

GEOLOGICAL SURVEY OF CANADA RADIOCARBON DATES I*

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INTRODUCTION

This paper reports the first ages determined in the C^{14} Dating Laboratory of the Geological Survey of Canada. The C^{14} dating program of the Geological Survey is a cooperative project; geologists of the Pleistocene Section assess and select samples for dating, and the Isotope and Nuclear Research Section, under Dr. R. K. Wanless, developed and operates the laboratory and calculates ages. The first part of this paper, devoted to sample preparation, counting procedure, and interlaboratory check dates was prepared by the first author, who built and operates the laboratory. The date list was compiled by the second author from descriptions of samples and interpretations of dates provided by various collectors. Most samples analyzed so far have originated within the Geological Survey.

Preparations for the development of a C^{14} laboratory within the Department of Mines and Technical Surveys, Ottawa, were begun by Dr. C. Lapointe, Nuclear Radiation Section, Mines Branch. At an early stage the project was turned over to the Geological Survey and active construction of the present laboratory was begun during 1959. By early 1961 one proportional-counting tube with highly satisfactory counting characteristics was in operation and systematic dating commenced. The age determinations reported here were completed from January to November 1961.

ACKNOWLEDGMENTS

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APPARATUS AND PROCEDURE

Sample Preparation

All organic samples, unless noted otherwise, were treated with hot 4% NaOH, hot 2N HCl, and washed with hot water.

Samples were burned in a stream of oxygen and the released CO_2 purified by passage through the following chemicals and traps: hot CuO, dil. H_2SO_4 , 0.1 N $AgNO_3$, H_2SO_4 - CrO_3 sol'n, drierite, an acetone-dry ice trap, hot Pt-asbestos, and hot Ag-wool. Radon was separated from CO_2 by fractional distillation as described by de Vries (de Vries, 1957). Final purification of CO_2 was achieved by passage through $Mg(ClO_4)_2$ and hot, freshly regenerated copper.

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Shells were cleaned with a stiff brush and water before and after removal of 10% of outer layers with HCl. CO₂ was liberated with H₃PO₄.

Counting Apparatus

The counting apparatus is situated in the sub-basement of the eight story Geological Survey building.

Samples were counted in a 2 L copper, proportional counter. The end plates and quartz insulators were glued in place with araldite. This counter is operated within a shield comprised of 8 in. of cast iron, 4 in. of paraffin, 21 G.M. tubes and a stainless steel vessel providing a 1 in. layer of Hg.

When filled with CO₂ to a pressure of 150 cm of mercury a background count of 1.5 counts/min and a net modern-wood count of 20.2 counts/min were recorded.

Experiments with several counters suggest the low background was obtained by machining the inside surface of the counter tube.

Counting Procedure

With a few exceptions the counter was operated at two atmospheres. During the first eight months of operation one background and one modern wood count were made each week and each unknown sample was counted at least twice for 20 hrs. Recently a less rigorous counting procedure was introduced as follows: background, two unknowns, modern wood, two unknowns, background. Unknowns counted over a weekend, unless very old, were not counted twice.

A new background and standard gas were prepared every six weeks. Each counter filling was checked with an external pitchblende source before and after the counting period in order to detect possible shifts in the operating voltage. Variations of up to 15 v were observed between different counter fillings, suggesting small differences in the concentration of electronegative impurities in the sample gases. A similar shift was observed after a gas was used four or five times.

Calculations and Errors

Ayll ages reported were calculated using the corrected activity of 105 yr old Douglas Fir wood from Vancouver Island as the reference standard. Two gas preparations of NBS oxalic-acid standard compared to two of the Douglas Fir wood gas preparations gave the following relationship:

$$0.945 A' = A$$

where A' is the counting rate of the oxalic-acid gas and A the counting rate of the wood corrected to zero age.

The value of 5568 ± 30 yr for the half life of C¹⁴ was used in these calculations.

Upper age limits were calculated from values obtained by adding four standard deviations to statistically insignificant counting rates.

No corrections for possible isotopic fractionation were applied. Although the C¹³/C¹² ratio for shells and terrestrial plants is different, ocean mixing rates are apparently such that the corresponding difference in the C¹⁴/C¹² ratio is not observed for shallow-water sea shells (Craig, 1954). Hence the

same standard was used for all samples. Close agreement between GSC-24 and GCS-38 lends support to this argument.

Errors reported were based on statistical variations observed. Counts outside the probability range, as predicted from the randomness of radioactive decay, were discarded; *i.e.* if one of three counts was more than two standard deviations away from the average. During the past 11 months six such anomalous counts were recorded.

Results of Check Samples

Determinations of ages of check samples listed in Table 1 were carried out over a period of eight months.

Satisfactory agreement between the ages determined in this laboratory and those from other laboratories is evident. However, slight trends appear to be present; three of the four Isotopes Inc. ages are older than the GSC ages, while all three Lamont ages are slightly younger.

