Comparison of Elevations of Archaeological Sites and Calculated Sea Levels in Arctic Canada

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ABSTRACT. Based on a study of postglacial uplift in the Canadian Arctic it has been proposed that relative emergence can be estimated if the age and elevation of late-glacial marine limits are known. This suggestion is used to construct 5 maps showing the amounts of relative sea level emergence since 4,000, 3,200, 2,400 1,600 and 800 B.P. The archaeological sequence of coastal arctic Canada has been artificially divided into 5 corresponding 800-year periods. Eighty-four archaeological sites are examined; 71 of these appear to have been located with reference to contemporaneous sea level. The mean elevation of the 71 sites is only 5.2 m. above the interpolated sea level for each period; the Spearman rank correlation between site elevations and interpolated sea level is 0.82. The maps can therefore be used to delimit area of search for cultural remains of specific ages in archaeological reconnaissance, but the relationship is not sufficiently close to allow the construction of a detailed chronological sequence using elevation data alone.

RÉSUMÉ. *Comparaison des altitudes de sites archéologiques et de niveaux marins calculés, dans l'Arctique canadien.* Sur la base d'une étude du relèvement post-glaciaire dans l'Arctique canadien, on a proposé que l'émergence relative peut être estimée si l'âge et l'altitude des limites marines fini-glaciaires sont connus. A partir de cette suggestion, on construit 5 cartes montrant les niveaux d'émergence relative du niveau de la mer depuis 4000, 3200, 2400, 1600 et 800 ans. Puis, on divise artificiellement la séquence archéologique du Canada arctique côtier en 5 périodes de 800 ans. Des quatre-vingt-quatre sites archéologiques examinés, 71 semblent localisés par rapport au niveau marin qui leur était contemporain, car l'altitude moyenne de ces 71 sites n'est que de 5,2 m au-dessus du niveau moyen interpolé pour chaque période; la corrélation de Spearman entre l'altitude des sites et le niveau marin interpolé est de 0,82. Ces cartes peuvent ainsi servir à délimiter une aire de recherche de vestiges culturels d'âges spécifiques dans une reconnaissance archéologique, mais la relation n'est pas suffisamment juste pour permettre la reconstruction d'une séquence chronologique détaillée n'utilisant que les seules données d'altitude.

РЕЗЮМЕ. *Сопоставление отметок высоты археологических площадок и древних уровней моря в канадской Арктике.* Предположние, что относительное поднятие уровней моря в послеледниковый период может быть определено если возраст и отметки позднеледниковых уровней моря известны, используется для построения соответсвующих карт, которые значительно облегчают поиски первобытных стоянок.

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INTRODUCTION

There are many research problems that provide an overlap of interests between Quaternary geologists and archaeologists; one of the best examples concerns the postglacial delevelling of the Canadian Arctic and the possible correlation between the elevation of prehistoric Eskimo sites and their ages. To the archaeologist, the ancient beaches, deltas and terraces lying between the late-glacial marine limit and present sea level provide a potential chronological sequence where elevation is some function of age. Conversely, the postglacial emergence, and in a few cases submergence, of Arctic Canada is a major interest of Quaternary geologists and one with important geophysical implications. This paper examines the relationship between the elevations of archaeological sites along Canadian Arctic coasts and the elevations of the contemporaneous shorelines calculated by empirical methods. The primary purpose of this examination is to give archaeologists an idea of the relationship between age of archaeological sites and their elevation above present sea level, and to ascertain if this relationship is close enough to allow chronological sequences to be developed on elevation data alone.

In the years since World War II our knowledge of the glacio-isostatic recovery of the area formerly loaded by the Laurentide and other arctic ice sheets has increased extensively. Fortunately, a major part of the research effort coincides with the development of the radiocarbon method of dating which resulted in a program of measuring the height and age of this time-transgressive limit. Syntheses of changes in marine limit elevations were presented by Craig and Fyles (1960), Farrand and Gajda (1962) and Bird (1967). The broad chronology of deglaciation has been documented by Bryson *et al.* (1969) and Prest (1969) through the construction of isochrones based on available radiocarbon dates.

Studies on the postglacial emergence of specific sites within arctic Canada were first reported by Farrand (1962) and Lee (1962); their data were presented in the form of time/elevation curves. The former author remarked on the overall similarity of the curves. Between 1962 and 1969 additional studies were made on the postglacial emergence of specific areas (e.g. Løken 1965; Matthews 1967; Craig 1969) and Andrews (1968) suggested that it was possible to reduce 21 postglacial uplift curves, from the area of the Canadian Arctic once covered by the Laurentide Ice Sheet, to a common form. This in turn enabled the elevation of a former sea level, say 4,000 years old, to be approximated given the age and elevation of a marine limit. Where there are data on several marine limits within an area the prediction equation (see (1) below) enables the geometry of crustal warping to be ascertained (Andrews 1970).

The ability to estimate the elevation of a former sea level at a specified date is potentially useful to students of arctic archaeology, as they are primarily concerned with the remains of maritime hunting peoples whose camps often appear associated with a presumed contemporaneous shoreline. Emergence estimates for different periods thus give the archaeologist an indication of the elevations at which he should search for cultural remains; they also provide a first estimate of the likely age of sites when they are found. When the age of the remains is determined by cultural comparisons or isotope dating, the relationship between the elevation of the remains and contemporaneous sea level may suggest the type of activity for which the camp was established. Summer boat-launching sites, for example, would be expected to be closely related to the shore, whereas winter hunting camps may have been built at higher elevations with better visibility.

Many archaeologists working in the Canadian Arctic have attempted to relate site elevations to ancient sea levels, but most have considered the relationship to be uncertain, or at most, imprecisely determined (Collins 1962, p. 128-9; Maxwell 1962, p. 35; Knuth 1967, p. 13; Taylor 1968, p. 99). At no place in the Canadian Arctic do we find the extremely close correlation of settlements with fossil shore lines that has been reported in certain parts of western Alaska where, in the Bering Sea region, sequences of beach ridges at uniform elevation are formed by wave deposition rather than by emergence (Giddings 1967, p. 16-18), and they can be used as the basis for establishing a chronology for the occupation sites found on the beach ridges. In the Canadian Arctic, elevated beach ridges have been used to establish a chronology only for the Pre-Dorset and Dorset occupations in the vicinity of Igloolik (Meldgaard 1962, p. 92-93). Elsewhere the action of extraneous variables has been considered to rule out this possibility. Taylor (1968, p. 99) has summed up the attitude of most Arctic archaeologists:

"Beaching boats, snow conditions, shelter, drinking water, visibility for offshore hunting, fishing and hunting opportunities and conditions in the immediate area and the availability of such building materials as gravel, stone and turf are factors, along with proximity to water's edge, that influence a choice of camp location. This does not deny the great value of site elevations for archaeological interpretations, but I hope it indicates that an elevation sequence is a sharp tool that can cut the carpenter as easily as it does the wood."

