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The observed postglacial recovery of Québec and Nouveau-Québec Since 12,000 BP
Le relèvement postglaciaire observé au Québec depuis 12 000 ans

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Résumé de l'article

Pour dresser six cartes isobases du niveau marin relatif vers 12 000, 10 000, 8 000, 6000 4000 et 2000 BP, nous nous sommes servis de niveaux marins relatifs datés au ^{14}C, de la valeur du relèvement de littoraux marins soulevés et de lignes de rivages d'anciens lacs proglaciaires, du sens de l'inflexion de ces littoraux ainsi que des courbes de dénivellation post-glaciaire. Aucune carte ne contient plus de 30 points de contrôle et la configuration des isobases ne repose bien souvent que sur 12 points valides. Le long de la limite méridionale de l'inlandsis laurentidien, le soulèvement post-glaciaire maximal a été sensiblement uniforme, l'isobase de 240 à 200 m étant toujours resté proche de la bordure glaciaire. Le long de la limite nord-orientale de l'inlandsis, le soulèvement post-glaciaire le long du front en retrait était proche de 100 m. Des diagrammes équidistants ont été tracés en direction du SE à partir du S de la baie d'Hudson et vers l'E à partir de l'île Southampton. Si l'on compare ces diagrammes au diagramme des relations entre littoraux (Shoreline Relation), les deux profils semblent similaires et coïncident assez bien avec un diagramme théorique des relations entre littoraux publié en 1969. Les isobases indiquent un centre de relèvement principal aux environs de la baie de James et du S de la baie d'Hudson où une emersion maximale de près de 300 m s'est produite durant les 7500 dernières années. Il serait utile de dater les limites marines du SO de la baie d'Ungava pour vérifier si elles remontent à près de 8000 BP, comme nous le pensons. Un tel âge impliquerait une emersion de cette région supérieure à celle admise jusqu'ici et, par conséquent, une couche de glace plus épaisse.

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THE OBSERVED POSTGLACIAL RECOVERY OF QUÉBEC AND NOUVEAU-QUÉBEC SINCE 12,000 BP

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ABSTRACT Radiocarbon dated relative sea levels, the tilts of proglacial lake shorelines and raised marine shorelines, the directions of the tilt of these features, and postglacial delevelling are used to construct six isobase maps showing relative sea level movements over the last 12,000, 10,000, 8000, 4000, and 2000 years, No map has more than 30 control points and usually there are only 12 "good" points controlling the isobase patterns. Each map shows the relationship of the isobases to the current ice sheet extent. Along the southern margin of the Laurentide Ice Sheet, the maximum postglacial emergence has been quite uniform with the 240 to 200 m isobase always close to the ice margin. Along the northeastern margin of the ice sheet, the postglacial emergence at the retreating ice edge was closer to 100 m. Equidistant diagrams are drawn along planes southeast from southern Hudson Bay and eastward from Southampton Island. If these diagrams are compared on a Shoreline Relation Diagram, the two profiles appear similar and compare moderately well with a theoretical SR Diagram published in 1969. The isobases show a major uplift center located around the area of James Bay and southern Hudson Bay where a maximum emergence of nearly 300 m occured in the last 7500 years. High marine limits southwest of Ungava Bay need to be dated because if they date close to 8000 BP as we suggest, then more emergence is suggested for the region southwest of Ungava Bay than we currently allow for.

RÉSUMÉ *Le relèvement postglaciaire observé au Québec depuis 12 000 ans.* Pour dresser six cartes isobases du niveau marin relatif vers 12 000, 10 000, 8 000, 6000 4000 et 2000 BP, nous nous sommes servis de niveaux marins relatifs datés au ^{14}C, de la valeur du relèvement de littoraux marins soulevés et de lignes de rivages d'anciens lacs proglaciaires, du sens de l'inflexion de ces littoraux ainsi que des courbes de dénivellation post-glaciaire. Aucune carte ne contient plus de 30 points de contrôle et la configuration des isobases ne repose bien souvent que sur 12 points valides. Le long de la limite méridionale de l'inlandsis laurentidien, le soulèvement post-glaciaire maximal a été sensiblement uniforme, l'isobase de 240 à 200 m étant toujours resté proche de la bordure glaciaire. Le long de la limite nord-orientale de l'inlandsis, le soulèvement post-glaciaire le long du front en retrait était proche de 100 m. Des diagrammes équidistants ont été tracés en direction du SE à partir du S de la baie d'Hudson *et vers l'E à partir de l'île* Southampton. Si l'on compare ces diagrammes au diagramme des relations entre littoraux *(Shoreline Relation),* les deux profils semblent similaires et coïncident assez bien avec un diagramme théorique des relations entre littoraux publié en 1969. Les isobases indiquent un centre de relèvement principal aux environs de la baie de James et du S de la baie d'Hudson où une émersion maximale de près de 300 m s'est produite durant les 7500 dernières années. Il sérait utile de dater les limites marines du SO de la baie d'Ungava pour vérifier si elles remontent à près de 8000 BP, comme nous le pensons. Un tel âge impliquerait une émersion de cette région supérieure à celle admise jusqu'ici et, par conséquent, une couche de glace plus épaisse.

РЕЗЮМЕ НАБЛЮДЕНИЯ НАД ПОСЛЕ-ЛЕДНИКОВЫМ ВОССТАНОВЛЕНИЕМ СРЕДЫ В КВЕБЕКЕ И НОВОМ КВЕБЕКЕ ЗА ПОСЛЕДНИЕ 12 ТЫСЯЧ ЛЕТ. Радиоуглеродным методом была произведена датировка изменений уровня моря, наклона береговых линий моренного озера и приподнятого морского берега, а также и направление этого наклона. Полученные данные вместе с собранными сведениями о после-ледниковом изменении уровня земной поверхности, дали возможность составить карты изобаз. Они дают представление о том, как менялся уровень моря за последние 12, 10, 8, 4, и 2 тысячи лет. Ни одна из карт не основана на более, чем 30 контрольных пунктах из которых обычно только 12 пунктов можно назвать «належными» и на которые в первую очередь и опираются все изобазы. На каждой карте указано также как далеко продвинулись в то время ледники. Вдоль южного края Лаврентийского Ледникового Покрова, максимальное после-ледниковое поднятие суши (эмергенс) носило весьма однообразный характер. Поэтому, изобаза равная от 240 до 200 метров, всегда проходит вблизи от края ледника. Вдоль же северовосточного края ледникового покрова, после- ледниковое поднятие суши вдоль края отступающего ледника составляло примерно 100 метров. Эквидистантные диаграммы были составлены для местности лежащей к юго-востоку от южной части Гудзонова залива и к востоку от острова Саутхемптон. Если сравнить эти диаграммы с диаграммой указывающей на зависимость береговой линии от состояния ледников, то оба профиля выглядят сходными и довольно точно соответствуют той диаграмме береговой линии, которая была разработана теоритическим путем и опубликована в 1969 году. Изобазы показывают, что центр наибольшего поднятия суши расположен в районе бухты Джеймса и южной части Гудзонова залива. В этом районе поднятие суши достигло 300 метров за последние 7 500 лет. Значительное поднятие берега в юго-западной части бухты Унгава имело место, как мы считаем, около 8 000 лет тому назад. Мы предполагаем, поэтому, что поднятие суши к юго-западу от бухты Унгава было более значительным, чем мы это допускаем в настоящее время.

