Table 1. Radiocarbon age determinations, Barrow, Alaska.

Sample no.	*Age*[1] *(yrs. B.P.)*	*Depth*[2] *(metres)*	*Surface Elevation (metres)*	*Sample Description*	*References*
Polygon Series					
I-699	1,775 ± 120	0.6	8.4	Frozen peat in fine-grained sediment	Brown 1965? Trautman 1964
I-700	9,550 ± 240	1.5	8.5	Frozen peat in fine-grained sediment	Brown 1965? Trautman 1964
I-701	10,525 ± 280	3.0	8.5	Frozen peat in fine-grained sediment	Brown 1965? Trautman 1964
I-992	8,200 ± 300	3.3	8.5	Organic residue in ice wedge	Brown 1965?
I-1171	14,000 ± 500	3.6	8.5	Organic residue in ice wedge	Brown 1965?
Beach Ridge Series					
L-400A	3,000 ± 130	0	5.6	A_1 horizon of Arctic Brown soil after humic-acid removal	Olson 1959
L-400A	2,100 ± 180	0	5.6	Humic-acid portion of L-400A	Olson 1959
I-1182	8,715 ± 250	0.4	5.1	Frozen humified peat overlying gravel	Brown Unpubl., Colinvaux 1964
I-1183	9,155 ± 300	0.9	5.2	Frozen peat in fine-grained sediment	Brown Unpubl., Colinvaux 1964
L-400B	10,700 ± 350	0.6	5.6	Frozen peat in fine-grained sediment after humic-acid removal	Olson 1959, Douglas 1960
L-400B	11,050 ± 350	0.6	5.6	Humic-acid portion of L-400B	Olson 1959, Douglas 1960
I-1384	25,300 ± 2,300	2.1	6.3	Thin, frozen organic layer in sandy gravel	Brown Unpubl.
Spit Series					
I-387	1,100 ± 120	1.9	4.1	Driftwood fragments in frozen gravel	Péwé 1962, Trautman 1962
I-388	1,090 ± 140	2.9	4.1	Driftwood fragments in frozen gravel	Péwé 1962, Trautman 1962
I-389	10,800 ± 300	3.3	4.1	Driftwood fragments in frozen gravel	Péwé 1962, Trautman 1962
Gx-0230	5,560 ± 375	2.5	4.8	Log in frozen stratified gravel	Hume Unpubl.
Lake Series					
W-432	3,540 ± 300	0.3	4.2	Buried peat in lacustrine silt	Rubin 1958, Coulter 1960
W-847	9,100 ± 260	1.1	4.2	Buried peat in lacustrine silt	Rubin 1960, Coulter 1960
I-1544	3,200 ± 230	0.4	2.7	Buried peat layer below lacustrine silt	Brown Unpubl.
I-1545	5,010 ± 320	1.2	2.7	Frozen peat mass over inactive ice-wedge	Brown Unpubl.
Topographic Highs					
L-567	3,400 ± 100	0.7	12.6	Frozen peat in fine-grained sediment after humic-acid removal	Douglas 1960, Olson 1961
L-567	3,400 ± 200	0.7	12.6	Humic-acid portion of L-567	Douglas 1960, Olson 1961
I-1202	8,330 ± 250	2.5	6.8	Frozen peat in fine-grained sediment	Brown Unpubl.
Gubik					
Tx-220	6,450 ± 400	10.5	0	Wood fragment in estuarine sediments	Faas 1964
W-380	> 38,000	10.0	13.5	Frozen log in base of upper member of Gubik	Rubin 1958, Coulter 1960
I-1394	> 36,300	18.9	3.5	Thin, frozen organic layer in silts and sands	Brown Unpubl.
Archeological Series					
P-73	1,430 ± 190	—	—	Wooden artifacts, individual dates from two portions are 1,620 ± 300 and 1,320 ± 220. Kugusugaruk site	Rainey 1959, Ralph 1961
P-97	1,146 ± 95	—	—	Wooden meat tray. Kugusugaruk site.	Rainey 1959, Ralph 1961

1 Age in years B.P. is presented as published in cited reference, no corrections are made for new half life or 1905 reference year.