DEFINITIONS

ISOBASES: Lines joining sites with similar postglacial uplift over the same interval of time.

MARINE LIMIT: The highest point to which the postglacial sea reached at a particular point.

POSTGLACIAL EMERGENCE: The relative and positive movement of former sea levels caused by glacio-isostatic recovery outstripping the eustatic sea level rise.

POSTGLACIAL UPLIFT: In general in the Canadian Arctic glacio-isostatic recovery and eustatic sea level changes have been self-cancelling (i.e. both were in the same direction). Thus marine limits and lower sites show only the relative sea level movement. On the other hand, postglacial uplift is computed as the amount of postglacial emergence at specific times less the eustatic sea level at those times measured from present sea level.

DELEVELLING: Relative sea level change, either positive (emergence) or negative (submergence).

CONSTRUCTION OF ISOBASE MAPS

The isobase maps presented in this paper are based on elevation estimates from 53 sites from northern and eastern Canada. The sites are shown in Fig. 1; calculated elevations of former sea levels as well as the elevation and age of the marine limit are listed in Table 1 (the site numbers are identical with those in Andrews 1970, Table 5-1 and Figure 1-1). Discussions of methods of calculating postglacial rebound as a function of time appear in Andrews 1968 and 1970 and are not repeated in detail. Suffice it to note that the estimates (Table 1) are derived from:

$$U^*p = A\ (i^t - 1)/i\text{-}1 \qquad (1)$$

where U^*p is postglacial uplift in t x 10^3 yr. BP, and where for each site A is the amount of uplift in the last 1,000 years and i is a constant approximated by 1.521. Given the amount of postglacial uplift, Up, and date of deglaciation it is possible to compute the value for A (Andrews 1970). Theoretical considerations (e.g. Brotchie and Silvester, 1969, and Walcott 1970) suggest that the model implied in equation (1) is probably an oversimplification, but from an empirical point of view the equation gives results that closely fit field observations (see Andrews 1970 for discussion and illustration).

There are a number of error sources in our method of approximating relative sea level changes. One of the most significant is that the figure for A is derived from considerations of the amount of postglacial uplift and date of deglaciation. If the amount of postglacial uplift is set equal to 100 per cent, then A per cent (equation (1)) is a function of the date of deglaciation (Andrews 1970, Figs. 3-5). The date of deglaciation cannot be ascertained better than about ± 200 years and consequently there is an error source at this point. Furthermore, the determination of the amount of postglacial uplift requires an accurate measurement of the marine limit and eustatic sea level at the time of deglaciation. At best, the former measurement is correct to $\pm$ 3m., whereas estimates of the latter vary within an even wider range. Problems of contamination of the dated material also arise as does the relation between radiocarbon years and calendar years (Stuiver and Suess 1966). Despite these difficulties, experience indicates (Andrews 1970) that the calculated sea levels for $\leq$ 4,000 BP agree with C-14 dated geological sites. Estimated error ranges are listed in Table 1.

Table 1 of this paper lists the individual A values for the 53 geological sites: equation (1) was solved for t = 1, 2, 3 and 4 x 10^3 yr. BP. For example, the west Baffin Island site, number 20, has an A value of 3.57 m. and thus the calculated amount of uplift in the last 2 x 10^3 yr. is: $U^*p = 3.57\ (1.521^2\text{-}1)/1.521 - 1 \approx 9$ m. Graphs were drawn showing uplift over the last 4,000 years, and the values of uplift at specific times listed in Table 1 were simply taken from the graphs of uplift for the 53 sites.

World (eustatic) sea level was very close to present sea level during that period (see Jelgersma 1966, for review); the 4,000 BP estimates range between + 5 and − 4 m. relative to present sea level, and converge towards the present day; most curves are, however, within $\pm$ 1.5 m. of present sea level for this period. Because the correction is small and not known in detail, eustatic corrections have not been applied to the estimates in Table 1. The range of possible corrections

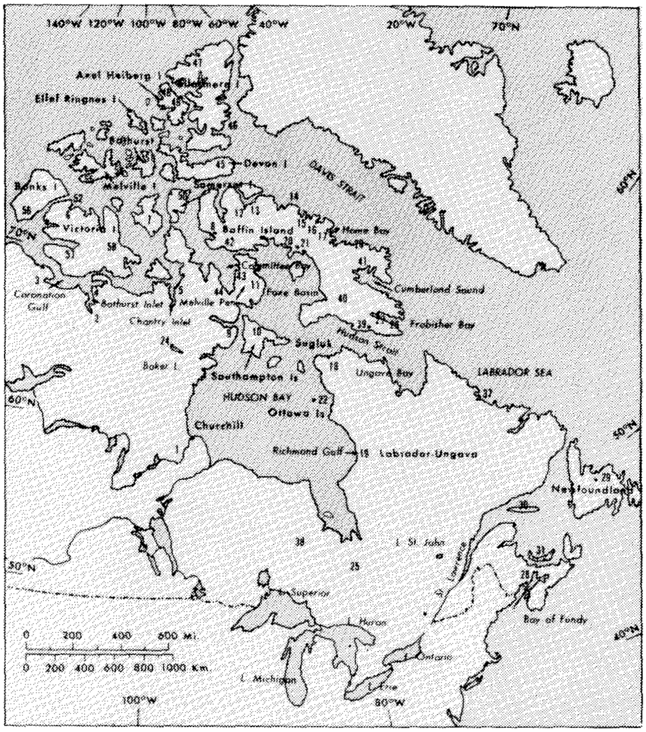

FIG. 1. Location of the 53 sites used to estimate the postglacial uplift.

is shown in Table 1. The problem is made more difficult by the effect of the eustatic sea level loads on coasts, which will vary from place to place. A comparison of radiocarbon dated postglacial emergence and calculated emergence based on equation (1) indicates that the calculated estimates agree with the radiocarbon dated sequences; compare, for example, the estimates in Table 1 with postglacial emergence curves from site 17 (Løken 1965), site 22 (Andrews and Falconer 1969) and site 1 (Craig 1969) amongst others.