INTRODUCTION

The area of Québec and Nouveau-Québec has a long history of research into postglacial recovery; indeed, some of the earliest maps showing the pattern of postglacial recovery apply directly to our area of interest. The earliest synthesis that we are aware of is the map in DeGEER (1892), and other early works include marine limit contour maps produced by FAIRCHILD (1918) and DALY (1934) (for a comparison of these maps, *see* ANDREWS, 1973). However, these and later studies (FARRAND and GAJDA, 1962; BIRD, 1967; ANDREWS, 1970) frequently emphasized the pattern of the metachronous marine limit, which is markedly time-transgressive over our region (its formation dates between about 14,000 BP in parts of the Maritimes to 7500 BP along parts of the coast of east Hudson Bay). Although most of the postglacial movements of the last 13,000 BP have resulted in a positive movement of the land surface and most coasts have been dominated by emergence nevertheless, toward the southeast of the Laurentide Ice Sheet, significant postglacial submergence has occurred — in other areas there has been a relative sea level stability for an appreciable length of time. ELSON (1969) provided an earlier summary on our area with a stress on postglacial emergence curves.

Although local isobases on postglacial recovery have been constructed for both marine and proglacial lake shorelines over locally restricted areas (LOKEN, 1962; McDONALD, 1968; SKINNER, 1974; and *see* ANDREWS and BARNETT, 1972 for review), regional patterns of the amount of synchronous postglacial recovery for the study area are the product of the last few years (ANDREWS, 1970; WALCOTT, 1972a). In the first reference, the pattern of postglacial uplift for various time periods was attempted by fitting rebound curves to a simple exponential equation, which was then used to predict uplift at other sites where only the elevation of the marine limit and date of deglaciation were available. Later, WALCOTT (1972a) produced ^{14}C controlled maps of postglacial emergence for northern North America. Both these maps and those of Andrews had $\leq$ 12 control points over the Québec, Nouveau-Québec, Labrador, and Maritimes region — a rather sparse degree of control!

More recently, however, specifically because of the significant accumulation of ^{14}C date sites, it is feasible to try and reconstruct the time-history of postglacial recovery using these dates for control. The first regional detailed study that attempted this approach on a suitable scale was that of DYKE (1974) for the area of the northeastern margin of the Laurentide Ice Sheet. His study area consisted of Baffin Island and Foxe Basin merging on Southampton Island. Our study area overlaps slightly with Dyke's in the north.

Importance of Observed Rebound Compilations

With the new generation of computers and with new approaches to geophysical modelling (FARRELL and CLARK, 1976; PELTIER, 1976), there is a growing need for good regional compilations of the changes in relative sea level through time. WALCOTT (1972a, 1972b) has repeatedly stressed how invaluable such data are to an understanding of the viscoelastic properties of the earth's mantle. Only a few years ago, many assumed that there was some «true» eustatic sea level that existed «somewhere» along a stable coast. However, the principle of the conservation of mass suggests that every point on the globe will be affected to a greater or lesser degree by the processes of ice sheet loading and unloading, and the opposite effects of ocean unloading and loading. Superimposed upon the elastic and viscous responses of the earth to changes in surface loads is the gravitational attraction of the geopotential surface by the load itself. CLARK (1976) has recently suggested that this effect could account for a significant fraction of the observed emergence in West Greenland. Interestingly, this explanation was offered in the late 19th century (WOODWARD, 1888), but has since been ignored. MÖRNER (1976) has also stressed the «rough» nature of the geoid surface and suggested that migrations of these anomalies can cause regional variations in sea level history. At the present moment in the interchange between the Quaternary scientist and the geophysist, the relative sea level movements that we can measure and date are being used to «tune» the models (PELTIER and ANDREWS, 1976; ANDREWS and PELTIER, 1976) so as to derive at a satisfactory solution for the nature of the earth's viscosity structure (CATHLES, 1975) (Fig. 1). However, the really exciting prospect for both sides of this interchange is the prospect of the inverse model (Fig. 1) in which the relative sea level history over the last 10^3 to 10^4 years is used to *reconstruct the ice load history* (PELTIER, 1976; CLARK, in press). This procedure is of great significance in understanding the late Quaternary glacial history, primarily because it enables us to arrive at some solution for what was happening to the ice in the interior of the ice sheets. With the current interest in the collapse of large ice sheets (ANDREWS and FALCONER, 1969; ANDREWS and PELTIER, 1976; HUGHES, 1975), we can only approach a solution through an initial educated guess and by reiteration of the ice load model to fit the observed relative sea level history (PELTIER and ANDREWS, 1976; ANDREWS and PELTIER, 1976).

Our paper thus has the following aims: (1) to produce a series of maps showing relative sea level changes for a number of specific periods using all available radiocarbon dates known to us (data in the papers in this volume thus may change some of our

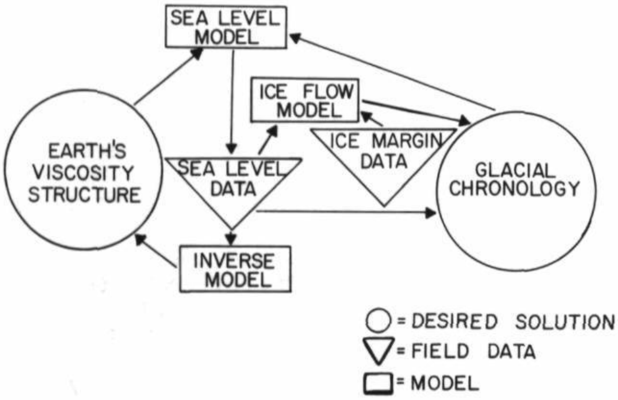

FIGURE 1. Schematic diagram showing the interrelationships between field studies, models and two of the solutions that can be arrived at from a study of this sort (from J. A. Clark).

Diagramme schématique montrant les rapports entre les études sur le terrain, les modèles et deux des solutions pouvant découler d'une étude de ce genre (d'après J. A. Clark).

conclusions), (2) to comment on these maps and on the graphs derived from them, and (3) to outline those areas where more dates and sea level control are required.