TABLE 1

Comparison of ages of identical sample fractions dated by various laboratories

GSC Laboratory		Other Laboratories		Reference	Sample
Sample No.	Age (yr)	Sample No.	Age (yr)	RADIOCARBON	Material
GSC-1	12,400 \pm 200	L-391 D	12,150 \pm 250 12,000 \pm 450	Lamont V Isotopes I	wood
GSC-2	7600 \pm 150	S-99	7300 \pm 120	Saskatchewan III	detrital peat
GSC-4	10,190 \pm 120	I(GSC)-185	10,600 \pm 320	Isotopes II	peat
GSC-5	10,140 \pm 160	I(GSC)-2	10,220 \pm 350	Isotopes I	wood
GSC-13	29,500 \pm 800	L-424C	29,300 \pm 1400	Lamont V	wood
GSC-14	26,000 \pm 600	L221A	25,900 \pm 300	Lamont V	wood
GSC-20	4275 \pm 100	S-25	4600 \pm 210	Saskatchewan II	wood
GSC-21	10,400 \pm 140	S-81	10,200 \pm 250	unpublished	wood
GSC-37	12,600 \pm 170	I(GSC)-248	12,800 \pm 175	Isotopes II	marine shells

The peat sample GSC-4 was dated three times and a summary of the sample treatment and results is shown in Table 2.

TABLE 2

Summary of treatment and results of sample GSC-4

Sample preparation	No. of counts	Chemical treatment	Age
1	2	40% of sample treated with NaOH Total sample treated with HCl	10,100 \pm 200
2	1	Total sample treated with base and acid	10,050 \pm 140
3	2	No chemical pretreatment	10,410 \pm 150

Although the age appears to decrease with increasing chemical pretreatment, the variation is not significant in view of the errors of the ages. The first count of the second preparation gave an age of 9860 \pm 160 yr but was

omitted because of the presence of some radon in the sample. Also the first count of the third preparation was omitted. Although no radon was detected in this preparation the counting rate was more than two standard deviations above average.

Sample GSC-5 was counted once at a reduced pressure of 147 cm and once mixed with 24.4% coal gas. The counts gave the ages $10,200 \pm 190$ yr and $10,090 \pm 130$ yr respectively.

Sample GSC-21 and its unpublished Saskatchewan date were provided by Dr. K. J. McCallum. As indicated in a letter from Dr. McCallum (November 28, 1961), this sample is from the Scrimbit site, Saskatchewan ($49^{\circ} 46' N$ Lat, $105^{\circ} 11' W$ Long). The wood is from a depth of 15 ft above till, and was taken from a large root of a stump nearly 4 ft high, which appeared to be preserved in its original upright position. Dating of a series of samples from this site is being undertaken in the Saskatchewan Laboratory.

SAMPLE DESCRIPTIONS (GEOLOGICAL SAMPLES)

SOUTHERN CANADA

Arranged East to West

GSC-11. Clareville, Newfoundland 3610 \pm 100

Peat from the bottom of a bog deposit at the head of SW arm of Random Sound, 10 mi S of Clareville, Newfoundland ($48^{\circ} 02' N$ Lat, $53^{\circ} 48' W$ Long). Sample collected with Hiller peat sampler 10 ft below bog surface at the contact of peat with underlying outwash gravel at alt 46 ft. The outwash is graded to a former sealevel at alt 35 to 40 ft. Coll. 1960 by E. P. Henderson, Geol. Survey of Canada, Ottawa. *Comment:* sample was dated to obtain a minimum age for the outwash; it is considerably younger than anticipated. In view of the much greater age of bog-bottom samples from the Avalon Peninsula to the SW (L-3911, 7400 ± 150 , Lamont V; I(GSC)-4, 8420 ± 300 , Isotopes I), the dated peat must be considerably younger than the underlying outwash. NaOH-leach was omitted from pretreatment.

GSC-18. Siegas, New Brunswick 9820 \pm 130

Wood from an organic layer, containing moss and fresh-water mollusc shells, lying within gravel 18 ft below ground on W bank of Siegas River 0.3 mi from its junction with St. John River, New Brunswick ($47^{\circ} 13' N$ Lat, $67^{\circ} 58' W$ Long). Approximately 10 ft of Lake Madawaska clay overlies the gravel enclosing the dated layer. Coll. 1956 by H. A. Lee, Geol. Survey of Canada. *Comment:* sample is believed equivalent to I(GSC)-2, $10,220 \pm 350$ (Isotopes I), and provides a minimum date for the Grand Falls drift (Lee, 1955). Organic material from the stratigraphically higher Lake Madawaska sediments at two localities nearby has ages of 8200 ± 300 (L-190B, Lamont II) and 8250 ± 200 (W-353, USGS IV).

