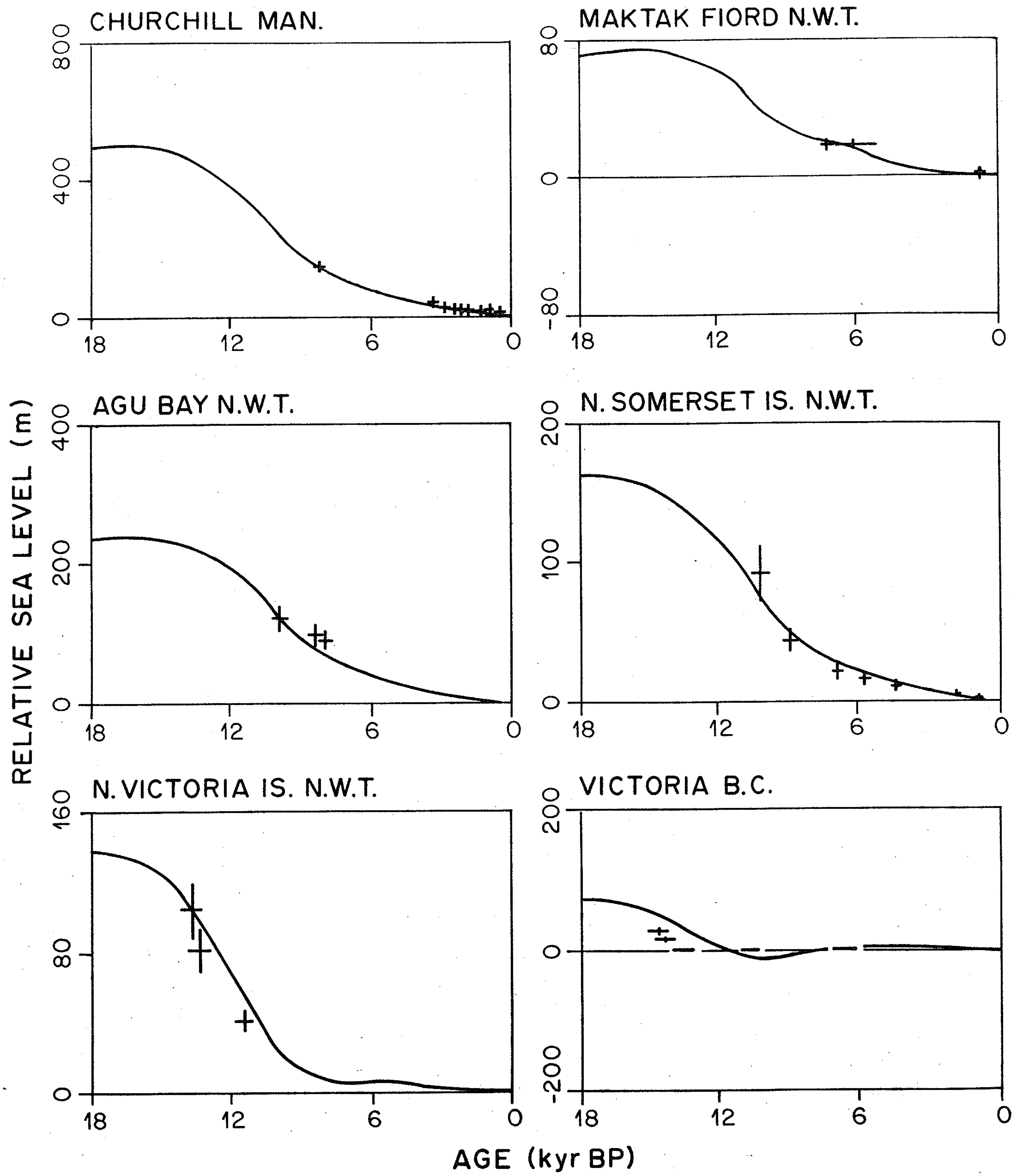

Figure 3. Relative sea-level data for six sites. The curve shows the prediction at each site by the deglaciation model ICE-3G (Tushingham and Peltier 1991). The uncertainties in elevation and age are ±15% and ±4%, respectively. Ages have been converted to sidereal year using the curve presented in Figure 1.

APPENDIX A

RELATIVE SEA LEVEL DATA

FIRST LINE: Site no., latitude (north), longitude (west), no. of data points, site.

SUBSEQUENT LINES: Age (^{14}C kyr BP), error (kyr), elevation (m asl), error (m).