The various error sources can be very significant when reconstructing the emergence of a specific site, but where a spatial array of data is considered there is a check on the acceptability of the technique. Neighbouring sites will differ in terms of the postglacial uplift and date of deglaciation, but we postulate that contours on the postglacial emerged surface should portray a relatively simple pattern of crustal deformation in line with the simple geometry of large ice sheets. Contouring the 53 sites represents a further level of approximation and loss of information. One last point of note is that the distribution of our sites is biased towards coastal locations and we have little information on the postglacial crustal uplift of the continental interiors; contours across these inland areas are schematic.

CALCULATED SEA LEVELS AND ARCHAEOLOGICAL SITE ELEVATIONS

We have artificially divided the Eskimo archaeological sequence of the Canadian Arctic into five 800-year periods (Table 2). This division is not based on

TABLE 1. Estimated elevation (m.a.s.l.) of sea levels for arctic Canada (see Fig. 1) based on the postglacial uplift equation (1); suggested error range of the calculated elevations and eustatic sea level ranges.

Site No.	800 BP	1600 BP	U*p 2400 BP	3200 BP	4000 BP	A
1	3	8	14	23	35	4.27
2	3	8	14	22	34	4.17
3	1	3	6	10	16	1.92
4	2	4	8	13	19	2.40
5	2	5	10	16	24	2.95
6	~0	1	2	3	5	0.63
7	1	3	6	9	14	1.68
8	1	3	6	10	15	1.90
9	4	10	18	28	44	5.41
10	4	9	17	26	41	5.02
11	3	9	16	25	38	4.73
12	1	3	6	10	15	1.83
13	1	3	6	10	15	1.76
14	1	2	3	5	8	0.99
15	1	3	6	9	14	1.78
16	2	5	10	15	22	2.77
17	1	3	6	9	14	1.70
18	3	6	11	18	28	3.44
19	5	12	22	35	52	6.45
20	3	7	12	19	29	3.57
21	3	8	14	22	34	4.14
22	3	8	14	22	35	4.34
23	1	1	2	4	6	7.68
24	4	10	19	30	45	5.67
25	3	6	11	18	28	3.47
26	1	2	4	6	9	1.14
27	2	3	6	10	16	1.91
28	~0	1	2	2	3	0.38
29	~0	1	2	3	4	0.45
30	0	1	2	2	3	0.36
31	~0	~0	1	1	2	0.22
37	1	2	3	5	7	0.89
38	4	9	17	26	40	4.90
39	2	5	9	14	21	2.64
40	3	7	12	19	30	3.65
41	1	2	4	7	11	1.39
42	2	5	8	13	20	2.44
43	3	6	11	18	27	3.38
44	3	7	12	20	30	3.65
45	1	2	4	7	11	1.41
46	2	4	7	12	18	2.20
47	2	4	7	11	17	2.07
48	1	2	4	6	9	1.13
49	3	7	12	19	29	3.54
50	1	2	4	8	12	1.45
51	1	3	6	10	15	1.79
52	~0	1	1	2	3	0.41
53	~0	1	1	2	3	0.32
54	1	2	4	6	10	1.21
55	~0	1	1	2	4	0.45
56	~0	~0	1	1	2	0.21
57	1	2	3	6	9	1.15
58	1	3	5	8	12	1.52
Max. Range (m.)	0-5	0-12	1-22	1-35	2-52	
Difference	5	12	21	34	50	
Contour Interval	1 m.	2 m.	3 m.	4 m.	5 m.	
Number of Contours	5	6	7	8	10	
Suggested error range	—	1-0	2-1	3-1	5-1	
Range of eustatic sea level estimates (m.)	±0.5	+1 to −1	+2 to −2	+3 to −3	+5 to −4	

TABLE 2. Cultural affinities for the isobase maps.

Date BP	Cultural Period	Fig.	Table
800-0	Recent	7	
1600-800	Late Dorset — Early Thule	6	6
2400-1600	Dorset	5	5
3200-2400	Late Pre-Dorset — Early Dorset	4	4
4000-3200	Pre-Dorset	3	3

distinctive cultural groupings, but on geological considerations of having a reasonable interval between periods. The 800-year periods are sufficient to allow site elevations to be differentiated, and most of the archaeological components can be definitely ascribed to one of these periods. The 84 archaeological components for which suitable age and elevation data are available are listed in Tables 3 to 6. The locations of these components are indicated in Fig. 2. The site elevations given in these tables are the *minimum* elevations for each component. The ages listed in Tables 3 to 6 are either the radiocarbon age determinations on which the period assignment is based, the age range estimated by the excavator of the component or, in the cases marked by an asterisk, the age range estimated by one of the present authors (McGhee) based on the cultural attributes of the component.

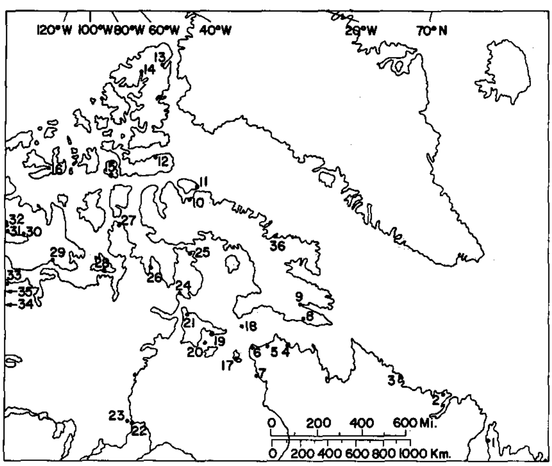

FIG. 2. Location of the archaeological sites used in the study — see Tables 3 to 6.