GSC-8. Northfield, Ontario 9430 \pm 140

Peat and gyttja overlying Champlain Sea sand and gravel 1.3 mi NW of Northfield, Ontario ($45^{\circ} 08' N$ Lat, $74^{\circ} 56' W$ Long). Composite Hiller

sample from base of bog deposits 475 to 485 cm below ground. Site is at alt ca. 325 ft, ca. that of a pause in recession of the Champlain Sea, indicated by widespread dunes in the adjoining Prescott area (Terasmae and Mott, 1959). Coll. 1959 by Jaan Terasmae, Geol. Survey of Canada. *Comment*: on the basis of pollen studies, the base of this bog section (corresponding to GSC-8) is ca. equivalent to the bottom of the St. Germain bog profile (Terasmae, 1960) dated as 9500 ± 300 (L-441C, Lamont VII). The date also provides a minimum age for the 325-ft stand of the Champlain Sea. Marine shell samples inferred to represent ca. the same phase in the history of marine submergence of the surrounding region have C^{14} dates averaging ca. 10,500 yr (Sample 10 mi E of Northfield site: L-604C, $10,600 \pm 200$, unpub. Samples from Ottawa: Y-216, Yale II; L-604A, L-604B, Lamont VII: L-604D, $10,200 \pm 200$, unpub.). NaOH-leach was omitted from sample pretreatment.

GSC-26. Rouge River, Ontario 2400 \pm 75

Gyttja from stream-terrace sand and gravel 2 mi ENE of Brown's Corners, Scarborough Township, Ontario ($43^{\circ} 49' N$ Lat, $79^{\circ} 12' W$ Long). Sample from bank of Rouge River 22 ft above stream and 5 ft below terrace surface. Coll. 1960 by P. F. Karrow, Ontario Dept. Mines and Jaan Terasmae. *Comment*: terrace and gyttja are younger than Lake Iroquois and relate to development of the valley of Rouge River after establishment of the present level of Lake Ontario. Pollen studies of terrace deposits along the river are in progress. NaOH-leach was omitted from sample pretreatment.

GSC-15. New Liskeard, Ontario 5780 \pm 100

Peat and gyttja from base of a bog overlying Glacial Lake Barlow-Ojibway sediments 9 mi NNW of New Liskeard at Maybrook Station, Ontario ($47^{\circ} 37' 03'' N$ Lat, $79^{\circ} 45' 20'' W$ Long). Sample coll. 1960 by Jaan Terasmae with Hiller peat sampler 300 to 310 cm below bog surface. *Comment*: date is minimum for drainage of Glacial Lake Barlow-Ojibway to below the alt of the Little Clay Belt. Pollen studies indicate that the lower, dated part of the bog profile records warmer and perhaps dryer conditions than the upper four-fifths of the profile. NaOH-leach was omitted from pretreatment of sample.

GSC-6. Underwood, Ontario 600 \pm 70

Wood enclosed in sand and gravel at foot of Lake Algonquin wave-cut cliff 3.2 mi NW of Underwood, SW Ontario ($44^{\circ} 19' N$ Lat, $81^{\circ} 33' W$ Long). Sample from 3 or 4 ft below ground on the cut-bank of a small stream at alt 650 ft. Coll. 1960 by Jaan Terasmae. *Comment*: wood and enclosing sand and gravel were inferred to have been deposited along the shore of Lake Algonquin. In view of the date, however, these deposits are of much younger age, and must therefore be alluvium of the adjoining small intermittent stream. NaOH-leach was omitted from pretreatment of sample.

GSC-7. Little Long Rapids, Ontario 6910 \pm 120

Wood at base of bog deposit, ca. 5 ft thick, 3 mi S of Smoky Falls on Mattagami River, Ontario ($50^{\circ} N$ Lat, $82^{\circ} 12' W$ Long). Peat section, exposed during excavations at a dam site, is underlain by clay and sand lying upon

bedrock. Site is higher than marine limit in James Bay Lowland. Coll. 1960 by Jaan Terasmae. *Comment*: site lies inside the limit of the Cochrane readvance, thus the date is minimum for that event.

GSC-31. Attawapiskat River, Ontario 5670 \pm 110

Peat from bog deposit exposed in bank of Attawapiskat River 4 mi above Muketei River, James Bay Lowland, Ontario (53° 07' N Lat, 85° 25' W Long). Sample is from bottom few inches of peat section, 6.5 ft thick, overlying clay-rich till at alt ca. 460 ft. It is less than 50 ft below the uppermost postglacial marine level (unpub. commun. from V. K. Prest). Coll. 1957 by H. Sjors; subm. by Jaan Terasmae. *Comment*: marine shells collected close to the marine limit in the James Bay area exceed 7000 yr in age (I(GSC)-14, 7875 \pm 200, Isotopes I; Gro 1698, 7280 \pm 80, Terasmae and Hughes, 1960). Hence development of the bog profile at this site (Sjors, 1959) began considerably after the initial influx of the sea. NaOH-leach omitted in pretreatment of this sample.