BRITISH COLUMBIA

1	54.3	130.2	3		PRINCE RUPERT, B.C.
	5.0	.2	4.0	1.0	
	6.0	.2	13.0	1.9	
	7.0	.2	32.0	4.8	
2	53.9	132.7	10		QUEEN CHARLOTTE ISLANDS, B.C.
	1.0	.2	2.0	1.0	
	2.0	.2	3.0	1.0	
	3.0	.2	4.0	1.0	
	4.0	.2	8.0	1.1	
	5.0	.2	11.0	1.6	
	6.0	.2	11.0	1.6	
	7.0	.2	11.0	1.6	
	8.0	.3	12.0	1.8	
	9.0	.3	8.0	1.2	
	10.0	.4	0.0	1.0	
3	52.0	131.0	4		ANTHONY ISLAND, B.C.
	1.0	.2	2.5	1.0	
	1.6	.2	3.7	1.0	
	1.8	.2	5.3	1.0	
	3.4	.2	12.7	1.9	
4	51.0	128.0	8		QUEEN CHARLOTTE SOUND, B.C.
	4.0	.2	-3.0	1.0	
	5.0	.2	-3.0	1.0	
	6.0	.2	-2.0	1.0	
	7.0	.2	1.0	1.0	
	8.0	.3	5.0	1.0	
	9.0	.3	10.0	1.4	
	10.0	.4	18.0	2.7	
	11.0	.4	32.0	4.8	

5	50.6	127.0	2		NORTHERN VANCOUVER ISLAND, B.C.
	12.3	.4	53.0	7.9	
	12.9	.5	17.0	2.5	
6	49.0	124.0	6		EASTERN VANCOUVER ISLAND, B.C.
	4.6	.2	15.0	2.2	
	8.7	.3	1.5	1.0	
	11.5	.4	37.0	5.5	
	11.9	.4	25.0	3.7	
	12.2	.4	49.0	7.3	
	12.5	.5	154.0	23.0	
7	48.5	123.3	5		VICTORIA, B.C.
	5.4	.2	2.0	1.0	
	9.3	.3	1.0	1.0	
	11.7	.4	2.0	1.0	
	12.4	.4	17.0	2.5	
	12.7	.5	28.0	4.2	
8	49.2	123.0	5		FRAZER LOWLANDS, B.C.
	7.3	.2	9.0	1.3	
	9.4	.3	11.0	1.6	
	11.0	.4	38.0	5.6	
	11.5	.4	92.0	13.7	
	11.9	.4	132.0	19.7	
9	49.2	123.0	6		FRASER DELTA, B.C.
	.4	.2	0.0	1.0	
	2.7	.2	0.0	1.0	
	4.8	.2	-2.0	1.0	
	6.2	.2	-4.0	1.0	
	7.0	.3	-8.0	1.2	
	8.0	.3	-12.0	1.8	

MANITOBA

10	58.0	95.0	8		CHURCHILL, MAN.
	0.4	.2	3.7	1.0	
	1.0	.2	6.4	1.0	
	1.2	.2	10.7	1.0	
	2.1	.2	21.9	1.0	
	2.4	.2	27.4	4.1	
	2.8	.2	38.1	5.7	
	3.2	.2	37.8	5.7	
	7.3	.3	141.7	21.3	

ONTARIO

11	55.0	82.5	6		CAPE HENRIETTA MARIA, ONT.
	1.0	.2	16.0	3.0	
	2.0	.2	34.0	5.0	
	3.0	.2	51.0	7.6	
	4.0	.2	69.0	10.3	
	6.0	.2	115.0	17.2	
	7.0	.2	138.0	20.6	
12	45.5	76.0	3		OTTAWA, ONT.
	9.0	.3	54.0	26.0	
	10.0	.4	100.0	20.0	
	11.0	.4	148.0	22.1	
13	45.3	74.6	1		CORNWALL, ONT.
	9.9	.3	107.0	16.0	

QUEBEC

14	45.5	74.0	5		MONTREAL, QUE.
	7.0	.2	5.0	5.0	
	8.0	.3	37.0	10.0	
	9.0	.3	80.0	11.9	
	10.0	.4	123.0	18.4	
	11.0	.4	166.0	25.0	
15	47.0	70.5	10		MONTMAGNY, QUE.
	1.0	.2	1.0	1.0	
	2.0	.2	2.0	1.0	
	3.0	.2	3.0	1.0	
	4.0	.2	5.0	1.0	
	5.0	.2	10.0	1.5	
	6.0	.2	0.0	1.0	
	7.0	.3	-6.0	1.0	
	8.0	.3	3.0	1.0	
	9.0	.4	20.0	3.0	
	9.8	.4	38.0	5.7	
16	48.0	69.0	5		RIVIÉRE DU LOUP, QUE.
	7.0	.2	10.0	10.0	
	8.0	.3	27.0	15.0	
	9.0	.3	50.0	20.0	
	10.0	.4	75.0	25.0	
	11.0	.4	107.0	35.0	
17	48.5	68.5	6		RIMOUSKI, QUE.