The range of sea level elevations (column 5) listed for each component in Tables 3 to 6 is derived from the isobase maps (Figs. 3 to 7). The range is defined by the high contour at the beginning of the appropriate period and the low contour at end of the period. The expected sea level at time of occupation of each component relates to the location of the component and the midpoint of the estimated temporal range of occupation. These estimates are based on linear regressions of emergence between each adjacent pair of contour lines and throughout each 800-year period; these interpolations should not be given as much considera-

TABLE 3. Pre-Dorset Components, 4,000-3,200 BP Locations on Fig. 2.

Site	Location	Date BP	Observed Elevation (m.)	Sea Level Range	Expected Sea Level	Reference
Village Bay	3	4000-3000*	12	3-10	7	Fitzhugh, N.D.
Meeus	6	3500	32	20-35	25	Taylor 1962; p. 81
Mungiok	6	3500	35	20-35	25	Taylor 1962; p. 81
Pita	6	3500	35	20-35	25	Taylor 1962; p. 81
Closure	8	4067±73 (P-707)	12	12-20	20	Maxwell, N.D.
Annawalk	8	3814±69 (P-708)	18	12-20	18	Maxwell, N.D.
Loon	8	3577±69 (P-710)	14	12-20	16	Maxwell, N.D.
Site 13	8	3480±200 (M-1531)	11	12-20	15	Maxwell, N.D.
Shaymark	9	4140±130 (GSC-849)	15	12-20	20	Maxwell, N.D.
Nunguvik V	10	4000-3000*	12	4-15	10	Rousselière, N.D.
Inavik	12	4000-3000*	12	4-15	10	Lowther 1962, Fig. 1
Burin Delta	13	4000-3000*	20	8-25	15	Knuth, N.D.
Lonesome, F. 42	13	4000-3000*	28	8-25	15	Knuth, N.D.
Kettle Lake S.	14	3930±130 (K-1260)	97	8-25	18	Knuth 1967; p. 63
Kettle Lake S.	14	3810±130 (K-1261)	95	8-25	18	Knuth 1967; p. 63
Kettle Lake N.	14	3760±130 (K-1262)	90	8-25	18	Knuth 1967; p. 63
Air Force Valley	14	4000-3000*	71	8-25	18	Knuth, N.D.
Tanquary Station	14	4000-3000*	22	8-25	18	Knuth, N.D.
Arnapik	17	3500-3000	28	20-40	27	Taylor 1968; p. 12
Roberts	17	4000-3000	28	20-40	30	Taylor 1968; p. 15
Thyazzi	23	3500	33	20-35	30	Nash 1969; p. 10
Parry Hill	25	3958±168 (P-207) 3906±135 (P-209)	51	16-25	25	Meldgaard, pers. comm.
St. Mary's Hill	26	4000-3500*	60	16-25	20	Rousselière 1964; p. 164
Wellington Bay	29	3180±120 (I-2057)	36	8-20	10	Taylor, pers. comm.
OdPq-4	31	4000-3000*	9	1-10	6	McGhee 1971
OhPo-5	32	4000-3000*	5	1-10	4	McGhee, In Press

tion as the range estimates in relating archaeological site elevations to ancient sea levels. The reader should note that the contour interval on the isobase maps decreases through time in accordance with a decrease in the range of estimated sea levels.

Pre-Dorset: 4,000-3,200 B.P. (Table 3, Figs. 3 and 4)

Postglacial emergence over the last 4,000 years at the 53 dated sites varied between 2 and 52 m.a.s.l. Few large anomalies were noted during the contouring of these data and the change of sea level since 4,000 B.P. could be mapped with ease. The resulting isobase map (Fig. 3) pictures a relatively simple raised topography with two high cells located over southeast and northwest Hudson Bay with maximum estimates of 52 m. and 45 m.a.s.l. respectively. A wide area of intermediate values separates the above-mentioned northwest centre from a smaller one located between east Axel Heiberg and west Ellesmere islands, and named the Innuitian Ice Sheet (Blake 1970). The maximum emergence at site 49 is 29 m.a.s.l. which is identical to that for site 20, west Baffin Island, and suggests that the Queen Elizabeth ice cap had a thickness equivalent to the Laurentide Ice Sheet over west Baffin Island. Fig. 3 demonstrates that the emerged surface is warped. The 5 m., 10 m., and 15 m. contours are well spaced, especially over the northwestern area of the map. They become increasingly grouped between the 15 m. and 30 m. isobases and then appear to become more widely spaced again between 35 m. and 45 m.a.s.l.

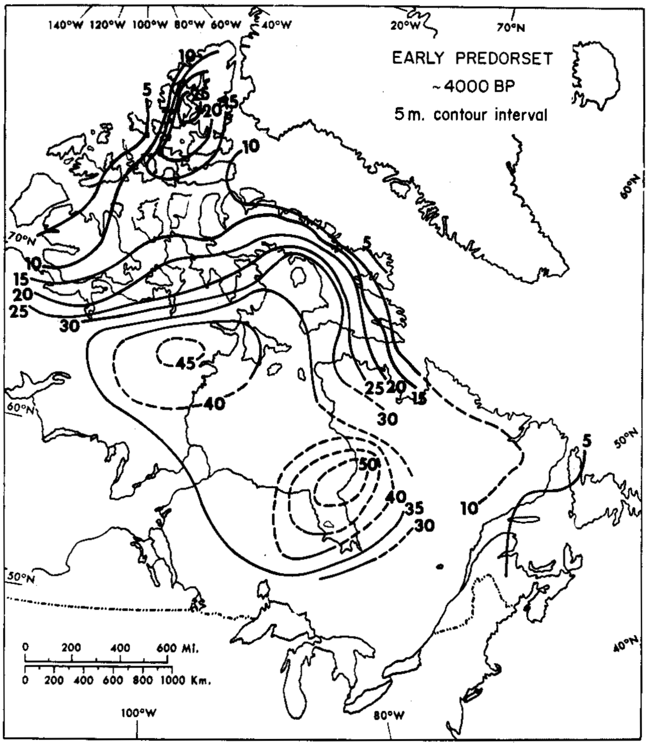

FIG. 3. Isobases of postglacial uplift in the last 4.000 years.