GSC-9. Nungesser Lake, NW Ontario 8860 \pm 250

Gyttja from kettle in NE part of basin of glacial Lake Agassiz, within 100 yd of W end of Nungesser Lake, Ontario (51° 26' N Lat, 93° 43' W Long). Composite Hiller sample from basal 2 in. of a bog section consisting of 14 ft of peat underlain by 1 ft of gyttja. The bog sediments overlie sand, but in the lowland to the W peat up to 15-ft thick overlie glacio-lacustrine clayey silt. Bog development in the kettle probably began soon after falling Lake Agassiz water uncovered the kettle rim, ca. 215 ft below the highest stand of the lake as recorded on the Trout Lake moraine 20 mi SE. Decrease in spruce and increase in pine in the lower part of the pollen diagram of the peat sequence in the kettle (unpub. commun. from Jaan Terasmae) indicates climatic amelioration early in the history of the bog. Coll. 1960 by V. K. Prest, Geol. Survey of Canada. *Comment*: age of this sample agrees with other dates and current ideas connected with deglaciation of northern Ontario, and supports the inference that the climatic amelioration recorded in the pollen profile corresponds to the beginning of the Hypsithermal interval. NaOH-leach was omitted in pretreatment of sample.

GSC-3. Taber Provincial Park, Alberta 10,500 \pm 200

Willow wood from sandy alluvium on the face of a strip coal mine adjacent to Oldman River just S of Taber Park, Alberta, in Sec. 12, T 10, R 17, W 4th Meridian (49° 48' 30" N Lat, 112° 10' 30" W Long). Sample from a buried sandy soil containing sticks and erect stumps of willow up to 6 in. in diam. Soil is overlain by 27 ft of sand (up to the prairie surface) and is underlain by 9 ft of silt and sand separated from bedrock by a few inches of gravel. The site lies within a small channel, eroded by Oldman River during early development of its postglacial valley and subsequently filled with alluvium. Coll. 1960 by A. M. Stalker, Geol. Survey of Canada. *Comment*: wood from same site, coll. by L. A. Bayrock, Research Council of Alberta, has been dated 11,000 \pm 250 (S-68, Saskatchewan II).

Puntledge River series, Vancouver Island

Wood and marine shells from excavation beside penstock above Puntledge River Hydro-electric Station, near Courtenay, British Columbia ($49^{\circ} 41' N$ Lat, $125^{\circ} 02' W$ Long). Samples from the bottomset part of a marine delta with top at alt 175 ft, ca. 375 ft below marine limit in the vicinity. Coll. 1956 by J. G. Fyles.

GSC-24. Puntledge River 12,200 \pm 160

Wood from a 2-ft layer of horizontally stratified silt and fine sand overlying pebbly marine clay and overlain by 10 ft of deltaic gravel.

GSC-38. Puntledge River 12,360 \pm 140

Marine pelecypod shells from same bed as GSC-24 and from uppermost few inches of the underlying clay.

General comment: close agreement between these two dates supports the reliability of dates on marine shells. The difference in age between these samples and a shell sample collected near the marine limit (I(GSC)-9, 12,500 \pm 450, Isotopes I) is smaller than anticipated. As I(GSC)-9 is based upon an exceedingly small collection of tiny shell fragments from a site partly covered with modern pond algae, it appears to be less reliable than the dates reported here, and may be only minimum for the marine limit. See also L-391D, L-391E, L-391F, and L-441B (Lamont V).

Campbell River series, Vancouver Island

Various sub-till nonglacial plant-bearing deposits on Vancouver Island, near NW end of Strait of Georgia, differ in one way or another from the widespread interstadial Quadra sediments (Fyles, in press). Geologic considerations have failed to indicate whether these materials are younger or older than the Quadra or equivalent to it. The following dates apply to two (of the many) occurrences of such materials.

GSC-30. Salmon River >40,000

Wood from borrow pit beside highway, S side of Salmon River Valley, 10 mi upstream from Sayward, Vancouver Island, British Columbia ($50^{\circ} 15' N$ Lat, $125^{\circ} 48' W$ Long). Sample from a 6-ft exposure of stony silt containing irregular lenses of peaty soil and fragments of wood. Silt is overlain by lenses of till 2-ft thick, capped by 9 ft of gravel and 3 ft of silty colluvium. Sub-till silt, perched on the bedrock wall of the U-shaped valley, appears to be a remnant of formerly much more extensive deposits that has fortuitously survived glaciation. Coll. 1950 by J. G. Fyles.

GSC-52. Campbell River >37,200

Wood from sub-till stream deposits in an excavation behind John Hart Hydro-electric Station, Campbell River, British Columbia ($50^{\circ} 07' 40'' N$ Lat, $125^{\circ} 18' 30'' W$ Long). Sample from 10 ft above the base of ca. 85 ft of horizontally stratified grit, sand and silt resting on laminated marine silty clay and overlain by till and deltaic deposits. Coll. 1958 by J. G. Fyles.