	2.2	.2	5.0	2.0	
	9.0	.3	33.0	10.0	
	10.0	.4	47.0	15.0	
	11.0	.4	65.0	20.0	
	12.0	.4	98.0	40.0	
	13.0	.5	124.0	50.0	
18	48.5	72.0	3		LAC ST. JEAN, QUE.
	8.6	.3	123.0	18.5	
	9.4	.3	160.0	24.0	
	9.6	.3	120.0	18.0	
19	49.0	66.0	7		GASPÉ, QUE.
	6.0	.2	5.0	1.0	
	7.0	.2	6.0	1.0	
	8.0	.3	12.0	1.8	
	9.0	.3	18.0	2.7	
	10.0	.4	28.0	4.2	
	11.0	.4	37.0	5.5	
	12.0	.4	50.0	7.4	
20	50.2	65.5	2		MOISIE, QUE.
	6.4	.2	27.0	4.0	
	8.3	.3	48.0	7.1	
21	50.0	60.0	1		NORTHERN GULF OF ST. LAWRENCE, QUE.
	7.5	.3	80.0	12.0	
22	53.0	79.0	7		JAMES BAY, QUE.
	1.0	.2	15.0	2.2	
	2.0	.2	30.0	4.5	
	3.0	.2	50.0	7.4	
	4.0	.2	80.0	11.9	
	5.0	.2	105.0	15.7	
	6.0	.2	155.0	23.2	
	7.0	.2	230.0	34.5	
23	56.2	75.5	10		RICHMOND GULF, QUE.
	.7	.2	10.0	1.4	
	1.5	.2	20.0	3.0	
	1.8	.2	27.0	4.0	
	2.4	.2	33.0	4.9	
	3.2	.2	60.0	8.9	
	3.7	.2	80.0	11.9	
	4.7	.2	125.0	18.7	
	5.6	.2	145.0	21.7	
	6.3	.3	197.0	29.5	
	7.5	.3	256.0	38.4	

24	62.0	75.0	6		UNGAVA PENINSULA, QUE.
	2.0	.2	3.0	1.0	
	3.0	.2	6.0	2.0	
	4.0	.2	13.0	3.0	
	5.0	.2	29.0	4.3	
	6.0	.2	51.0	7.6	
	7.0	.2	110.0	16.4	

PRINCE EDWARD ISLAND

25	47.0	64.0	6		TIGNISH, P.E.I.
	2.0	.2	-3.0	1.0	
	3.0	.2	-6.0	3.0	
	8.0	.3	-8.0	15.0	
	10.0	.4	1.0	11.0	
	12.0	.4	12.0	9.0	
	13.0	.5	20.0	9.0	
26	46.0	62.4	6		NORTHUMBERLAND STRAIT, P.E.I.
	3.0	.2	-12.0	4.0	
	4.6	.2	-15.0	5.0	
	5.4	.2	-21.0	7.0	
	7.3	.2	-22.0	10.0	
	9.7	.4	-45.0	12.0	
	10.5	.4	-35.0	13.0	
27	46.3	63.3	5		CHARLOTTETOWN, P.E.I.
	1.0	.2	-1.2	1.0	
	1.5	.2	-2.4	1.6	
	2.0	.2	-3.2	2.4	
	3.0	.2	-6.4	4.0	
	4.0	.2	-10.0	5.0	

NOVA SCOTIA

28	46.0	60.0	1		CAPE BRETON ISLAND, N.S.
	8.5	.3	-25.0	3.8	
29	45.0	63.0	5		CHEZZETCOOK, N.S.
	1.0	.2	-2.0	1.0	
	2.0	.2	-8.0	1.1	
	3.6	.2	-9.0	1.3	
	5.1	.2	-12.0	1.8	
	6.7	.2	-13.0	1.9	
30	44.7	63.7	1		HALIFAX, N.S.
	10.5	.5	-45.0	6.8	