The majority of the 26 archaeological components placed in this period have elevations which fall within the range of sea-level elevations predicted by the isobase maps, or are at least within a few metres of the range limits (Table 3). The Ungava site elevations are fairly consistent, suggesting that these coastal camps were closely associated with contemporaneous shore lines. The southern Baffin Island sites listed (Shaymark, Closure, Annawalk, Loon, Site 13) are only those for which radiocarbon dates are available; the elevations of these sites are consistent with those of other undated sites which Maxwell (N.D.) places in the same period. It may be noted that the Baffin Island radiocarbon dates were obtained on samples of seal fat, which has been noted to yield dates a few centuries older than dates obtained from associated samples of wood charcoal (Wilmeth 1969, p. 119); still earlier radiocarbon dates from some of these sites are ignored for this reason. This may explain why the calculated sea levels are up to 5 m. *above* the measured elevation of these sites; nevertheless, only one of these sites falls below the calculated range of sea levels of the time.

The Kettle Lake and Air Force Valley sites in northern Ellesmere Island are far above calculated sea levels at the time of occupation. The fact that identical cultural materials were recovered from the Tanquary Station site in the same immediate area but at a much lower elevation indicates that this discrepancy is not due to error in the isobase maps; the Burin Delta and Lonesome sites in northeastern Ellesmere Island are also at low elevations and relatively close to the calculated sea levels at time of occupation. The high elevations of the Kettle

Lake and Air Force Valley sites are probably related to the fact that these components are thought to represent muskox-hunting camps and were established without any concern for coastal activities (Knuth, N.D.). A similar situation probably explains the 60 m. elevation of the St. Mary's Hill site, which is several km. inland and which Rousselière (1964, p. 164) notes to have been an excellent lookout station for caribou hunters. The remaining two components which show major discrepancies with predicted sea levels are the Parry Hill and Wellington Bay sites. Both of these components show evidence of coastal hunting activities, and there is no apparent reason why their elevations should be 26 m. above the predicted elevations of contemporaneous sea levels. The rate of emergence in these local areas may have been different from that suggested by the isobase maps, although this possibility is considered unlikely.

Late Pre-Dorset — Early Dorset: 3,200-2,400 B.P. (Table 4, Figs. 4 and 5)

Isostatic recovery in the last 3,200 years has obviously been less than over the last 4,000 years. Table 1 shows that the maximum range between any two sites has fallen to 34 m. Fig. 4 is an isobase map showing the present elevation of the sea level at 3,200 B.P. The contour interval is 4 m., not 5 m. as for Fig. 3. Postglacial emergence proceeded most rapidly over southeast and northwest Hudson Bay, and over the Queen Elizabeth Island centre. Over southeast Hudson Bay sea level changed by about 17 m. in the 800 years. In Fig. 3, Hudson Bay, Foxe Basin and a large section of the Arctic mainland lie within the 30 m. contour, whereas in Fig. 4 the same areas are enclosed by the 20 m. isobase. It is within this large area that the cultural variation with elevation is most likely to be of significance to archaeological field investigations. If encampments of the early people were closely related to the sea level of the time, then a change in level of about 10 m. should be detectable in the archaeological record. Converse-

TABLE 4. Late Pre-Dorset — Early Dorset Components, 3,200-2,400 BP.

Site	Location	Date BP	Observed Elevation (m.)	Sea Level Range	Expected Sea Level	Reference
Ticoralak 2	2	2690±140 (GSC-1179)	9	3-5	3	Fitzhugh, N.D.
Thalia Point 2	3	3200-2400*	9	3-5	4	Fitzhugh, N.D.
Tyara	5	2670±130 (GSC-701) 2630±130 (GSC-703)	17	12-24	13	Taylor 1968; p. 45
Ohituk	6	2900-2400*	18	12-24	16	Taylor 1962; p. 81
Killilugak	8	3043±63 (P-699)	10	6-16	12	Maxwell, N.D.
Tanfield	8	2608±50 (P-698)	7	6-16	10	Maxwell, N.D.
Nanook 1	8	2410±120 (M-1535)	12	6-16	8	Maxwell, N.D.
Button Point	11	3200-2400*	6	3-8	5	Mathiassen 1927; p. 207
Lonesome, F. 15	13	2500	15	6-12	8	Knuth, In Press
T1	19	2632±128 (P-76) 2508±130 (P-75)	21	15-24	19	Collins 1957; p. 23
Twin Lakes	22	3000-2500	38	12-24	18	Nash 1969; p. 55
Seahorse Gully	22	2900±100 (S-521)	30	12-24	18	Nash, pers. comm.
Alarnerk	25	2910±129 (P-213)	22	12-20	16	Meldgaard, pers. comm.
Menez	29	2880±105 (I-2058)	36	6-12	9	Taylor, pers. comm.
Buchanan	29	2990±125 (I-2054) 2910±105 (I-2053)	25	6-12	9	Taylor, pers. comm.
Begg	29	3200-2800*	29	6-12	9	Taylor, pers. comm.
Cape Hooper	36	2400±90 Gak 1992	2.5	1-2	1	Andrews 1970

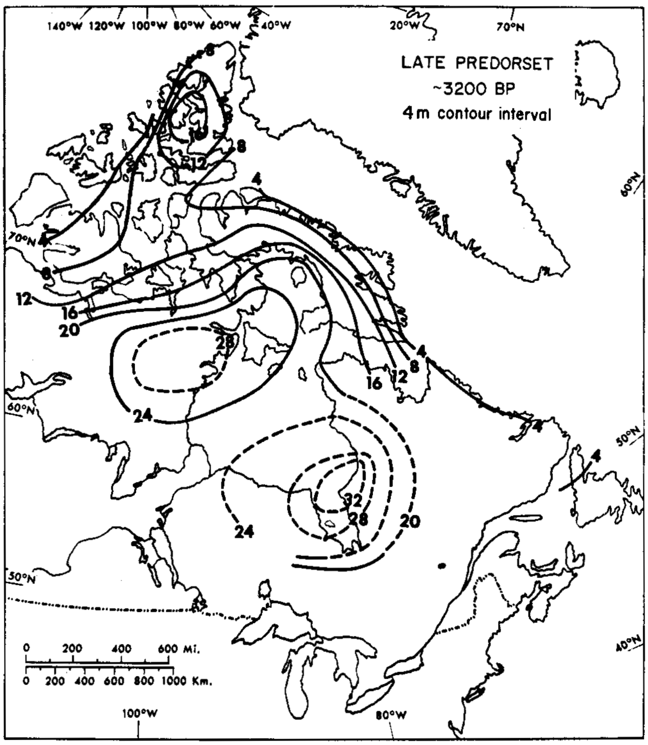

FIG. 4. Isobases of postglacial uplift in the last 3,200 years.

ly, consider the north coast of Cumberland Peninsula, Baffin Island (Figs. 3 and 4) where estimated changes of sea level between 4,000 and 3,200 BP are of the order of 1 m. (or less); an elevation/cultural sequence is not to be expected in such locations.