2 Depth below ground surface.

RADIOCARBON DATING, BARROW, ALASKA

Jerry Brown*

Introduction

In recent years a diversified group of samples has been collected and processed for radiocarbon age determination from the Barrow, Alaska area. The ages have been acquired in support of several scientific disciplines, including pedology, geology and archeology. These dates are presented in this paper in an attempt to clarify several aspects of the complex pedologic and geomorphic history of this arctic region.

The Barrow peninsula, the northernmost tip of the arctic Coastal Plain, is mantled by the Pleistocene Gubik formation which comprises three main lithologic units: the oldest Skull Cliff unit, the intermediate-aged Meade River unit and the Barrow unit thought to be predominantly Wisconsin (Black 1964). The Barrow unit is both marine and nonmarine in origin and contains abundant organic matter in the upper section. At Barrow it is approximately 10 m. thick and is thought to unconformably overlie the Skull Cliff unit (Black 1964). The land area is underlain by perennially frozen ground to depths in excess of 300 m. The average depth of seasonal thaw in the fine-grained soils is 0.4 m. The dominant agent of erosion and deposition is the thaw-lake cycle (Britton 1957). Cryopedological processes are manifested in all forms with ice-wedge polygons covering almost the entire land surface.

Samples and Methods

Types and origins of the samples

The organic materials that have been dated are of several types and origins. Reworked woody and peaty materials are found in horizontal layers or beds and are deposited in on- and near-shore marine and lacustrine environments. These organic materials were derived from the erosion of *in situ* vegetation, surface peat layers, and older buried organic matter. Source areas may be distant in the case of driftwood. Radiocarbon ages for these materials provide only maximum dates for the depositional events.

A second group of organic materials consists of small, irregular shaped masses of buried peat from depths of 0.3 m. downward to 3 or 4 m. These

* Soil Scientist, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

frozen masses of organic matter interfinger with ice-rich mineral sediment. The mineral sediment frequently appears to have been intruded into a once nearly continuous layer of peat. The origin of this buried zone is not well established. In some instances, it is postulated that surface organic matter was buried from below by the heaving of soil during the refreezing of a deeper, seasonally thawed soil zone (Douglas and Tedrow 1960).

A third type of organic matter dated is that found in the vertical foliations of ice-wedge ice. Fragments of surface vegetation and other organic debris fall into contraction cracks formed during the arctic winter (Lachenbruch 1962). The organic residues recovered from the melted ice provide a means of determining the approximate age of that particular portion of the ice mass.

One sample of organic matter derived from the surface horizons of a present-day soil is included. An extensive study is at present under way to determine the age of lakes by dating the surface peats (C. E. Carson, University of Minnesota, personal communication).

Several wooden artifacts, presumably derived from driftwood, are the final type of sample dated.

Methods

Methods of collecting the frozen samples varied. The majority of samples were obtained from sections exposed in auger holes that were approximately 0.8 m. in diameter. Other samples were obtained from excavations or exposures dug by hand or with dynamite. The locations of the sample sites are presented in Fig. 1.

The sample designations (Table 1, Figs. 1, 2 and 3) indicate by letter the laboratory which made the age determination and the assigned number. The methods employed by the several laboratories are readily available in the cited references. The pretreatment discussed by Olson and Broecker (1958) was generally followed for most samples. Large twigs and rootlets were removed or the sample sieved prior to the NaOH and HCl pretreatment. Age determinations were made on separate organic fractions of several Lamont samples in order to determine the errors resulting from contamination by soluble organic materials. (Olson and Broecker 1958, 1959, 1961; Douglas and Tedrow 1960).

Particle-size analyses were performed on selected mineral samples by the standard hydrometer and sieving methods. Loss-on-ignition was determined at 500°C. oven temperature. Results of these analyses are presented in Figure 3. A number of the samples were analyzed for pollen content (Colinvaux 1964).