31	44.5	64.3	2		LUNENBURG BAY, N.S.
	5.8	.2	-22.0	3.3	
	7.1	.2	-28.0	4.2	
32	43.9	66.0	5		CHEBOGUE HARBOUR, N.S.
	1.4	.2	-2.0	1.0	
	2.5	.2	-3.3	1.0	
	2.6	.2	-4.5	1.0	
	2.7	.2	-5.7	1.0	
	3.2	.2	-7.0	1.0	
33	45.0	65.0	9		BAY OF FUNDY, N.S.
	1.3	.2	-2.3	1.0	
	2.5	.2	-4.0	1.0	
	3.1	.2	-6.0	1.0	
	3.6	.2	-8.5	1.2	
	5.0	.2	-13.0	2.5	
	6.0	.2	-15.0	2.5	
	11.0	.4	-14.0	6.0	
	12.0	.4	5.0	9.0	
	13.0	.5	29.0	11.0	
34	45.2	64.3	3		KINGSPORT, N.S.
	2.4	.2	-4.0	1.0	
	2.9	.2	-6.5	1.0	
	4.4	.2	-9.5	1.4	
35	46.5	65.5	3		GRANVILLE FERRY, N.S.
	2.7	.2	-4.0	1.0	
	3.0	.2	-6.0	1.0	
	3.1	.2	-10.0	1.5	
36	43.8	60.6	1		SABLE ISLAND BANK, N.S.
	14.0	.9	-110.0	16.5	
37	43.5	63.7	1		LaHAVE BASIN, N.S.
	13.0	.5	-86.0	12.9	

NEW BRUNSWICK

38	45.9	64.2	4		FORT BEAUSEJOUR, N.B.
	1.3	.2	-2.2	1.0	
	2.2	.2	-4.3	1.0	
	2.6	.2	-6.0	1.0	
	3.8	.2	-11.5	1.7	
39	45.7	64.7	4		MARY'S POINT, N.B.
	2.2	.2	-3.3	1.0	
	3.1	.2	-5.0	1.0	

	3.2	.2	-6.0	1.0	
	3.6	.2	-10.0	1.5	
40	45.3	66.0	6		ST. JOHN, N.B.
	5.6	.2	-20.0	3.0	
	7.3	.3	-23.0	3.5	
	12.4	.5	33.0	5.0	
	12.7	.5	45.0	6.8	
	13.3	.5	42.0	6.3	
	13.6	.5	45.0	6.8	

NEWFOUNDLAND

41	51.5	56.5	9		NORTHWESTERN NEWFOUNDLAND
	1.0	.2	1.0	1.0	
	2.0	.2	2.5	1.0	
	3.0	.2	4.0	2.0	
	4.0	.2	6.0	2.0	
	5.0	.2	8.0	3.0	
	8.0	.3	30.0	8.0	
	9.0	.3	41.0	14.0	
	10.0	.4	57.0	13.0	
	12.0	.4	98.0	18.0	
42	50.2	57.6	1		COW HEAD, NFLD.
	8.3	.3	8.0	1.2	
43	48.5	58.7	9		ST. GEORGE'S BAY, NFLD.
	2.3	.2	-1.8	1.0	
	2.8	.3	-2.8	1.0	
	5.8	.2	-18.5	7.5	
	7.3	.3	-5.0	5.0	
	9.4	.4	-3.0	3.0	
	10.6	.4	14.0	13.0	
	11.9	.5	27.0	4.1	
	12.6	.5	19.0	8.0	
	13.6	.5	39.0	5.9	

LABRADOR, NFLD.

44	53.0	60.0	7		GOOSE BAY, NFLD.
	1.6	.2	9.1	1.3	
	2.0	.2	9.1	1.3	
	2.1	.2	9.1	1.3	
	3.1	.2	24.0	3.6	
	4.8	.2	29.0	4.4	
	5.3	.2	33.0	4.9	
	6.0	.2	110.4	16.4	

45	54.2	58.0	7		HAMILTON INLET, NFLD.
	2.3	.2	4.1	1.0	
	2.5	.2	5.0	1.0	
	3.9	.2	6.7	1.0	
	4.5	.2	6.7	1.0	
	5.1	.2	13.8	2.1	
	5.4	.2	10.7	1.6	
	8.6	.3	50.0	7.4	
46	55.8	60.6	5		HOPEDALE, NFLD.
	0.4	.2	5.0	1.0	
	1.5	.2	5.8	1.0	
	2.0	.2	5.8	1.0	
	3.4	.2	12.0	1.8	
	5.1	.2	27.6	4.1	
47	56.7	61.3	6		NAIN, NFLD.
	1.4	.2	3.0	1.0	
	2.7	.2	8.5	1.3	
	3.3	.2	10.1	1.5	
	3.7	.2	11.1	1.7	
	6.1	.2	24.2	3.6	
	7.1	.3	40.8	6.1	

NORTHWEST TERRITORIES

48	64.5	95.0	4		KEEWATIN, N.W.T.
	4.0	.2	60.0	8.9	
	5.0	.2	77.0	11.5	
	6.0	.2	103.0	15.4	
	7.0	.2	140.0	20.9	
49	59.8	80.3	6		OTTAWA ISLANDS, N.W.T.
	1.2	.2	4.0	1.0	
	3.5	.2	15.0	6.0	
	5.0	.2	51.0	7.7	
	5.9	.2	76.0	11.3	
	6.6	.2	97.0	14.6	
	7.4	.3	148.0	22.2	
50	64.5	84.0	7		SOUTHAMPTON ISLAND, N.W.T.
	1.0	.2	5.0	2.0	
	2.1	.2	17.0	2.0	
	2.7	.2	22.0	2.0	
	3.7	.3	36.0	6.0	
	5.3	.4	83.0	12.5	
	6.6	.3	117.0	17.6	