General comment: dates are older than those yielded by plant materials from comparable parts of the Quadra sediments (range: 24,000 to 36,000; L-221A, L-221B, L-424B, L-424C, L-424E, Lamont V; L-502, Lamont VII). Nonetheless, as marine shells from the basal part of the Quadra have infinite dates (L-475A, L-475B, Lamont VII), there is no assurance that the deposits in question represent a nonglacial interval or intervals older than and separate from the Quadra interstadial. See also I(GSC)-5, >35,000 (Isotopes I).

NORTHERN CANADA I

General

GSC-50. North Fork Pass, Yukon 7510 ± 100

Gyttja from lowermost 2 in. of a bog deposit occupying a depression in an arcuate terminal moraine in North Fork Pass at head of North Klondike River, Ogilvie Mountains, Yukon Territory (64° 34' N Lat, 138° 15' W Long). Sample collected with a ship's auger 5 ft below ground. The moraine marks the limit of the restricted latest advance of valley glaciers in the region, separated from an earlier more extensive glaciation by a considerable interval of erosion. Coll. 1961 by O. L. Hughes. *Comment:* date is minimum for the late advance of valley glaciers and admits, but does not demand, correlation of this advance with Riley Creek glaciation of Nenana Valley, Alaska, considered by Wahrhaftig (1958, p. 18) to have reached a maximum ca. 11,000 yr ago on the basis of W-49 (10,560 ± 200, USGS I). NaOH-leach was omitted from pretreatment of sample. Date based on one weekend count only.

GSC-29. Inuvik, Northwest Territories >39,000

Wood from sand and gravel, containing much ground ice, ca. 30 ft below the original surface, in gravel pit ca. 1 mi E of Inuvik, District of Mackenzie (68° 21' 20" N Lat, 133° 41' 10" W Long). Site lies within the area of a delta-kame complex at the mouth of an abandoned channel apparently eroded by a W-flowing stream during the last deglaciation of the region. Coll. 1960 by J. Ross Mackay, Univ. of British Columbia; subm. by the Geog. Branch, Dept. Mines and Tech. Surveys, Ottawa, Canada. *Comment:* sample was dated to gain information about the age of retreat of the last (late Pleistocene, probably classical Wisconsin) ice sheet from the area. In view of the infinite date, the wood is now thought to be older than the delta. Sample was counted once at a reduced pressure of 125 cm and once mixed with 23.0% of coal gas. Net corrected counting rates: $-0.049 \pm .041$ counts/min and $+0.066 \pm .031$ counts/min respectively. The negative value may be misleading since no background count at similarly reduced pressure was carried out. Ignoring the negative count would give an age of >37,000 yr instead of the quoted value of >39,000 yr.

GSC-25. Inuvik, Northwest Territories 8200 ± 300

Wood from base of bog deposit, 12-ft thick, exposed on shore of Twin Lakes, 0.3 mi NW of Inuvik, District of Mackenzie (68° 21' 50" N Lat, 133° 44' 10" W Long). Sample site, at alt ca. 20 ft, has stood above sealevel at least

during accumulation of the bog deposit. Coll. 1960 by J. Ross Mackay, Univ. of British Columbia; subm. by Geog. Branch, Dept. of Mines and Tech. Surveys, Ottawa. *Comment*: on the basis of this date, peat has accumulated at ca. 1.5 ft/1000 yr, assuming that the exposed peat face represents the true thickness of the deposit, and that accumulation at the top of the section has not been retarded appreciably adjacent to the encroaching bank. The site is approximately at the tree line.

GSC-16. Eskimo Lakes, Northwest Territories 7400 ± 200

Wood from 6 in. above base of bog deposit, 7.5-ft thick, exposed in bank of a channel between "fingers" of the Eskimo Lakes, E of the mouth of Mackenzie River, District of Mackenzie ($69^{\circ} 12' N$ Lat, $132^{\circ} 27' W$ Long). The deposit overlies organic-rich lake-bottom sand in a tundra area. The sample site, at alt ca. 3 ft, has stood above sealevel at least during accumulation of the deposit. Coll. 1960 by J. Ross Mackay; subm. by Geog. Branch, Dept. of Mines and Tech. Surveys, Ottawa. *Comment*: on the basis of this date, peat has accumulated at ca. 1 ft/1000 yr, subject to the assumptions noted above for GSC-25. Sample received no chemical pretreatment.

GSC-10. Kellett River, Banks Island 6940 ± 110

Peat 2-ft below the ground in the wall of a gully 4 mi N of Kellett River, Banks Island, District of Franklin ($71^{\circ} 56' N$ Lat, $123^{\circ} 14' W$ Long). Sample is from the upper part of an 8-ft sec. of pond and bog sediments in a shallow depression in the upland adjoining the river valley. Coll. 1960 by J. G. Fyles. *Comment*: on the basis of this date and of I(GSC)-197 (9820 ± 220 , Isotopes II), from base of peat section at the same locality, peat has accumulated at ca. 2 ft/1000 yr.