THE DATA

Two primary data bases were used in order to try and include all available radiocarbon dates. The first was a specific data bank at the University of Colorado which was designed to include material on the postglacial sea level changes for northern North America. The bank is updated every two years and includes about 1400 dates described by 16 descriptors. The bank was last updated in 1975. For our study we requested all radiocarbon dates between latitudes 44° and 62°N and longitudes 55° and 86°W. The bank uses a system called TAXIR and further details are in DYKE (1974) and BRILL (1971). This query resulted in a listing of 250 dates along with the elevation of the collection, inferred relative sea level, and a judgment on the reliability of the date as it applied to the relative sea level.

In addition to our own data bank, we also requested a printout of all radiocarbon dates between the above coordinates from *Radiocarbon Dates, Inc.* This list included all ^{14}C dates that have been published in *Radiocarbon* up to the end of 1974. Cross-referencing the two lists led to a final list, which was then added to and enlarged by recent publications (LOWDEN and BLAKE, 1974, 1976; SKINNER, 1974; RICHARD, 1975).

In addition to individual radiocarbon dates which describe a relative sea level at some instance of time, there are two other important resources available to us for constructing the isobase maps, namely: 1) postglacial emergence and submergence curves that have been constructed within our study area (Fig. 2), and which thus provide a continuous trace of relative sea level movements; 2) the directions of the tilting of lake or marine shorelines which provide guidelines to the direction of the isobases, frequently in areas where there are very few ^{14}C control points (such as northernmost Labrador), and of course especially for areas above the marine limit where we have virtually no other type of control. Fortunately, Labrador-Ungava was characterized by the extensive development of large proglacial lakes (IVES, 1960; BARNETT and PETERSON, 1964), and the same applies to other parts of the study region (McDONALD, 1968; HUGHES, 1965).

We have screened the dates and elevations by a continuous process of evaluation. We have arrived at no subtle or sophisticated methods to do this and have rather relied on our own judgment and especially on the rather subjective assessment as to whether a dated sea level made «sense.» Underlying this process of evaluation is the truism (or assumption?) that glacio-isostatic response to ice unloading acts as a broad filter, removing much of the local «noise» of the final patterns of deglaciation and preserving the broader dimensions of the ice sheet during the earlier phase when the geometry of the ice mass was simpler. This simplification is due to the lithosphere which tends to act as a spatial filter removing perturbations with wave lengths of 100 km or less. Accordingly, we feel justified in assuming that the isobases of relative sea level changes over the last 13,000 years will be smoothly curved. In addition, the involvement of two people in the compilation did serve to modify personal biases that could be checked against one form of evidence or another.

DEGLACIAL HISTORY

Since the theme of this volume is the late Quaternary history of the area, we do not need to describe in any detail the complexities of deglaciation (see other papers in this volume). Rather, we will simply list what we consider to have been some of the critical events and processes:

1. Simulation of an ice load history involving the collapse of the Hudson Bay ice dome between 12,000 and 10,000 BP with the final clearance by 8000 BP has resulted in good agreement between the observed postglacial emergence and that predicted from an earth model with a viscosity of 10^{22} poises (ANDREWS and PELTIER, 1976; PELTIER and ANDREWS, 1976).

2. The concept of «calving bays» was stressed in Scandinavia by HOPPE (1967) and these ideas were applied to the deglaciation of Hudson Bay (ANDREWS

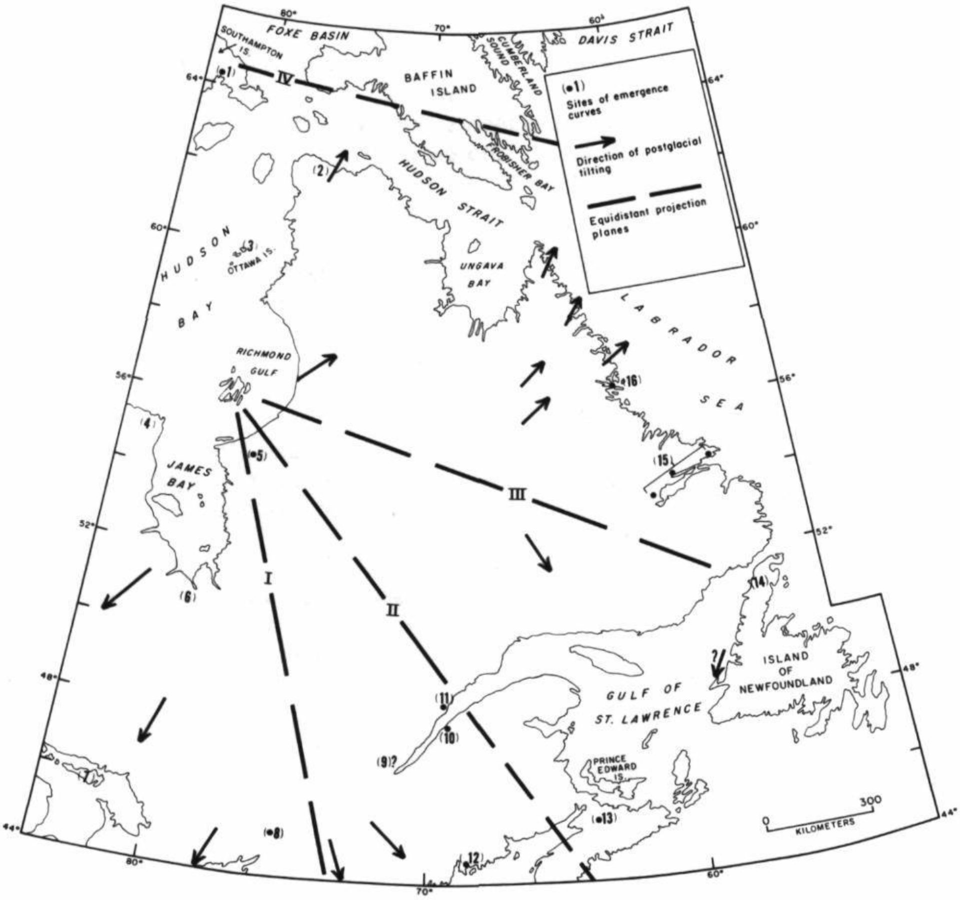

FIGURE 2. Location of sites of emergence curves, directions of post-glacial warping, and profiles normal to the local isobases (Fig. 9-10). 1) BIRD, 1967, 1969; 2) MATTHEWS, 1967; 3) ANDREWS and FALCONER, 1969; 4) WEBBER *et al.*, 1970; 5) LEE, 1962; 6) SKINNER, 1974; 7) LEWIS, 1970; 8) KENNY, 1964; 9) ELSON, 1969; 10) ELSON, 1969; 11) KENNY, 1964; 12) STUIVER and BORNS, 1975; 13) GRANT, 1970; 14) GRANT, 1972; 15) FITZHUGH, 1972; 16) FITZHUGH, 1973; also FARRAND, 1962.