	7.0	.3	130.0	19.5	
51	68.2	82.6	6		AJAQUTALIK RIVER, N.W.T.
	1.6	.2	5.0	1.0	
	3.6	.2	14.0	2.1	
	4.2	.2	26.0	3.9	
	4.6	.2	35.0	5.3	
	5.0	.2	60.0	9.0	
	6.2	.2	90.0	13.5	
52	68.5	82.8	6		KINGORA RIVER, N.W.T.
	2.4	.2	8.0	1.2	
	4.0	.2	21.0	3.2	
	5.1	.2	35.0	5.3	
	5.6	.2	53.0	8.0	
	6.2	.2	43.0	6.4	
	6.5	.3	113.0	17.0	
53	69.3	85.3	7		WESTERN MELVILLE PENINSULA, N.W.T.
	3.0	.2	10.0	5.0	
	4.0	.2	18.0	5.0	
	5.0	.2	29.0	5.0	
	6.0	.2	69.0	10.4	
	7.0	.3	141.0	21.2	
	8.0	.3	165.0	24.8	
	9.0	.4	203.0	30.5	
54	69.5	82.0	7		NORTHERN MELVILLE PENINSULA, N.W.T.
	.6	.2	4.0	1.0	
	1.1	.2	7.0	1.0	
	2.9	.2	20.0	3.0	
	4.0	.2	24.0	3.6	
	6.9	.3	127.0	19.1	
	8.0	.3	168.0	25.1	
	8.6	.3	190.0	28.5	
55	69.0	82.0	7		IGLOOLIK ISLAND, N.W.T.
	1.0	.2	6.0	2.0	
	2.0	.2	14.0	3.0	
	3.0	.2	24.0	5.0	
	4.0	.2	36.0	6.0	
	5.0	.2	53.0	13.0	
	6.0	.2	80.0	20.0	
	7.0	.2	135.0	20.2	
56	69.0	92.0	5		BOOTHIA PENINSULA, N.W.T.
	4.0	.2	22.0	3.3	
	5.0	.2	29.0	4.3	
	6.0	.2	40.0	5.9	

	7.0	.2	52.0	8.0	
	8.0	.3	100.0	25.0	
57	67.5	107.0	6		BATHURST INLET, N.W.T.
	2.0	.2	8.0	5.0	
	3.0	.2	16.0	5.0	
	4.0	.2	27.0	7.0	
	5.0	.2	44.0	11.0	
	7.0	.2	95.0	15.0	
	8.0	.3	145.0	25.0	
58	68.5	116.0	3		CAPE KRUSENSTERN, N.W.T.
	9.6	.4	105.3	15.8	
	10.3	.4	90.0	13.5	
	11.2	.4	125.0	18.8	
59	70.0	133.0	4		TUKTOYAKTUK PENINSULA, N.W.T
	3.7	.2	-20.5	3.0	
	6.6	.2	-29.6	4.4	
	7.7	.3	-41.7	6.2	
	8.8	.3	-41.9	6.2	
60	69.0	136.0	5		MACKENZIE DELTA, N.W.T.
	1.4	.2	-3.0	1.0	
	2.7	.2	-3.0	1.0	
	3.4	.2	-1.0	1.0	
	6.8	.3	-34.0	5.1	
	12.6	.9	-55.0	8.3	
61	72.8	93.6	6		SOUTHERN SOMERSET ISLAND, N.W.T.
	4.0	.2	18.0	3.0	
	5.0	.2	22.0	5.0	
	6.0	.2	30.0	5.0	
	7.0	.2	36.0	6.0	
	8.0	.3	47.0	7.0	
	9.0	.3	90.0	23.0	
62	74.0	93.7	7		NORTHERN SOMERSET ISLAND, N.W.T.
	1.0	.2	3.0	2.0	
	2.0	.2	6.0	2.0	
	4.0	.2	12.0	4.0	
	5.0	.2	17.0	5.0	
	6.0	.2	22.0	6.0	
	8.0	.3	44.0	8.0	
	9.0	.3	92.0	20.0	
63	73.7	99.0	4		NORTHERN PRINCE OF WALES IS., N.W.T.
	9.5	.3	95.0	25.0	
	9.8	.3	95.0	14.2	