GSC-12. Northern Banks Island 5730 ± 100

Organic silt from a depth of 8 ft in the wall of a gully 8 mi W of Castel Bay and 8 mi S of N coast of Banks Island, District of Franklin ($74^{\circ} 10' N$ Lat, $120^{\circ} 05' W$ Long). Sample from near the base of peaty colluvium, ca. 10-ft thick, flooring a small valley cut into an extensive gravel outwash, alt ca. 200 ft. Coll. 1960 by J. G. Fyles. *Comment*: although definite evidence of recent marine submergence has not been found in this part of Banks Island, the gravel terrace may possibly relate to a shoreline at alt 150 to 200 ft. The date relates to a later time, subsequent to dissection of the terrace. NaOH-leach was omitted from sample pretreatment.

GSC-51. Fosheim Peninsula, Ellesmere Island $28,700 \pm 600$

Fragments of marine-mollusc shells (including *Hiatella arctica*) from alt 630 ft, 10 mi S of Eureka, Ellesmere Island, District of Franklin ($79^{\circ} 51' N$ Lat, $85^{\circ} 42' W$ Long). Sample from the surface, on a hilltop consisting of shale rubble strewn with erratic stones. Within ca. 500 ft of sealevel marine shells, strandlines, and other features record former marine submergence; at higher altitudes (up to 2000 ft or more) thick solid marine-shell fragments and rare thick whole shells are scattered on the surface, but other evidences of submergence are lacking. Coll. 1961 by J. G. Fyles. *Comment*: marine shells

from nearby localities at lower altitudes than this sample lie in the normal postglacial age range (*e.g.* I-264, 8080 ± 160 , Isotopes II, coll. 35 mi to NW at alt 510 ft). The much older date of this sample confirms the limit of recent marine submergence at slightly more than 500 ft alt. The shells at higher altitude are inferred to have been carried into their present elevated positions by glacier ice. Another shell sample belonging in this category, coll. 8 mi NW at alt 2000 ft, dated $19,500 \pm 1100$ (L-548, Lamont VII; Sim, 1961). Although it is possible that both L-548 and GSC-51 provide only minimum age for the high shells, it is tempting to suggest that they originated in Eureka Sound some 30,000 to 20,000 yr ago and were carried to their present positions during a glacial invasion between 20,000 and 10,000 yr ago.

GSC-27. Little Whale River, Hudson Bay 4740 ± 110

Wood from marine clay exposed in a 160-ft river bank ca. 4 mi E of Hudson Bay on the S side of Little Whale River ($55^{\circ} 59' \text{ N Lat}$, $76^{\circ} 43' \text{ W Long}$). Sample from 10 ft above sealevel and 10 ft above base of a 155-ft sec. of clay with sand lenses, overlain by ca. 5 ft of alluvial sand. Coll. 1957 by W. W. Heywood for H. A. Lee, Geol. Survey of Canada. *Comment*: the wood-bearing material is inferred to have accumulated when the sea stood 155 ft (or slightly more) above its present position relative to the land. Date fits well into the middle part a previously drawn uplift/time curve based on nine C^{14} -dated strandlines formed during regression of the Tyrrell Sea (Lee, 1960).

NORTHERN CANADA II

The following dates, and about a dozen companion dates appearing in Isotopes, Inc. date lists I and II, relate to emerged marine shorelines within a zone ca. 800 mi long, trending SE from Banks Island to the W side of Hudson Bay. This zone extends from the outermost moraine built by the Laurentide Ice Sheet during the last glaciation to the Keewatin ice divide (Lee, Craig and Fyles, 1957). If it is assumed that the marine limit at any locality relates to the time of glacial retreat, this group of dates supports the following conclusions (Craig and Fyles, 1960): (1) the last glacial invasion of this part of North America was contemporaneous with the classical Wisconsin glaciation of the Great Lakes region. (2) retreat of the glacial margin within the zone proceeded from W to E and from N to S toward the Keewatin ice divide, as concluded independently from the glacial features, and occurred at about the same time as retreat of the southern margin of the ice sheet.

GSC-48. Richard Collinson Inlet, Victoria Island $11,310 \pm 150$

Shells of *Hiatella arctica*, coll. ca. 5 mi SW of the head of the E bay of Richard Collinson Inlet, NW Victoria Island, District of Franklin ($72^{\circ} 34' \text{ N Lat}$, $113^{\circ} 53' \text{ W Long}$). Sample from the surface of a silt-floored depression at alt 220 ft, apparently ca. 60 ft below the marine limit. Coll. 1960 by J. G. Fyles. *Comment*: site is ca. 50 mi SE of I(GSC)-18 ($12,400 \pm 320$, Isotopes I), collected about the same distance below the marine limit at the NW extremity of Victoria Island. It has been inferred from glacial geology that the

sea penetrated into the latter area when glacier ice still covered the Richard Collinson Inlet site.