Discussion of radiocarbon dates

In interpreting the radiocarbon dates, the reader should be aware that the individual age of many of the samples represents the average value for numerous discrete organic components which in themselves can vary widely around the reported radiocarbon date. The determination of this variation

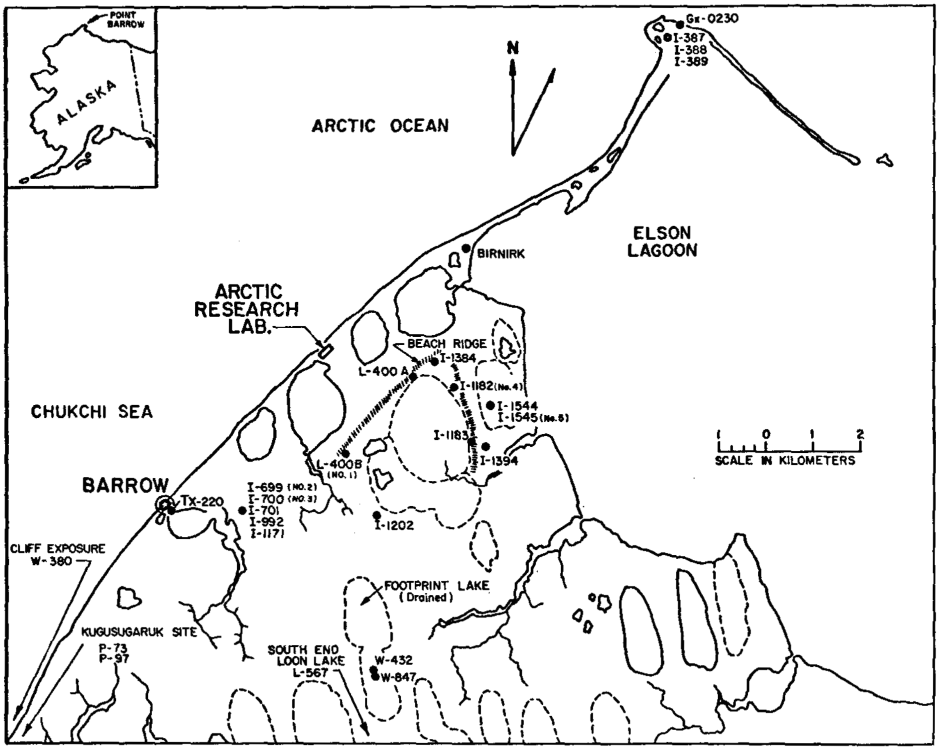


Fig. 1. Location map of sample sites, Barrow, Alaska.

for each sample is not practical. Therefore, in the present discussions, the dates are interpreted at face value. The assumption is made that deviations from the average are equal for at least similar type samples, such as buried peats. The writer occasionally uses the terms *minimum* and *maximum* within the above-stated limitations.

Polygon Series

The sample site is an ice-wedge polygon situated on a "primary surface", or one that has not been recently reworked by the thaw-lake cycle. The samples were exposed by auger holes in the perennially frozen soil and tunnelling through the buried ice mass C. Figure 2 is an idealized block diagram of the sample location (Brown 1965?).

Buried peat samples are associated with three distinctly different ice masses. Sample I-699 (1,775 ± 120) overlies the active ice wedge as small peaty masses in the ice-rich silty soil. Sample I-700 (9,550 ± 240), an elongated mass of peat, is adjacent to a thin, inactive, fissure-like wedge B and was apparently derived from the overlying zone of buried peat. A silty surface soil (Fig. 3, Nos. 2 and 3) mantles the polygon and trough. Sample I-701 (10,525 ± 280) is embedded in a grayish, high-ice silt, and is sparsely present as small peaty masses overlying the nearly horizontal ice contact of buried ice wedge C at 3.0 m. All three samples contain small twigs.