	10.4	.4	126.0	18.9	
	11.0	.4	130.0	27.0	
64	73.0	111.0	3		NORTHERN VICTORIA ISLAND, N.W.T.
	9.9	.3	43.0	6.5	
	11.3	.4	67.0	24.0	
	11.8	.4	112.0	16.8	
65	74.8	110.2	2		WINTER HARBOUR, N.W.T.
	9.0	.4	27.4	4.1	
	9.6	.4	25.0	6.0	
66	75.0	109.0	6		SOUTHERN MELVILLE ISLAND, N.W.T.
	.6	.2	1.6	1.0	
	1.2	.2	1.8	1.0	
	1.7	.2	1.8	1.0	
	9.7	.3	38.0	5.6	
	10.3	.4	55.0	8.3	
	11.7	.4	82.0	12.3	
67	75.5	106.0	8		EASTERN MELVILLE ISLAND, N.W.T.
	.8	.2	2.7	1.3	
	4.9	.2	16.5	2.5	
	5.4	.4	16.8	2.5	
	5.9	.2	16.5	3.5	
	7.9	.3	27.0	4.1	
	9.0	.4	52.5	7.9	
	9.8	.4	55.5	8.3	
	10.2	.4	55.7	8.4	
68	76.0	100.0	4		BATHURST ISLAND, N.W.T.
	7.1	.3	80.0	12.0	
	8.5	.3	100.0	15.0	
	9.0	.3	100.0	15.0	
	9.2	.3	135.0	20.0	
69	74.7	94.9	6		CORNWALLIS ISLAND, N.W.T.
	4.0	.2	15.0	3.0	
	5.0	.2	19.0	3.0	
	6.0	.2	24.0	4.0	
	7.0	.2	28.0	5.0	
	8.0	.3	38.0	10.0	
	9.0	.3	104.0	20.0	
70	76.0	90.0	1		BOAT POINT, N.W.T.
	5.2	.2	26.5	3.9	

71	75.6	84.6	5		TRUELOVE INLET, N.W.T.
	2.4	.2	3.6	1.0	
	2.9	.2	3.0	1.0	
	5.2	.2	11.0	1.7	
	8.3	.3	42.0	6.3	
	9.4	.3	73.0	13.0	
72	79.3	90.9	4		WESTERN AXEL HEIBERG ISLAND, N.W.T.
	5.3	.2	35.0	5.3	
	6.8	.3	42.0	6.3	
	7.1	.3	58.0	8.7	
	9.0	.4	80.0	12.0	
73	78.0	100.0	4		ELLEF RINGNES ISLAND, N.W.T.
	7.6	.3	25.0	8.0	
	8.3	.3	25.0	5.0	
	8.5	.3	33.0	4.9	
	8.9	.4	42.0	6.3	
74	77.5	105.0	5		LOUGHEED ISLAND, N.W.T.
	8.2	.3	27.0	4.1	
	10.1	.4	60.0	9.0	
	10.2	.4	90.0	13.5	
	10.4	.4	43.5	6.5	
	10.5	.4	40.5	6.1	
75	72.0	125.5	1		SOUTHERN BANKS ISLAND, N.W.T.
	10.7	.4	12.0	1.8	

BAFFIN ISLAND, N.W.T.

76	63.0	70.0	4		CAPE TANFIELD, N.W.T.
	1.0	.2	1.0	1.0	
	2.0	.2	2.0	1.0	
	4.0	.2	6.0	3.0	
	8.0	.3	80.0	20.0	
77	62.3	66.3	6		JACKMAN SOUND, N.W.T.
	8.0	.3	9.5	1.4	
	8.2	.3	29.0	4.3	
	8.3	.3	20.0	3.0	
	8.5	.3	46.0	6.8	
	8.6	.3	38.0	5.6	
	8.9	.5	69.0	10.3	
78	62.5	65.5	8		WARWICK SOUND, N.W.T.
	1.4	.3	-5.0	1.0	
	8.8	.3	29.0	4.3	