During this period the correlation of component elevations with sea level predictions is not as close as in the preceding period, although most of the elevations are within a few metres of the upper end of the expected sea level ranges (Table 4). The Labrador sites are slightly higher than expected, but as before the Ungava and Baffin Island site elevations fall within the expected ranges. The Alarnerk site at Igloolik is higher than expected, as was the Parry Hill occupation in the preceding period. The Twin Lakes and Seahorse Gully sites are at approximately the same elevations as was the Thyazzi site of the preceding period (Table 3) and thus there is no indication of elevation changes in response to the rapid rebound which occurred in this area during the preceding 800 years. The Seahorse Gully occupation, on top of a rocky ridge adjacent to the present coast, may have been located above contemporaneous sea level as a look-out station. The Twin Lakes site, now located on an isolated ridge 18 km. inland and remote from hunting areas is thought to have been occupied while close to the shore (Nash 1969, p. 55). It should be noted, however, that a sea-level rise of 24 m., the upper end of the expected range for this occupation, would have brought the shore within 2 km. of the site location (Nash 1969, p. 54). Finally, the Menez, Buchanan and Begg sites, all located in the valley of the Ekalluk River a few km. inland from

TABLE 5. Dorset Components, 2,400-1,600 BP.

Site	Location	Date BP	Observed Elevation (m.)	Sea Level Range	Expected Sea Level	Reference
Port aux Choix 2	1	2000-1600*	4	1-3	2	Harp 1964; p. 18
Ticoralak 3	2	2380±140 (GSC-1217)	8	2-3	3	Fitzhugh, N.D.
Ticoralak 5	2	2400-1600*	7	2-3	3	Fitzhugh, N.D.
East Pompey I.	2	2400-1600*	8	2-3	3	Fitzhugh, N.D.
Niaqungut	4	2400-2000	12	4-11	7	Barre 1969
Eeteevianee	6	2000-1600*	12	6-15	8	Taylor 1962; p. 81
Kemp	8	2200±120 (M-1534)	8	4-9	7	Maxwell, N.D.
Killuktee	8	1670±150 (M-1533)	4	4-9	4	Maxwell, N.D.
M1	15	2400-1600*	19	2-6	4	Collins 1955; p. 23
JlGu-5	17	2400-1600*	23	8-15	12	Taylor 1968; Fig. 2
JlGu-6	17	2400-1600*	14	8-15	12	Taylor 1968; Fig. 2
T3	19	2191±120 (P-77)	14	8-18	15	Collins 1957; p. 28
Walrus Island	20	2400-2000	15	8-18	15	Collins 1957; p. 32
Seahorse Gully	22	2080±95 (I-3973)	18	8-15	11	Nash 1969; p. 154
Ferguson Lake	29	2400-1800*	19	2-9	5	Taylor, pers. comm.
Buchanan	29	2400-1800*	22	2-9	5	Taylor, pers. comm.
Ballantine	29	2450±220 (GSC-658) 2220±140 (GSC-640)	24	2-9	6	Taylor, pers. comm.
Joss	30	1860±100 (Gak-1257)	7	0-2	1	McGhee 1971
Bernard Harbour	33	1900	10	2-6	4	Taylor, N.D.

Wellington Bay, are all caribou hunting stations (Taylor 1967, p. 225) which were probably established with no regard to the location of the contemporaneous shore.

The expected decrease in site elevation is apparent between this period and the preceding. For 21 sites occupied between 4,000 and 3,200 BP and probably located with some reference to contemporaneous sea levels, the average elevation is 22.3 m.; for the 13 sites occupied between 3,200 and 2,400 BP and similarly located, the mean elevation is only 14.3 m.

Dorset: 2,400-1,600 BP (Table 5, Figs. 5 and 6)

This period saw the greatest expansion of Dorset culture, from Dolphin and Union strait in the west to Newfoundland in the southeast. An isobase interval of 3 m. is employed in Fig. 5 in accordance with the decreased range of uplift values. The 3 m. isobase is situated on the landward side of Newfoundland (Fig. 5); the same isobase crosses Victoria Island. Maximum crustal emergence at the three uplift centres amounted to 22 m., 19m., and 12 m. (Table 1, sites 19, 24 and 49 respectively (Fig. 2)). There is a pronounced gradient along Hudson Strait with the 3 m. isobase crossing the mouth of the Strait and values increasing to between 12 m. and 15 m.a.s.l. at the western end.

The only Dorset site on the northern peninsula of Newfoundland for which elevation is available, the Port aux Choix 2 site, is at a low elevation and close to that of expected sea level. The Labrador sites are slightly lower than those of the preceding period, but are a few metres higher than the range of contemporaneous sea levels. Of the Ungava Dorset sites, only J1Gu-5 is several metres higher than the expected range of sea levels; the reason for this anomaly is not apparent. The Baffin, Southampton and Walrus Island sites are again within the expected range of sea levels but the M1 site on Cornwallis Island, in a