Localisation des sites de référence des courbes d'émersion; sens des gauchissements postglaciaires et profils perpendiculaires aux isobases locales (fig. 9-10).

and FALCONER, 1969) and Foxe Basin (ANDREWS, 1970b). This concept has also been applied to the southern margin of the ice sheet in a paper in this volume (BORNS and HUGHES, 1977). Rapid deglaciation of the margins is possible under these conditions.

3. The pattern of deglaciation of the northern Torngat Mountains to central Labrador has been outlined by IVES (1960) and has not changed appreciably in detail. Radiocarbon dates on lakes related to the Naskaupee Glacial Lakes (IVES, 1960; BARNETT and PETERSON, 1964) bracket these waterplanes between 8700 and 6800 BP (from Short, unpubl. *in* IVES *et al.*, 1976). On presently available evidence, the margin of the late Wisconsin ice sheet may be delimited by the Kangalaksiovik Moraines in the Torngat Mountains (LØKEN, 1964; FALCONER *et al.*, 1965).

4. With the deglaciation of the St. Lawrence Valley, probably involving a relatively long and complex response over about 1000 years between 12,800 and 11,700 BP (RICHARD, 1975; LASALLE and ELSON, 1975), and the collapse of the Hudson Bay center, the Laurentide Ice Sheet was centered over Labrador (IVES, 1960). A final date for the disappearance of the ice in the vicinity of Schefferville is not known with any certainty (BRYSON *et al.*, 1969; PREST, 1969; MORRISON, 1969), but probably occurred close to 6000 BP.

5. The shifting of the ice center sometime after 12,000 BP from over Hudson Bay to central Labrador has been looked for in the postglacial rebound data (ANDREWS and BARNETT, 1973), but no firm evidence is available. The direction of strandline tilts may be explained by the geometry of the Laurentide Ice Sheet (SUGDEN, 1977; PATERSON, 1972), which has a broad ridge extending from Hudson Bay southeast toward Newfoundland. However, as I suggested at this meeting, there may be the first glimmerings of evidence to indicate that the Laurentide Ice Sheet was rather stable along its Labrador margin, possibly because of increased precipitation in the area associated with the break-up of the permanent pack or ice shelf over the Labrador Sea.

6. The work of Grant and Prest (GRANT, 1972; 1975; PREST, 1973) indicates that the Maritime area was strongly influenced by a series of local ice caps. Such local ice sheets might be detected on the basis of postglacial rebound, particularly through the use of the

inverse model (PELTIER, 1976). A preliminary study (ANDREWS and HARRISON, 1974) did in fact result in postglacial rebound being consistently over-predicted for this area thus suggesting less ice than would be assumed under a «normal» ice sheet profile.

These then are some of the primary themes that influenced the various styles of deglaciation. Whether they are detectable in the postglacial rebound record remains to be seen.

MAPS OF POSTGLACIAL RELATIVE SEA LEVEL CHANGES

Figures 3 to 8 depict our best judgments on the amount and pattern of postglacial land movements in the study area. Although the greater part of these movements are related to glacioisostatic recovery, there may well be superimposed long- or short-term tectonic movements. Such an example would be the strong sinking in the vicinity of Lac St. Jean which has been interpreted as a collapsing forebulge, «partially decoupled from its surroundings by major faults» (DUNBAR and GARLAND, 1975, p. 711).

RELATIVE SEA LEVEL MOVEMENT SINCE 12,000 BP

For each map we have used dates that fall in a band ±500 years on either side of the assigned age[1]. This has little effect on the maps from 6000 BP and younger, but with the fast rates of recovery immediately after deglaciation, the radiocarbon error is very critical and can cause strong anomalies. This is quite obvious when it is realized that, during the initial postglacial recovery, falls in relative sea level amounted to between 3 and 10 m+/100 yr.

The map at 12,000 BP is dominated by the information from the St. Lawrence Valley, the Ottawa Valley, and the Maritimes. Our searches indicated a total of 24 dates may be used to define this waterplane, but of these dates only ten were judged excellent in their stratigraphic relationship to a former sea level. Postglacial emergence has varied between 180 m to near sea level along the coast of Maine (STUIVER and BORNS, 1975), and, if a tenuous link can be made between the outer coast of eastern Baffin Island and the outer islands of the Torngat Mountains, then relative sea level may have been below present. The same association may have existed on the Continental Shelves southeast of Newfoundland and off the coast of Maine.

1. The chronological scale is a ^{14}C one. This implies: 1) possible distorsions (atmospheric ^{14}C variations — various isotopic fractionation — Mangerud & Gulliksen's effect), for instance, between the 6 000 yr BP and 4 000 yr BP models; 2) the possibility of abnormal isolate ^{14}C dates.

RELATIVE SEA LEVEL MOVEMENT SINCE 10,000 BP

By 10,000 BP ice unloading and margin retreat was affecting the southern part of the region but there are only a few dates at 10,000 BP on eastern Baffin Island and none as yet along the Labrador coast. Relative sea level was below present in the southeast and inclined toward the northwest to a maximum recorded emergence of about 160 m. We were able to locate 20 dates that bracketed the 10,000 BP waterplane, but of these only nine were judged to be of high quality. However, the basic pattern is clear and shows the isobases looping down toward the southeast and thus infer the maximum center for postglacial rebound to lie northwest in the vicinity of Hudson Bay. Although ANDREWS and PELTIER (1976) suggest that by this time the Hudson Bay ice center had collapsed and that the ice center now lay over central Labrador-Ungava, there is no evidence for this migration in the isobases.

If analogies with eastern Baffin Island can be drawn, at least in the sense of developing the hypothesis, 10,000 BP saw a significant marine transgression along the outer coast of northernmost Labrador. This transgression was primarily due to the worldwide rise of sea level onto a still, isostatically depressed coast. A first order model for the Baffin Island coast (ANDREWS, 1975) nicely explains the distribution of ^{14}C dated marine shorelines and it might apply to the Torngat Mountains (LOKEN, 1962).

RELATIVE SEA LEVEL MOVEMENTS SINCE 8000 BP

The map (Fig. 5) of relative sea level movements over the last 8000 years is an important one because, for the first time, we can gain some understanding of the spatial variations in emergence and submergence over a large part of the region, not just the southeast sector. Dramatic events characterize the period about 8000 radiocarbon years ago (based on dates on marine shells). These have now been discussed by several workers (ANDREWS and FALCONER, 1969; FALCONER *et al.*, 1965; BLAKE, 1966; PREST, 1970; SKINNER, 1974; ANDREWS and PELTIER, 1976). However, the rapid clearing of ice between Hudson Strait and James Bay about 8000 BP does mean that over this immense distance the marine limit is essentially isochronous. SKINNER (1974) has argued along similar lines and has reconstructed the emergence for the southern James Bay area. His map (SKINNER, 1974, p. 41) shows isobases curving around southern James Bay with a maximum emergence of 182 m and declining to around 130 m over a distance of *ca.* 150 km. Along the north shore of the St. Lawrence River, considerable emergence is indicated by recent dates on marine shells; for example, GSC-1809 from northwest of Sept Iles (LOWDEN and BLAKE, 1975, p. 10) is dated at 7580 ± 70 from an altitude of 72 m.