	8.9	.3	17.0	2.5	
	9.1	.3	26.0	3.9	
	9.4	.3	11.0	5.0	
	9.5	.3	28.0	12.0	
	10.1	.4	73.0	10.9	
	10.8	.4	68.0	10.2	
79	63.7	68.6	6		BURTON BAY, N.W.T.
	4.1	.2	15.0	2.2	
	6.1	.2	15.0	2.2	
	6.8	.2	22.0	8.0	
	7.1	.2	22.0	7.0	
	7.5	.3	38.0	5.7	
	8.2	.3	95.0	14.2	
80	66.1	65.7	3		PANGNIRTUNG FIORD, N.W.T.
	5.8	.2	-10.0	1.5	
	7.9	.3	26.0	3.9	
	8.7	.3	8.0	1.2	
81	67.4	65.0	3		MAKTAK FIORD, N.W.T.
	.9	.2	0.5	1.0	
	5.3	.9	18.0	2.7	
	6.4	.2	18.0	2.7	
82	67.5	64.0	1		BROUGHTON ISLAND, N.W.T.
	9.9	.3	3.0	2.0	
83	67.7	65.4	5		NARPAING FIORD, N.W.T.
	.8	.2	0.5	1.0	
	3.6	.2	6.5	1.0	
	5.0	.2	10.0	1.5	
	7.1	.3	16.0	2.4	
	8.0	.3	46.0	6.9	
84	68.0	66.0	2		OKOA FIORD, N.W.T.
	4.8	.2	8.0	1.2	
	8.4	.3	38.0	5.7	
85	67.5	66.0	2		NEOLUKSEAK FIORD, N.W.T.
	5.2	.2	21.0	4.0	
	7.9	.3	40.0	5.9	
86	69.0	68.7	4		HOME BAY, N.W.T.
	3.6	.2	3.0	2.0	
	6.1	.2	20.0	4.0	
	8.3	.3	68.0	10.2	
	8.4	.3	72.0	10.8	

87	70.0	68.0	4		INUGSUIN FIORD, N.W.T.
	2.8	.2	5.4	1.0	
	6.0	.2	8.0	4.0	
	7.0	.2	13.0	4.0	
	8.0	.3	21.0	4.0	
88	70.0	71.5	5		SAM FORD FIORD, N.W.T.
	3.0	.2	7.0	2.0	
	5.0	.2	19.0	3.0	
	6.0	.2	28.0	4.2	
	7.0	.2	41.0	6.1	
	8.0	.3	60.0	8.9	
89	71.2	75.0	7		INNER CAMBRIDGE FIORD, N.W.T.
	4.0	.2	9.0	3.0	
	4.3	.2	17.0	5.0	
	4.7	.2	31.0	7.0	
	4.9	.2	25.0	4.0	
	5.5	.2	37.0	8.0	
	6.3	.3	39.0	7.0	
	7.0	.3	47.0	7.1	
90	71.4	75.0	5		OMEGA BAY, N.W.T
	2.9	.2	8.0	3.0	
	7.8	.3	71.0	12.0	
	7.9	.3	79.0	11.9	
	8.1	.3	84.0	12.6	
	8.2	.3	63.0	10.0	
91	72.3	79.0	3		TAY SOUND, N.W.T.
	3.6	.2	15.0	5.0	
	4.9	.2	38.0	9.0	
	8.4	.3	75.0	15.0	
92	72.0	80.0	6		MILNE INLET, N.W.T.
	3.0	.2	14.0	5.0	
	4.0	.2	23.0	7.0	
	5.0	.2	36.0	7.0	
	6.0	.2	52.0	7.7	
	7.0	.2	66.0	9.8	
	8.0	.3	83.0	12.4	
93	69.0	74.0	6		BAIRD PENINSULA, N.W.T.
	2.0	.2	8.0	2.0	
	3.0	.2	16.0	2.4	
	4.0	.2	27.0	4.0	
	5.0	.2	44.0	6.5	
	6.0	.2	69.0	10.3	
	7.0	.2	109.0	16.3	

94	69.8	77.0	7		GRANT-SUTTIE BAY, N.W.T.
	2.1	.2	9.2	2.0	
	3.5	.2	18.0	2.7	
	4.8	.2	21.4	3.2	
	5.1	.2	43.0	6.5	
	5.8	.2	55.0	8.2	
	6.1	.2	77.0	11.6	
	6.7	.2	89.0	13.4	
95	70.9	86.7	3		AGU BAY, N.W.T.
	7.2	.2	89.0	13.4	
	7.7	.3	97.0	14.6	
	8.8	.3	119.0	17.9	
96	71.0	85.0	4		BRODEUR PENINSULA, N.W.T.
	.9	.2	3.0	1.0	
	7.0	.2	93.0	13.9	
	7.6	.3	90.0	13.4	
	8.7	.3	122.0	18.2	

ELLESMERE ISLAND, N.W.T.