The buried ice mass (wedge C) is a complex structure of nearly vertically foliated ice and probably consists of several coalesced ice wedges. From measurements obtained in tunnelling and coring, the lateral extent of the buried ice mass is conservatively estimated at 10 by 15 m. The ice contains lemming droppings and considerable quantities of plant fragments. The presence of these inclusions as single fragments suggests that the source was the surface vegetation and debris of a polygon trough and not an older, previously consolidated mass of buried organic matter. Two blocks of ice, each containing approximately 10 organic-rich foliations, were sampled along the axis of the wedge (Fig. 2). The blocks of ice were melted and the organic residue collected by ordinary vacuum filtration. Sample I-1171 (14,000 ± 500) was obtained approximately 2 m. from a lateral sediment contact and sample I-992 (8,200 ± 300) 4 m. from it towards the centre of the ice mass. The ages of the organic residue recovered from the buried ice provide evidence for estimating the period of ice-wedge development for this large buried ice mass at between 8,200 and 14,000 years. However, the complex structure and history of the ice mass prevents correlation of growth increments and time between these two sample sites. In fact, growth could have conceivably started and stopped several times within this 6,000-year interval.

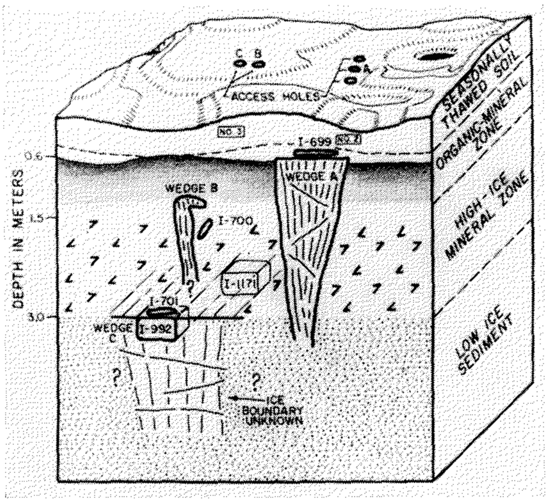


Fig. 2. Block diagram of Voth polygon site and sample locations.

Additional paleoclimatic evidence is available from this site in the pollen record (Colinvaux 1964). A significant abundance of alder is observed in the youngest peat (I-699) with a paucity or complete absence in the two older peats (I-700 and I-701). All three samples were dominated by grass pollen. This distribution lends support to the theory that the older peats were buried and frozen prior to the alder maximum that occurred during the proposed hypsithermal period (Livingstone 1957; Porter 1964). The residue sample I-1171 was found to represent an extreme tundra condition with the absence of both alder and *Betula nana* pollen. It may be implied from this evidence that more recent contraction cracks did not penetrate or contaminate the buried ice mass with either present-day organic matter or pollen and that conditions 14,000 years ago were colder than today and were ideal for the growth of ice wedges at perhaps a rate greater than at present.

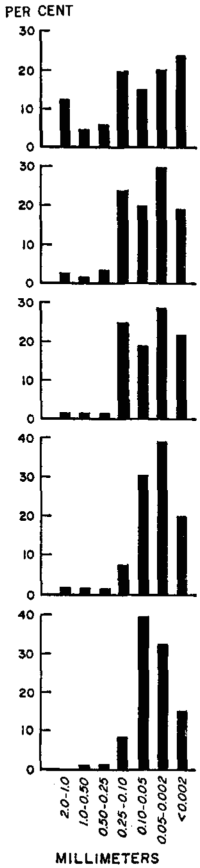
The following generalized events have been tentatively postulated to explain the stratigraphic sequence. At least part of the buried ice mass formed some 14,000 years ago and perhaps under a more severe climate. The ice mass C was later partly truncated by a deeper thaw that was caused by either a warmer period or some other surface thermal disturbance. The overlying thawed sediments refroze with a considerable increase in ground volume due to the segregation of excess water into ground ice. Growth of the upper wedges (A and B) was initiated after this freeze-up. Development of wedge B probably started before wedge A and was then terminated by deposition of additional mineral soil or a decrease in the depth of the thawed soil zone. Development of wedge A began at that point and continued until the present. The ages of I-700 and I-701 suggest that the entire buried organic zone of this section with the exception of that overlying the surface wedges is approximately 9,000 to 10,500 years old. The age of the youngest peat (1,775 ± 120), if assumed to be correlative with ice-wedge growth, places the formation of wedge A within the estimate of 2,500 years made by Black (unpublished manuscript) for a similar, nearby polygon site. Caution is advisable in directly correlating the age of buried peat with the age of associated ice wedges unless a supplemental chronological tool such as ice-increment counts is available.