GSC-43. Richard Collinson Inlet, Victoria Island 10,220 \pm 150

Marine pelecypod shells from alt 10 to 15 ft at head of E bay of Richard Collinson Inlet, NW Victoria Island, District of Franklin (72° 38' N Lat, 113° 41' W Long). Sample from silt lying beneath a few ft of gravel and sand forming a shore terrace at alt 20 ft. Marine limit nearby is at ca. 280 ft. Coll. 1960 by J. G. Fyles. *Comment*: sample is believed to represent a stand of the sea at or only a few ft above the 20-ft shoreline, although it is possible that sealevel was appreciably higher (GSC-19). Assuming that GSC-43 and GSC-48 originated in similar near-shore environments, the land rose relative to the sea, ca. 20 ft per century, between 11,300 and 10,200 yr ago.

GSC-19. Richard Collinson Inlet, Victoria Island 2200 \pm 75

Peat from alt ca. 20 ft at head of E bay, Richard Collinson Inlet, NW Victoria Island, District of Franklin (72° 38' N Lat, 113° 41' W Long), at same locality as GSC-43. Sample from base of 2-ft peat bed overlying clay at inland edge of 20-ft shore terrace. Coll. 1960 by J. G. Fyles. *Comment*: sample and GSC-43 were dated to bracket the age of the 20-ft shoreline. In view of the large difference between the dates of the two samples, either the peat must be much younger than the shoreline or, less probably, the shells appreciably older.

GSC-49. De Salis Bay, Banks Island 10,920 \pm 100

Shells of *Hiatella arctica* collected several hundred ft inland from NE shore of De Salis Bay, 1 mi W of Cape Cardwell, SE Banks Island, District of Franklin (71° 24' N Lat, 121° 26' W Long). Shells from surface of gullied clay at alt 50 to 60 ft. Shells and indistinct shorelines were found in the vicinity up to ca. 80 ft. Marine limit not clearly evident but possibly at or slightly above 100 ft. Coll. 1960 by J. G. Fyles. *Comment*: site is ca. 25 mi SE of the outer margin of the outermost (NW) prominent moraine, and probably was invaded by the sea fairly early in glacial retreat. Date based on one weekend count.

GSC-42. Prince Albert Sound, Victoria Island 9710 \pm 150

Marine pelecypod shells from alt 450 ft, 40 mi ESE of head of Prince Albert Sound, central Victoria Island, District of Franklin (70° 06' N Lat, 109° 50' W Long). Sample consists of fresh shells from centers of clayey frost boils. Marine limit at alt ca. 520 ft. Coll. 1959 by J. G. Fyles. *Comment*: as expected from the pattern of glacial features in the region, this sample is considerably younger than GSC-48 (above), collected about the same distance below the highest marine level some 200 mi NW.

GSC-39. Rae River, Coronation Gulf 9440 \pm 120

Marine pelecypod shells from gullied surface of marine clay, alt 320 ft, just N of Rae River 16 mi W of Coppermine, District of Mackenzie (67° 57' N Lat, 115° 38' W Long). Site ca. 100 ft below marine limit. Coll. 1959 by

W. L. Davison for B. G. Craig, Geol. Survey of Canada (Craig, 1960, Locality 15). *Comment*: other shell samples from high marine levels in the same area have dates ranging from 8300 to 10,500 yr (I(GSC)-13, 16, 17, 22, and 25, Isotopes I). It has been inferred from the glacial features that the ice-sheet margin retreated from this area at about the time it left the area to the NE represented by GSC-42 (above).

GSC-17. Tree River, Coronation Gulf **1830 \pm 80**

Tundra plants dug from an 8-ft sec. of silt in a bank at the mouth of Tree River, Port Epworth, District of Mackenzie (67° 41' N Lat, 111° 51' W Long). Sample collected from alt 2 ft from one of several organic layers in the bank. Coll. 1959 by B. G. Craig. *Comment*: sample is believed to have been deposited when sealevel was less than 10 ft above its present position.

Northern Keewatin series

Marine shells found at various alt within an area ca. 100 mi in diam S of Boothia Isthmus, between Pelly Bay and Rasmussen and St. Roch Basins. Marine limit ranges from ca. 600 to ca. 650 ft. Samples are from sites that appear to represent near-sealevel environment. In addition to the following five dates, the series includes dates I(GSC)-179, 212, 213, and 215 in Isotopes, Inc. date list II (this volume). Coll. 1960 by officers of Geol. Survey of Canada "Operation Back River;" interpreted by B. G. Craig (Craig, 1961).