97	76.5	88.0	8		CAPE STORM, N.W.T.
	1.0	.2	3.0	1.0	
	2.0	.2	6.0	1.0	
	3.0	.2	10.0	1.5	
	4.0	.2	13.5	2.0	
	5.0	.2	21.0	3.1	
	6.0	.2	30.0	4.5	
	7.0	.2	40.0	5.9	
	8.0	.3	59.0	8.8	
98	76.5	84.0	7		SOUTH CAPE FIORD, N.W.T
	2.0	.2	4.5	1.0	
	3.0	.2	8.0	1.5	
	4.0	.2	13.5	2.0	
	5.0	.2	20.0	3.0	
	6.0	.2	25.5	3.8	
	7.0	.2	38.0	5.6	
	8.0	.3	57.0	8.5	
99	78.5	86.0	4		BAY FIORD, N.W.T.
	6.4	.2	37.0	5.6	
	6.7	.2	56.5	8.4	
	7.2	.3	82.0	12.3	
	7.7	.3	82.0	12.3	

100	80.5	80.6	4		GREELY FIORD, N.W.T.
	7.0	.3	81.0	12.1	
	7.7	.3	119.0	17.9	
	7.8	.3	134.0	20.1	
	8.0	.3	138.0	20.7	
101	80.2	82.6	3		CANON FIORD, N.W.T.
	7.6	.3	113.0	17.0	
	8.0	.3	113.0	21.0	
	8.9	.3	122.0	26.0	
102	80.9	77.3	3		ANTOINETTE BAY, N.W.T.
	6.7	.2	71.0	32.0	
	7.6	.3	109.0	16.3	
	7.8	.3	85.0	18.0	
103	81.0	78.0	4		TANQUARY FIORD, N.W.T
	4.2	.2	9.0	1.3	
	5.7	.2	13.0	2.0	
	6.3	.2	25.0	5.0	
	6.8	.2	56.0	8.3	
104	81.2	69.0	3		ARCHER FIORD, N.W.T.
	5.5	.2	60.0	10.0	
	6.9	.2	91.0	13.7	
	8.0	.3	111.0	16.7	
105	81.5	65.5	2		CAPE BAIRD, N.W.T.
	7.4	.2	111.0	16.7	
	10.8	.4	115.0	17.3	
106	81.7	66.0	7		DISCOVERY HARBOUR, N.W.T.
	3.9	.3	20.0	3.0	
	4.6	.2	61.0	9.1	
	6.5	.2	72.0	10.7	
	6.8	.2	78.0	11.6	
	7.0	.3	72.0	10.7	
	7.4	.2	97.0	16.0	
	7.8	.3	108.0	16.2	
107	82.1	61.4	2		LINCOLN BAY, N.W.T.
	7.3	.3	85.0	12.8	
	8.6	.3	95.0	14.3	
108	82.5	63.0	8		ALERT, N.W.T.
	1.0	.2	2.0	1.0	
	1.8	.2	4.0	1.0	

	4.7	.2	23.0	3.4	
	5.5	.2	35.0	5.2	
	7.0	.2	66.0	10.0	
	7.8	.3	59.0	8.9	
	9.2	.4	85.0	40.0	
	10.1	.4	120.0	18.0	
109	82.6	68.0	8		CLEMENTS MARKHAM INLET, N.W.T.
	2.2	.2	6.0	1.0	
	4.2	.2	21.0	3.1	
	4.6	.2	22.5	3.3	
	6.4	.2	43.0	6.4	
	6.7	.2	59.0	8.8	
	7.9	.3	89.0	14.0	
	8.9	.4	91.0	13.7	
	9.7	.4	108.0	16.2	
110	83.1	74.0	4		WARD HUNT ISLAND, N.W.T.
	4.7	.2	7.0	3.0	
	6.0	.2	12.0	3.0	
	7.0	.2	42.0	10.0	
	7.8	.3	64.0	12.0	
111	82.6	72.8	10		THORES RIVER, N.W.T.
	4.0	.2	2.0	2.0	
	5.7	.2	36.0	15.0	
	6.5	.2	37.0	14.0	
	6.9	.2	6.0	6.0	
	7.1	.2	42.0	10.0	
	7.3	.2	42.5	10.0	
	7.8	.3	70.0	11.0	
	8.0	.3	70.0	11.0	
	8.2	.3	70.0	11.0	
	10.1	.4	70.0	11.0	
112	82.8	73.8	3		DISRAELI FIORD, N.W.T.
	7.7	.2	53.0	14.0	
	8.2	.3	68.0	23.0	
	8.9	.3	71.0	25.0	
113	83.0	75.7	1		RAMBOW HILL, N.W.T.
	8.6	.3	55.0	13.0	
114	82.6	75.7	2		M'CLINTOCK INLET, N.W.T.
	7.8	.3	69.0	10.3	
	8.9	.3	84.0	12.5	

115	82.0	85.0	6		PHILLIPS INLET, N.W.T.
	4.3	.2	9.0	1.3	
	7.1	.2	58.0	15.0	
	7.5	.3	55.0	15.0	
	7.8	.3	54.0	15.0	
	8.0	.3	54.0	15.0	
	8.3	.3	67.0	20.0	

APPENDIX B

REFERENCE LIST FOR SITES

Note: When a site is listed inside brackets, the reference is an additional reference.

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