Beach Ridge Series

A raised beach ridge, located some two kilometers from the present-day beach (Fig. 1) is composed of poorly stratified gravels and sands (Rex and Taylor 1953; Koranda 1954; Black 1964). The upper part of the sections contains gravels, silts and organic materials which have been mixed and modified by frost processes. The surface 0.3 m. is generally a poorly sorted silt (Fig. 3, Nos. 1 and 4) overlying a contorted buried peat layer which extends downward a metre or more in places.

The materials sampled from this ridge are of 3 types: surface organic horizon, buried soil organic matter and water deposited, reworked peat.

Sample L-400A (3,000 ± 130) is from the surface A_1 horizon of an Arctic Brown soil (Drew and Tedrow 1957; Olson and Broecker 1959). The occurrence of this zonal soil of arctic Alaska is limited to well-drained sites which have deeper than normal thawed zones. These conditions occur on a small gravelly area of the beach ridge where the silty mantle is not present (Drew *et al.* 1958). The surface A_1 horizon contains 12% organic matter predominantly in the form of well-decomposed humus. The soluble organic materials (L-400A, 2,100 ± 180) are a natural *in situ* product of soil forming processes



	Depth	Loss-on-Ignition	Above Sample
No. 1*	5-20 cm.	2.1%	L-400B
No. 2	30-35 cm.	5.3%	I-699
No. 3	25-30 cm.	4.3%	I-700
No. 4	5-30 cm.	3.8%	I-1182
No. 5	100-110 cm.	3.2%	I-1545

*Douglas and Tedrow, 1960

Fig. 3. Particle-size distribution and loss-on-ignition of soils and sediment overlying buried peat, Barrow, Alaska.

and not the result of contamination from adjacent soils, since this soil occupies a topographic high. The 3,000-year date, although an average value for the insoluble constituents, indicates the great age of this soil (Tedrow and Douglas 1958) and provides a *minimum* length of time during which the beach ridge surface was stable. That is, no major deposition or erosion has occurred during the development of the A_1 horizon. Surface peats from other arctic soils have yielded dates of less than 200 years (Douglas and Tedrow 1960; Olson and Broecker 1961).

The second group of samples from this beach deposit is of the more ambiguous buried organic type. Sample I-1182 (8,715 ± 250) consisting of partially humified peat overlies a clean gravel and conceivably was a surface horizon of a soil very similar to the present-day Arctic Brown. This buried organic layer which is about 10 cm. thick is continuous for several metres and is overlain by 30 to 50 cm. of brown silt (Fig. 3, No. 4). Assuming that this organic layer had developed *in situ* as seems the case, the average age of 8,715 ± 250 for the layer provides a maximum date for an event which resulted in widespread modification of the Barrow soils of that time. This may have been a period of more active eolian deposition (Black 1951). The humified composition of this organic sample (I-1182) may also be a result of post-burial decomposition. Minor fluctuations in the depth of thaw since burial could have created better aeration over the gravelly substrate resulting in the decomposition of a peaty layer into a more humified one.