GSC-44. Simpson Lake, East **8870 \pm 140**

Pelecypod shells from fine sand in creek bank in esker delta (?), alt 510 ft, 5 mi NE of E end of Simpson Lake, District of Keewatin (68° 30' N Lat, 91° 05' W Long). Coll. by B. G. Craig.

GSC-47. Arrowsmith River (560 ft) **8700 \pm 120**

Pelecypod shells from ground surface at alt 560 ft on W side of Arrowsmith River 25 mi from Pelly Bay (68° 05' N Lat, 90° 09' W Long). Sample from silt in a terrace deposit on the side of a bedrock hill in an area of thick marine sediments. Coll. by M. Tremblay for B. G. Craig.

GSC-46. Murchison River **7790 \pm 100**

Pelecypod shells from horizontally bedded fine sand at alt 261 ft, 3 mi from Murchison River on E side of river draining Simpson Lake (68° 29' N Lat, 92° 09' W Long). Sample from eroded terrace on the valley wall. Coll. by B. G. Craig. Date based on one weekend count.

GSC-45. Balfour Bay **4460 \pm 80**

Pelecypod shells from surface of the uppermost of a series of beaches extending to the top of a drumlin, alt 80 ft, 3 mi E of N end of Balfour Bay (69° 09' N Lat, 93° 59' W Long). Coll. by J. D. Aitken for B. G. Craig.

GSC-40. Arrowsmith River (25 ft) **8450 \pm 110**

Pelecypod shells from the surface, alt 25 ft, S side of Arrowsmith River 11 mi SW of Pelly Bay (68° 18' N Lat, 90° 40' W Long). Shells derived from sand in an area of thick marine sediments. Unusual dark grey to black layers

occur within the shells. These layers, most noticeable after treatment with HCl, were not observed in other shell samples. Coll. by W. W. Heywood for B. G. Craig. *Comment*: date is much older than expected from the low altitude of the site. A second preparation of the sample yielded a date of 8200 ± 150 , based on one count. Although the unexpectedly old date may result from contamination, more probably the shells represent deeper-water conditions than anticipated or have been reworked from a higher site.

General comment: above samples, together with I(GSC)-179, 212, 213, and 215 are from a small enough area to be treated as a unit in considerations of glacial retreat and subsequent uplift. As expected from the glacial geology, the oldest dates in the series, applying to sealevels close to the marine limit, are younger than dates of comparable high-level shells cited above from Coronation Gulf and Victoria Island to the W and NW. An alt/time curve for the series (neglecting eustatic sealevel change) indicates that initial rate of emergence was at least 30 ft per century from 8900 to 7800 yr ago. The rate decreased to ca. 14 ft per century from 7800 to 7200 yr ago and then decreased further to ca. 3.5 ft per century from 7200 to 4500 yr ago. Sample I(GSC)-178 (3690 ± 120 from alt 72 ft, Isotopes II) is not included in this series because the locality is outside (W of) the area arbitrarily chosen for the series. Nonetheless, the date fits well into the alt/time curve for the series.

GSC-41. Wager Bay, Northwest Territories

5470 ± 140

Marine pelecypod shells from fine sand on surface of a terrace, alt 184 ft, on valley wall above a fiord-like lake 6.5 mi N of E end of Ford Lake, near head of Wager Bay ($66^{\circ} 10' \text{ N Lat, } 90^{\circ} 14' \text{ W Long}$). The terrace may be a remnant of a delta formed when the seashore stood ca. 200 ft below the marine limit (alt ca. 400 ft). Coll. 1960 by M. Tremblay for B. G. Craig. *Comment*: date is considerably younger than I(GSC)-212 (7160 ± 160 , Isotopes II) from a comparable altitude in the Northern Keewatin series. Site is just W of the Keewatin ice divide, which is inferred to have been the locus of the last ice-sheet remnant(s) W of Hudson Bay. Marine submergence of the site could not have taken place until glacial retreat in the ice-divide zone permitted the sea to penetrate across the divide from Hudson Bay.

GSC-23. Baker Lake, Northwest Territories

1800 ± 60

Tundra-plant debris from stream-terrace deposits where Prince River enters Baker Lake, District of Keewatin ($64^{\circ} 18' \text{ N Lat, } 95^{\circ} 46' \text{ W Long}$). Sample from organic layer, ca. 10 ft above lake, in crossbedded sand in a terrace 25 ft above Baker Lake and ca. 30 ft above sealevel. Coll. 1954 by J. G. Fyles. *Comment*: date is assumed to record the age of the terrace or (less probably) of a slightly higher river-mouth deposit into which the terrace has been cut. The terrace originated either when Baker Lake, and presumably the sea, stood 20-25 ft higher than at present or when the sea flooded the lake basin 25-30 ft above present sealevel. The date fits well into the chronology of postglacial uplift around Hudson Bay compiled by Lee (1960). NaOH-leach omitted from sample pretreatment; coal gas added to sample for counting (51.8% sample, 48.2% coal gas at 2 atm pressure).

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