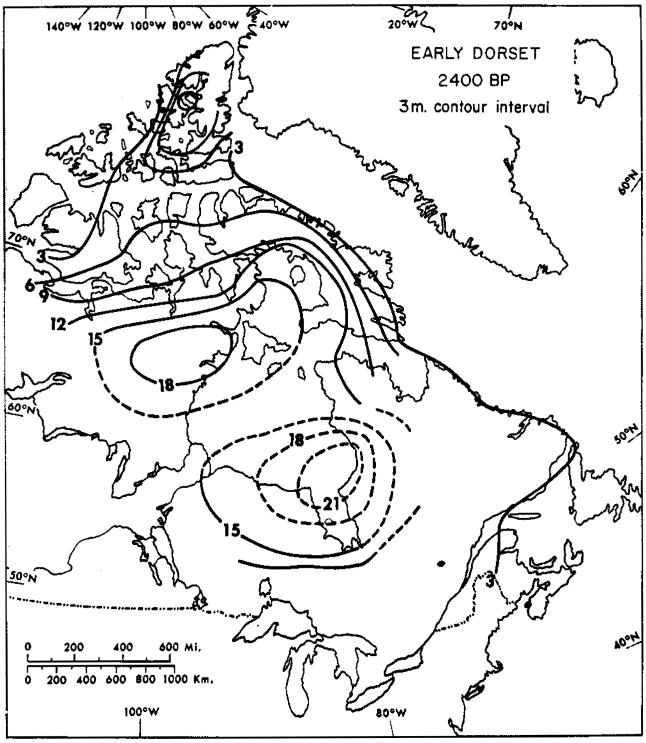

FIG. 5. Isobases of postglacial uplift in the last 2,400 years.

situation in which it should relate closely to contemporaneous sea level, is for some unexplained reason 15 m. higher than expected. The Dorset component of the Seahorse Gully site is a few metres higher than expected, but 12 m. lower than the occupation of the Pre-Dorset component of the same site. The Dorset components at Ferguson Lake, Buchanan and Ballantine sites are lower than the Pre-Dorset components of the preceding periods but, as might be expected for these caribou-hunting stations, show no closer relation to contemporaneous shore lines. The western Dorset components of Joss and Bernard Harbour are somewhat higher than expected, but still relatively low and probably located with reference to contemporaneous sea levels.

In sum, the site elevations of the Dorset period tend to be somewhat higher than the predicted range of sea level elevations for that period. On the other hand, the mean elevation for the 16 sites which were probably located with some reference to contemporaneous sea level is 11.4 m., some 3 m. less than the mean elevation for the preceding period. Only one site is 1 m. lower than the calculated sea level for the time. The south Baffin Island sites (Fig. 2, site 8) are close to predicted sea level in opposition to their position during the earlier periods.

Late Dorset-Early Thule: 1,600-800 B.P. (Table 6, Figs. 6 and 7)

The amount of isostatic recoil in the last 1,600 years varied between 0 and 12 m. (Table 1). Fig. 6 is a map of the isobases from this period with a 2 m. contour interval. The separation between successive 800-year intervals becomes less and

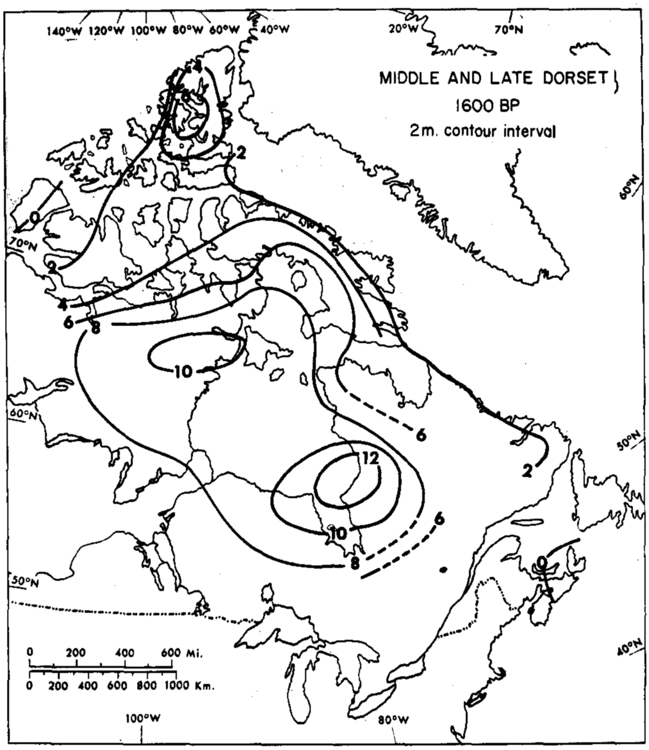

FIG. 6. Isobases of postglacial uplift in the last 1,600 years.

TABLE 6. Late Dorset-Early Thule Components, 1,600-800 BP.

Site	Location	Date BP	Observed Elevation (m.)	Sea Level Range	Expected Sea Level	Reference
Smith Island	7	1600-1000*	17	3-8	6	Manning 1951; p. 64
Sandy	8	1470±110 (M-1529)	4	1-6	4	Maxwell, N.D.
Mitimatalik	10	1000-800*	6	1-4	2	Mathiassen 1927; p. 133
Qilalukan	10	1000-800*	6	1-4	2	Mathiassen 1927; p. 138
Nunguvik I	10	1380±95 (S-478) 1290±120 (Gak-2339)	3	1-4	2	Rousselière, N.D.
Eqaluit II	10	100-800*	8	1-4	2	Rousselière, N.D.
Basil Norris	13	1000-800	14	2-4	2	Maxwell 1960; p. 77
Lonesome, C. 6	13	800*	3	2-4	2	Maxwell 1960; p. 77
M1	15	1000-800*	19	1-4	2	Collins 1955; p. 23
M2	15	1600-800*	6	1-4	2	Collins 1955; p. 22
McCormick Inlet	16	1150±160 (GSC-148)	2	0-3	1	Henoch 1964; p. 122
Mill Island	18	1600-1000*	18	3-10	7	O'Bryan 1953; p. 42
Kuk	21	800*	6	3-10	5	Mathiassen 1927; p. 224
Naujan	24	1000-800*	12	3-10	5	Mathiassen 1927; p. 6
Alarnerk	25	1100	8	2-6	3	Meldgaard, pers. comm.
Nudlukta	27	1000-800*	15	1-4	1	VanStone 1962; p. 18
Malerualik	28	1000-800*	15	1-6	2	Mathiassen 1927; p. 307
Freezer	29	1600-1000*	8	0-4	3	Taylor, pers. comm.
Memorana	31	800*	18	0-2	0	McGhee, In Press
Morris	34	1000-800*	5	0-4	1	Taylor, N.D.
Jackson	35	935±90 (I-2088)	2	0-2	0	Taylor, N.D.
Vaughn	35	1000-800	5	0-2	0	Taylor, N.D.

less towards the present though it always remains greatest in the vicinity of the uplift centres. For example, 10 m. separates the 2,400 and 1,600 BP sea levels in southeast Hudson Bay (Figs. 5 and 6), whereas in peripheral areas, such as the outer east coast of Baffin Island, sea level changed by 1 m. or less. Indeed, if eustatic sea level was still rising towards present at 1,600 BP, then a marine transgression could have affected some of the outer coastal sites in Baffin Island, Banks Island and the Maritimes.