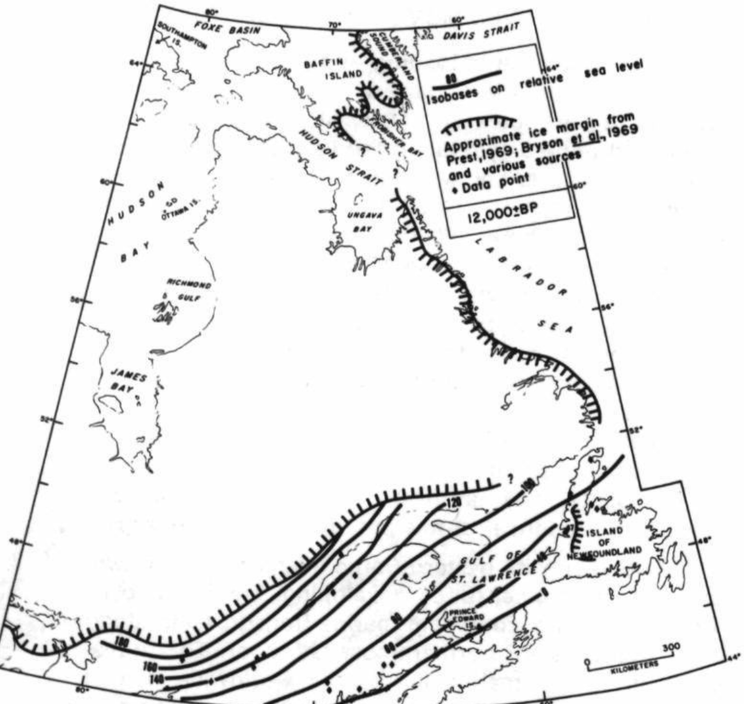

FIGURE 3. Ice margin and isobases for 12,000 BP.
Limite glaciaire et isobases de 12 000 BP.

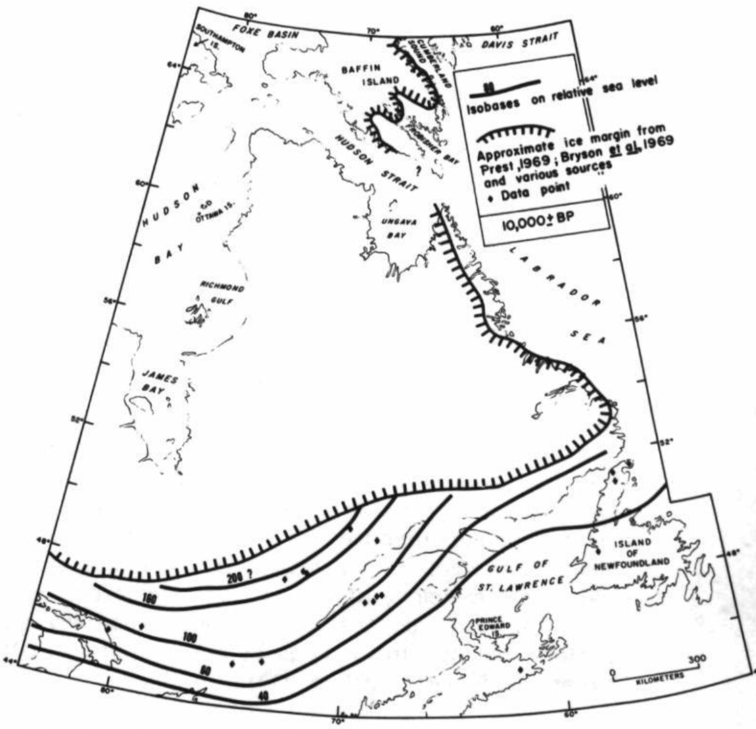

FIGURE 4. Ice margin and isobases for 10,000 BP.
Limite glaciaire et isobases de 10 000 BP.

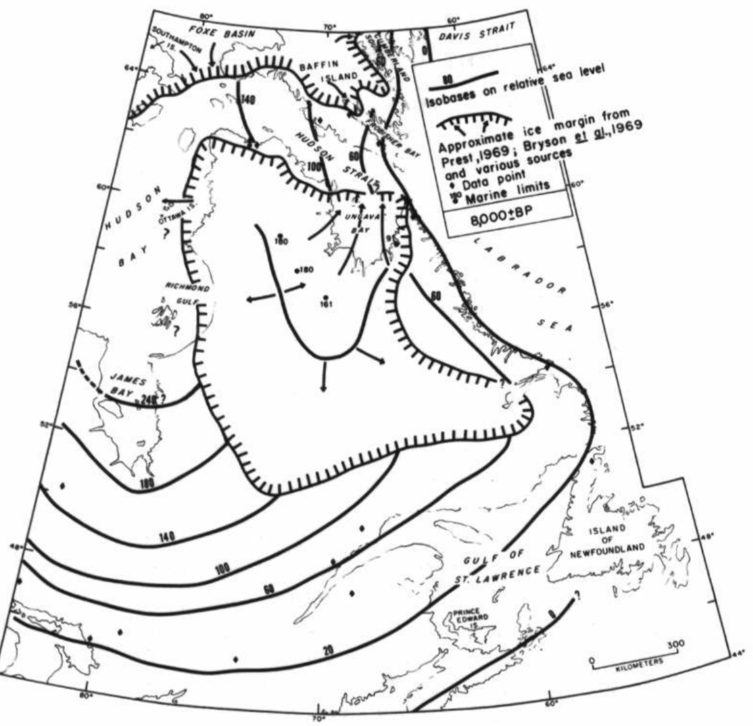

FIGURE 5. Ice margin and isobases for 8000 BP.
Limite glaciaire et isobases de 8000 BP.