The reliability of the date is enhanced by comparable ages for 2 other buried samples obtained from opposite ends of the beach ridge, L-400B (10,700 ± 350) and I-1183 (9,155 ± 300) (see Fig. 1). These samples are frozen, peaty organic masses in ice-rich silty sediment. Since the sites are located at or near the top of the beach ridge, the peat was presumably formed *in situ* as a surface horizon of a wet tundra soil. The small deviation in the two fractions of L-400B indicates that the frozen samples were not subjected to contamination by younger soluble organic substances. This conclusion can be reliably extended to I-1183. These three dates of buried soil organic matter (approximately 8,700, 9,100 and 10,700) are reasonable evidence for the presence of a surface horizon some 8,700 to 10,700 years ago on this ridge.

Pollen analyses from samples I-1182 and I-1183 are assigned to Livingstone's Zone I (Colinvaux 1964). Again the paucity of alder pollen supports the belief that the buried organic materials have not been exposed to surface contamination during or since the alder high.

The date 25,300 ± 2,300 (I-1384) for the reworked water-deposited organic fibres provides a maximum age for the upper section of the beach ridge. The sample is from a semi-continuous organic layer, less than 2 cm. thick, in a sandy gravel. The organic layer was deposited during the aggradation or reworking of the beach deposits. Since sea level was considerably lower during the period of deposition (absolute minimum 11,000 to maximum 25,000) it seems probable that the Barrow land surface was lower than at the present time. Isostatic changes and sea level fluctuations during Wisconsin and post-Wisconsin times are not as well-established for this coastal plain area as in western Alaska (Hopkins *et al.* 1960; Moore and Scholl 1961), although detailed near-surface stratigraphic studies are now under way (Faas 1964; Sellmann *et al.* 1963, 1964).

Spit Series

A group of 3 dates was originally presented by Péwé and Church (1962; Trautman and Walton 1962) for wood fragments recovered from a single auger hole in the present-day spit (Fig. 1). The samples occurred in stratified gravels and sands adjacent to a small, active ice wedge. The 2 dates of about 1,100 years (I-387, 1,100 ± 120 and I-388, 1,090 ± 140) seem valid for an approximate age of the upper 2 to 3 metres of spit sediment. The older sample (I-389, 10,800 ± 300), as the authors point out, is more likely to be subject to the uncertainty encountered in dating driftwood than the other two nearly duplicate samples and might also represent the reworking of older sediments. The date of approximately 1,100 years agrees with Black's values of 700 to 1,000 years based upon his estimates of the ages of the ice wedges (unpublished manuscript).

On 3 October 1963 the most severe windstorm ever recorded at Barrow during the ice-free period caused the breaching of the spit in three places. Beach elevations were increased up to 4 m. in places and the low bluffs on the spit retreated as much as 13 m. (Hume 1964). However, it is important to document the fact that the sample location (Péwé and Church 1962) was not affected by the storm. This severe storm in no way invalidated the previous conclusions, but did demonstrate the rapidity at which these beach ridges can be drastically modified. As a result of the storm erosion, Hume recovered a buried log from a cliff exposure located northeast of Péwé's site and stratigraphically lower. This wood sample yielded a date of 5,560 ± 375 (Gx-0230) (Unpublished date, Hume, Tufts University).

Ford (1959) in his archeological observations at Birnirk (Fig. 1) suggested that the present-day spit did not exist while the Birnirk settlement was occupied. A continuing subsidence of the Barrow land area was postulated to explain the deposition of the present-day beach deposits and spit. A more appropriate explanation may be that the increases in sea level have caused the formation of the higher beaches and the near-drowning of Birnirk site. According to Lachenbruch's thermal analyses (1957), this western shoreline of the Barrow peninsula has been relatively stable for the past few thousand years.