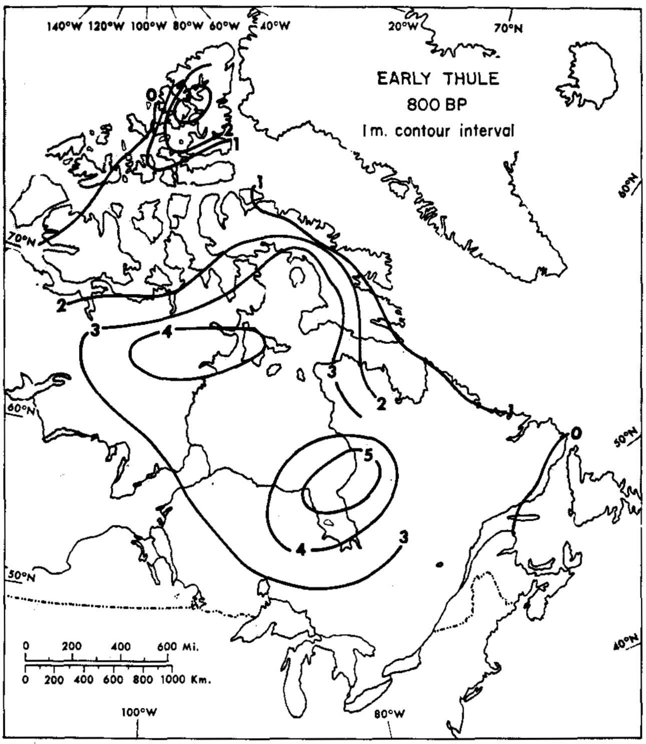

FIG. 7. Isobases of postglacial uplift in the last 800 years.

The majority of site elevations in this period are somewhat higher than would be expected if sites were located close to calculated contemporaneous sea levels. Only on Baffin Island are most sites within the expected sea level elevation ranges. The Mill Island and Smith Island sites, located on low relief limestone islands, are much higher than would be expected. The Basil Norris and M1 sites on Ellesmere and Cornwallis Islands are in similar elevated locations, and in each locality there are sites at much lower elevations (Lonesome complex 6; M2) which were occupied contemporaneously or at only slightly later dates. In the case of the Cornwallis Island sites, Collins (1955, p. 23) considers M1 to have been the winter village which was abandoned during the summer in favour of the M2 site located closer to open water. The Nudlukta and Malerualik sites also represent Thule winter occupations approximately 10 m. higher than predicted sea levels. The final anomalous case, the Memorana site, is also a Thule winter occupation site located in a small boggy area at the top of sheer basalt cliffs which here line the coast of Amundsen Gulf; the location of the site is therefore coastal, but not directly related to contemporaneous sea level.

The large semi-subterranean winter houses of the Thule period are easily located, and probably bias the selection of sites in this period towards winter occupations which are most likely to be not directly related to contemporaneous sea levels. Nevertheless, the mean elevation of the 21 sites for this period which show some possible relation to sea levels is only 8.7 m., which is approximately 3 m. lower than the mean elevation of Dorset sites in the preceding period.

Recent: 800-0 B.P.

The past 800 years has seen the development of historic Eskimo peoples out of the Thule population who had spread throughout the Canadian Arctic during the preceding period. The amount of postglacial rebound which has occurred since the Thule occupation of the area has amounted to a maximum of $\geq$ 5 m. and $<$10 m. If anything, Fig. 7 underestimates the amount of recoil in the past 800 years because the original model of postglacial uplift was approximated by a simple exponential function that on differentiation gives a present rate of rebound that is appreciably less than anticipated on the basis of radiocarbon dates on raised marine deposits. Archaeological sites occupied during this period may be related directly to modern sea levels, since these are approximately equal to sea levels during the period of occupation of the sites.

SUMMARY AND CONCLUSIONS

Of the 84 archaeological components examined, 13 can probably be distinguished as sites located without regard to the position of the shore or sea level of the time. These sites are either caribou or muskox hunting camps, or else coastal camps such as Memorana where elevation was controlled by local topography. The remaining 71 sites were probably located with some reference to contemporaneous sea levels, that is, they were occupied by people engaged in hunting or travelling on the sea who could be expected to have camped close to the shoreline. Some of these sites were probably located very close to the shore while others, such as J1Gu-5, M1, and Malerualik, were located several metres above the predicted sea level. The mean elevation of all 71 sites is only 5.2 metres above the interpolated sea levels for each occupation.

There is obviously a relationship between site elevations and the interpolated estimates of contemporaneous sea levels; for the 71 sites examined the two variables are highly correlated (Spearman rank correlation coefficient r_s = .82; significant at .001 level). With the exception of the Igloolik area, and possibly the Churchill and Wellington Bay regions, the site elevations are generally consistent with the sea levels predicted by the emergence curves. These curves, however, give us only a general idea of the expected altitudes of archaeological components. The relationship between archaeological occupations and ancient sea levels in the Canadian Arctic is not sufficiently close to allow the construction of chronological sequences on the basis of these predicted sea levels alone; ancillary information is required for meeting such a goal. Nevertheless, from the geological viewpoint, the agreement is very satisfactory. In a way, the relationship of occupation sites and predicted sea levels allows a "one-tailed" test of the empirical methods so far developed to estimate sea levels (Andrews 1970). That is, we can make a condition that occupation sites should not lie below the predicted sea level for the time (obviously!). This condition is met with the exception of one site on south Baffin Island, which lies 1 m. below the calculated range of sea levels. In general the archaeological data indicate that the form of predicted isostatic recoil is not too slow, that is, sites are *not* found below the calculated sea level. Our maps can and should be used as reasonable elevation guidelines when archaeological investigation of new areas is undertaken.

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