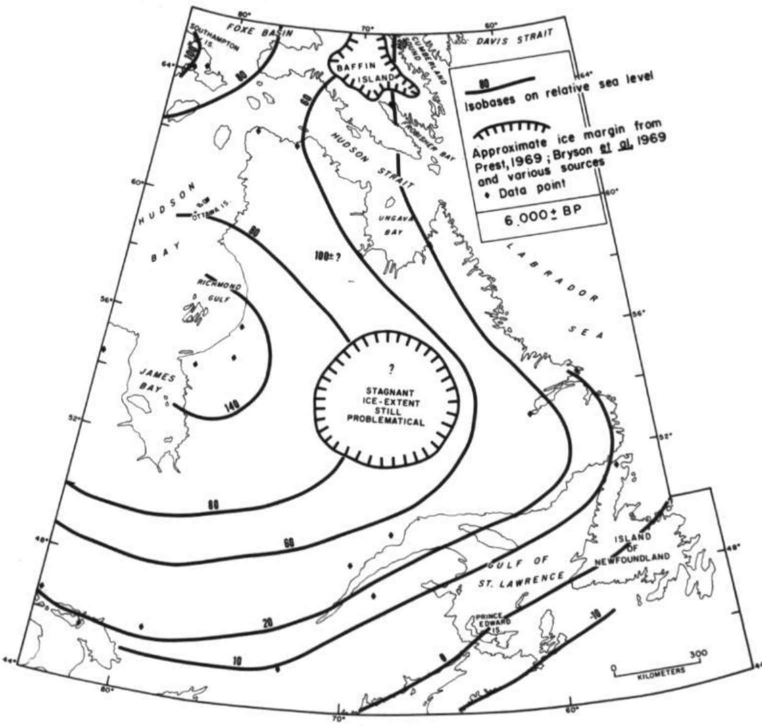

FIGURE 6. Ice margin and isobases for 6000 BP.
Limite glaciaire et isobases de 6000 BP.

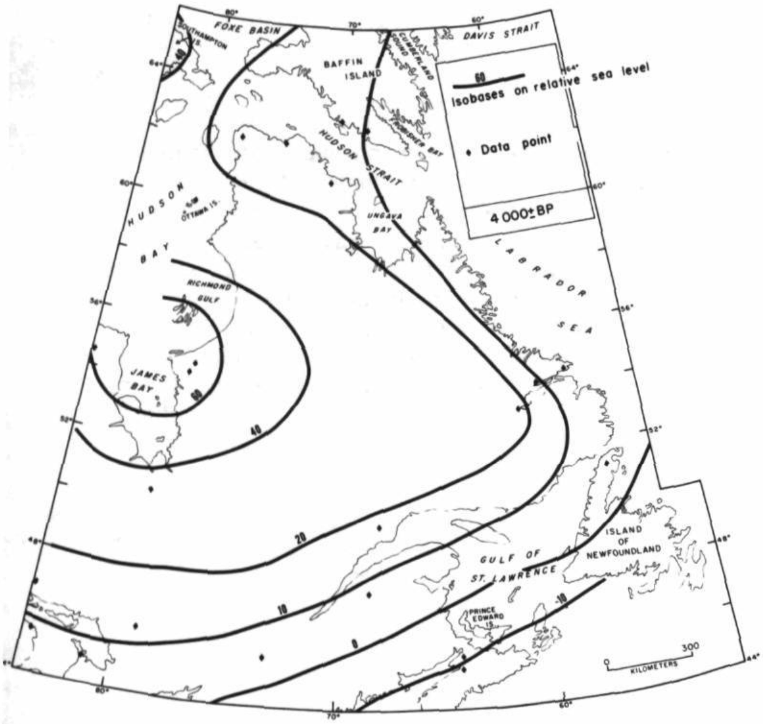

FIGURE 7. Isobases for 4000 BP
Isobases de 4000 BP.

FIGURE 8. Isobases for 2000 BP.
Isobases de 2000 BP.

The Naskaupee Glacial Lakes (IVES, 1960; BARNETT and PETERSON, 1964; IVES *et al.*, 1976) date close to 8000 BP. The deformation of the glacial lake shorelines (Fig. 2), and the tilting of marine shorelines along the outer Labrador coast of approximately the same age (LOKEN's 1962 S-strandline), form important guidelines to the pattern of the isobases in the north-central part of the region. In addition, the numerous ^{14}C dates on shells from southern Baffin Island (BLAKE, 1966; MATTHEWS, 1967; DYKE, 1974) enable us for the first time in our sequences to extend the isobases from northern Labrador and Nouveau-Québec onto Baffin Island (Fig. 4 and 5).

We have encountered problems in accomodating the significant rebound near the west end of Hamilton Inlet as implied by GSC-1254 of 7490 ± 150, which is a « maximum for formation of the extensive terraces at 60-80 m elevation... » (LOWDEN and BLAKE, 1975, p. 7). Additional control on the amount of emergence in the last 8000 years would be forthcoming if the ages of the marine limits within Ungava Bay were known. We have seen no dates on this area in the literature, but we strongly suspect that the marine limit will date very close to 8000 BP. On this assumption we have used the height of the marine limits in that region (PREST *et al.*, 1969) to guide the isobases. However, the suggested elevations of close to 180 m southwest of Ungava Bay (PREST *et al.*, 1969) do need to be verified although our construction can certainly include such amounts of emergence (Fig. 5).

RELATIVE SEA LEVEL MOVEMENTS SINCE 6000 BP

By 6000 BP Hudson Bay was completely deglaciated and most workers infer that residual, stagnant ice masses may have been in the final stages of disintegration in central Labrador (BRYSON *et al.*, 1969; PREST, 1969). Thus, by 6000 BP all the coastline of Québec and Nouveau-Québec was ice free, and, in addition, the ice sheet had now cleared from Southampton Island (BIRD, 1970) and Foxe Basin (BLAKE, 1966; ANDREWS, 1970b). Our present map (Fig. 6) is based on a total of 26 dates, of which seven were judged excellent. This figure can be compared with earlier reconstructions in WALCOTT (1972a) and ANDREWS (1970). Some new important data are the observations and collections in Richmond Gulf by Haselton (*in* WALCOTT, 1972a) and by the date of 6640 ± 180 (GSC-1928) from Sakami Lake (LOWDEN and BLAKE, 1973, p. 17) at an elevation of about 185 m a.s.l. Figure 6 shows a broad dome of emergence concentric with southern Hudson Bay with amounts of 150 m (?) or more. Nearly equal amounts of emergence have been recorded from Southampton Island for the same age (DYKE, 1974), whereas the well-dated emergence curve from the Ottawa Islands (ANDREWS and FALCONER, 1969) indicates that about 75 m of emergence occurred over the same time. This data causes the isobases to be concave into Hudson Strait and northern Hudson Bay, with an extensive ridge trending southeast toward Newfoundland.

RELATIVE SEA LEVEL MOVEMENT SINCE 4000 BP

This surface is defined by 22 dates, of which ten are judged to be of high quality. Dates from Cape Henrietta Marie (WEBBER *et al.*, 1970) and the islands near Great Whale River (WALCOTT and CRAIG, 1974) indicate that near the center of the postglacial rebound emergence of close to 100 m has occurred. The isobases mirror those of earlier maps. We have not been able to determine any specific movement of the 0 m isobase, although the regional control in the St. Lawrence Valley and the Maritimes is such that any migration might not be detected by our methods.

RELATIVE SEA LEVEL MOVEMENT SINCE 2000 BP

The maximum emergence in the last 2000 years is close to 40 m and has been recorded from the northwestern coast of James Bay (WEBBER *et al.*, 1970). Many of the dates for this map, and that for 4000 BP, are based on dates on archaeological sites, and in northern areas these sites were occupied by the pre-Dorset Eskimo and Dorset people, respectively (ANDREWS, *et al.*, 1971). Sea level was below present across parts of the Maritimes and possibly at or slightly below present in those northern areas lying beyond the late Wisconsin glacier margin.

EQUIDISTANT DIAGRAMS

Equidistant diagrams for the glaciated tract of North America were first placed on a quantitative basis by FARRAND (1962), who constructed a series of uplift curves and then drew graphs showing the recovery of the crust along a north-south transect. Our approach is identical and similar to that of DONNER (1969) in a recent study of ^{14}C recovery across Fenno-scandia. We present these graphs for three main reasons: (1) they allow a much easier visual appreciation of the pattern and amount of crustal movements since deglaciation than is obtained by viewing the six maps that we have constructed (Fig. 3-8); (2) these diagrams enable us to ascertain if there are any marked anomalies in our maps; that is, we do not expect to see the isochronous surfaces sharply upwarping; and (3) we can use the diagrams to see if the concept of Shoreline Relation Diagrams (SR Diagrams) appear valid over these large distances. In passing we must note that DYKE's (1974) reconstructions across Baffin Island did in fact strongly suggest that the isochronous surfaces were not simple tilted or warped surfaces.

RESULTS

Diagrams have been drawn normal to the isobases along the projection planes illustrated on Figure 2. They were drawn radiating from the apparent center of rebound in southern Hudson Bay/James Bay, and another equidistant diagram was drawn from another center of recovery over Southampton Island eastward to the vicinity of the mouth of Hudson Strait. Figures 9 and 10 illustrate the form of the reconstructed shorelines taken directly from the maps. These equidistant diagrams show a broad updoming over southern Hudson Bay with the strandlines gently warped.

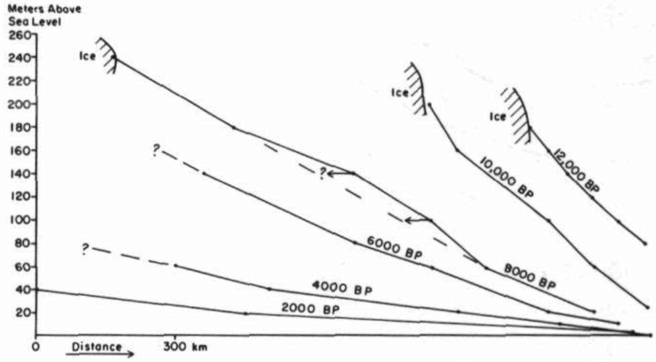

FIGURE 9. Equidistant diagram along the plane of Projection I of Figure 2.

Diagramme équidistant du plan de la projection de la figure 2.

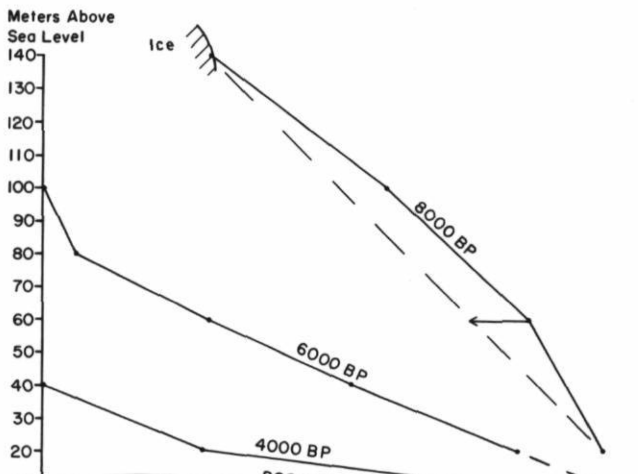

FIGURE 10. Equidistant diagram along the plane of Projection IV of Figure 2.

Diagramme équidistant du plan de la projection IV de la figure 2.

SHORELINE RELATION DIAGRAM

The use of this diagram in North America has been discussed by ANDREWS (1969). The technique was developed in Fenno-scandia but has been criticized. However, several papers (e.g. GEMMEL, 1973) have taken up this concept and applied it with some success to areas in Norway and Scotland. In our study we use the SR Diagram as a test of the hypothesis that the postglacial recovery across the entire study area can be ascribed to the same processes acting at proportionally the same rates. By this we state that, if along one of the profiles of Figure 2, the postglacial emergence since 6000 BP is 10 m, and that since 8000 BP the emergence has been 30 m, then on the other profiles the same 10:30 ratio should apply. If this is indeed the case, then the SR Diagram plots isochronous surfaces as straight, inclined lines (Fig. 11). If the hypothesis is not correct, then a simple SR Diagram cannot be drawn. If this is the case, then it is telling us something about the varying forms of postglacial emergence curves across the Labrador, Nouveau-Québec, Québec and Maritimes area. We stress that some irregularities in our SR Diagrams are likely simply because of the sparcity of control points. We use as the reference level the 2000 year old shoreline which has a total of 26 dates, of which 14 were judged to be of good quality in controlling the isobases. The resulting SR Diagrams can be checked against the model originally established by ANDREWS (1969) based on an oversimplified approximation of postglacial uplift.

Figure 11 shows the SR Diagram based on profiles I and IV (Fig. 2 and Fig. 9 and 10). In addition, the elevations from ANDREWS's 1969 diagram are included. There is a moderate amount of agreement between all three reconstructions for 4000 and 8000 BP, but the 6000 BP line from Profile I is slightly higher than that from the Hudson Strait region. The lines from the suggested model (ANDREWS, 1969) have appreciably steeper gradients, which is in part an artifact of the reconstruction and implies that the zero isobase is stationary. The theoretical 4000 BP line falls so close to that from both profiles I and IV that it has not been included. The fact that some of the lines on Figure 11 are not perfectly straight can easily be explained by the margin of error in drawing isobases between widely scattered control points. This is illustrated by Figure 12, which indicates the amount of movement of the isobases required in order to make the 6000 BP isobases be in accord with the SR Diagram from Profile I. The only significant change required is to move the zero isobase at 6000 BP seaward by the amount indicated

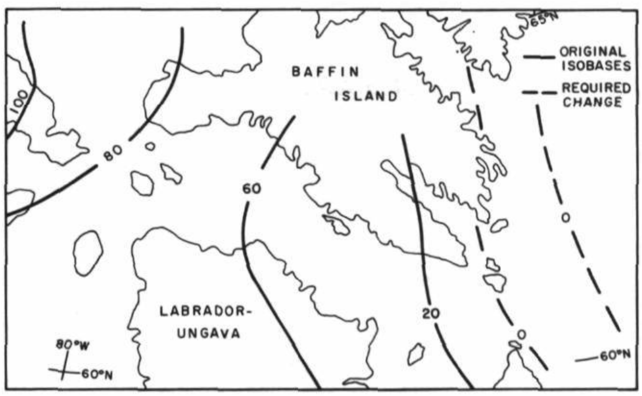

FIGURE 12. Sketch of the Hudson Strait area (Profile IV) showing the amount of change in the isobases required to make the 6000 BP isobases conform to those of Profile I (Fig. 9). The main change is in the zero isobase which is poorly controlled in Profile IV.

Croquis de la région du détroit d'Hudson (profil IV) montrant les modifications nécessaires pour faire correspondre les isobases de 6000 BP à celles du profil I (fig. 9). La modification principale concerne l'isobase zéro, qui n'est pas contrôlée de manière satisfaisante sur le profil IV.

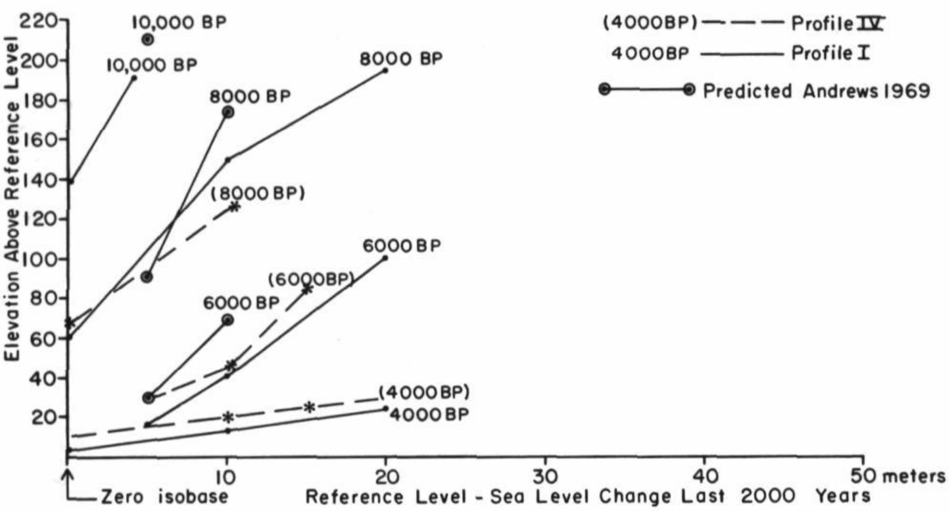

FIGURE 11. Shoreline Relation (SR) Diagram using the 2000 BP emergence surface as the reference level. The diagram compares results from Figures 9 and 10, and compares them with the diagram in ANDREWS (1969).

Diagramme des relations entre littoraux (Shoreline Relation) utilisant comme niveau de référence la surface d'émersion de 2000 BP. Ce diagramme compare les résultats des figures 9 et 10 entre eux, puis le résultat obtenu à ceux du diagramme d'ANDREWS (1969).

(Fig. 12). Note that the intersection of the 4000 and 6000 BP lines on Figure 11 suggest submergence of sites lying beyond (to the left of) the intersection.

In summary then, we admit to being surprised that the isobase maps, plotted solely on the basis of available ^{14}C dates, appear to support the broad concept that postglacial crustal recovery has been proportionally similar across this large area. Figure 11 suggests that within reason the concepts discussed in ANDREWS (1969, 1970) can be used to provide ancillary information on the ages of specific shorelines where material for radiocarbon dating is missing or has not yet been found. The geophysical implications of this figure are also interesting but we have no explanations to offer.

CONCLUSIONS AND COMMENTARY

Figures 3 to 8 may serve their most useful function as indicators of where future field research should be directed. The Labrador coast remains extremely poorly dated although this is being slowly filled in as a result of archaeological interests (FITZHUGH, 1972, 1973, for example). An extremely critical area is the shores of Ungava Bay. We are not aware of any ^{14}C dates on the marine overlap on either the eastern or southern shores. We would hazard a prediction that the marine limit around the Bay will tend to be essentially isochronous and date from slightly less than 8000 BP. The date on this marine incursion will also provide a maximum date on the age of the Naskaupee Glacial Lakes because they would drain as soon as the ice withdrew from the valley of the George River.

Because of the size of the area and the absence of deeply interfingering coastal embayments (apart from the St. Lawrence Valley), studies on the direction and amount of tilt of glacial lake shorelines should be actively pursued within the region (see Fig. 2 for areas that have been studied). The tilt of the lake shorelines provides an important control on the trend of the isobases, whereas the amount of tilting can be used (FARRAND, 1962) to provide an estimate of the amount of postglacial recovery. The Equidistant diagrams (Fig. 9 and 10) indicate that the warping of the strandlines is not extreme, and hence, if the location of the zero isobase can be found, then it is possible to get an approximate idea of the amount of postglacial uplift in the central parts of the Labrador-Ungava Peninsula. Estimates so derived for the Naskaupee Glacial Lakes give results of 200 and 175 m and thus are comparable with uplifts at the margin of the ice sheet as it retreated between 12,000 and 8000 years ago (Fig. 3-5 and Fig. 9).

Figures 3-5 and Figure 9, as mentioned above, indicate that the crustal deflection at the ice margin varied from 240 to 180 m along the southern margin of the Laurentide Ice Sheet. These figures have to be increased by 10 to 50 m to allow for eustatic sea level variations since these times. However, the main point here is that these figures are considerably higher than the marginal deflections observed along the northeastern margin of the Laurentide Ice Sheet where the maximum elevation of glaciomarine ice contact deltas is about 100 m. This indicates that the ice was considerably thinner in the area of Baffin Island/Foxe Basin when compared to the St. Lawrence Valley/southern Hudson Bay transect.

ACKNOWLEDGEMENTS

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QUESTIONS AND COMMENTS

L. HARDY:

"Dans une publication récente concernant l'île de Baffin, vous avez démontré l'influence du taux de retrait de la marge glaciaire sur le relèvement post-glaciaire. Croyez-vous que cette relation taux de retrait – valeur du relèvement pouvait expliquer les variations de l'altitude de la limite marine dans certains secteurs du Québec?"

J. T. ANDREWS:

"The question is a good one. On this paper I have tried to present a synthesis of the field evidence; hopefully future modeling will aid in giving quantitative figures on the importance of the rate of deglaciation on amount of uplift."

G. SAMSON:

"What is your interpretation of the early date of about 41,000 BP from Iron Strand (Labrador) at a low elevation above sea level?"

J. T. ANDREWS:

"I think the date fits into the glacial-climatic-chronology model developed by several workers at the University of Colorado. In a general sense the report of ANDREWS *et al.* (1972) in *Quaternary Research* still stands."

(Please refer to the note of IVES in this volume.)
(Veuillez consulter la note de IVES à la fin de ce volume.)