Lake Series

Buried peat samples are available from two drained lake basins at approximately similar depths (0.4 and 1.1 m.). The one tundra-covered lake basin is located east of the beach ridge (Fig. 1). Sample I-1544 (3,200 ± 230) is from a continuous layer of buried peat which underlies approximately 30 cm. of surface peat and organic lacustrine silt. Sample I-1545 (5,010 ± 320) is from a mass of fibrous peat found in the same section and overlying a small, buried ice wedge. A well-delineated layer of light gray silt (Fig. 3, No. 5), approximately 20 cm. thick and containing randomly oriented ice lenses, is found between samples I-1544 and I-1545. This gray silt layer is nearly continuous across the lake basin and has been observed more casually in other lake basins. If one accepts these two dates as representing maximum ages for deposition of each peat, then it follows that the gray silt layer is at a maximum between 3,200 and 5,000 years old. The silt was probably deposited in the lake as a windblown material. If the gray silt had been exposed to soil forming processes the uniform gray colour would probably not be preserved. The lake drained by erosional processes sometime during the past 3,200 years.

The second set of lake samples is from the artificially drained Footprint Lake. They were collected from two closely spaced exposures. The upper sample (W-432, 3,540 ± 300) was from a semi-continuous, thin layer of clean peat that appeared to have formed *in situ*. The lower sample (W-847, 9,100 ± 260) consisted of a small mass of peat in otherwise clean silts and fine sands (O'Sullivan, personal communication). Since these sample locations were not seen by the author further comment is reserved. However, the similarity in depth and age between W-432 and I-1544 should be pointed out and may well represent a regional pattern in the thaw-lake cycle. The validity of dating buried lake peats is open to criticism as they are often derived from the older buried peats of the eroding lake edge. Therefore, actual erosional and depositional events may be considerably younger than a radiocarbon date would indicate. No attempt should be made to determine rates of deposition from such sampling and dating.

Topographic Highs

These two samples (I-1202, 8,330 ± 250 and L-567 3,400 ± 100) are from local areas of prominent elevations and are considered to represent land surfaces that have not been recently reworked by thaw-lake cycle. In this respect they are similar to the polygon and beach ridge series. The 3,400 year age is obtained from a frozen organic-rich horizon at a depth of 0.7 m. in an upland tundra soil (Douglas and Tedrow 1960; Olson and Broecker 1959). This date is anomalous in that buried organic layers of presumably similar origin at that depth, and not associated with ice wedges such as I-699, are generally in the order of 10,000 years old (Tedrow 1965). If this peat was buried by the mechanism of ground-volume changes postulated by Douglas and Tedrow (1960), then this process was active as late as 3,000 years ago and perhaps is a reflection of a return to a cooler period following the hypsithermal period (Porter 1964). Further speculation might lead to a proposed correlation between the deposition of the gray silt layer in the lake basin (3,200 to 5,000 years ago) and eolian burial of this soil. Again the agreement between the humic portion and the residue after alkali treatment (L-567) substantiates the view that contamination is not serious in the perennially frozen layers.

Sample I-1202 (8,330 ± 250) is within the depth and age range of samples I-700 (9,550 ± 240) and I-701 (10,525 ± 280). At both sites ground ice volumes are considerable and thawing to the lower limit of the buried organic matter would result in settlements in excess of 50%, and in surface elevations approximately the same as L-400B (10,700 ± 350). It appears that the events of burial associated with these three sites may be comparable and reflect a condition of considerably deeper thaw.

Gubik Series

The frozen log (W-380, > 38,000) of questionable primary origin was from a cliff exposure in the base of the Barrow unit and exceeded the limits of the radiocarbon age determination (Rubin and Alexander 1958; Coulter *et al.* 1960; O'Sullivan 1961). The reworked organic layer obtained from a frozen core (Sellmann *et al.* 1964) (I-1394, > 36,300) is according to Black (1964) in the Skull Cliff unit. Both samples simply confirm field correlation and provide no further evidence for Wisconsin chronology. The age of a fragment of wood (Tx-220, 6,450 ± 400) recovered in the Barrow Village Slough at a depth of 10.5 m. below sea level implies that deposition in an estuarine environment coincided with a rising sea level and perhaps uplift (Faas 1964).

Archeological Series

Several wooden artifacts were dated from the Kugusugaruk diggings located some 18.5 km. southwest of Barrow village (Ford 1959). One item yielded a date of 1,430 ± 190 (P-73) with dates on individual segments of 1,620 ± 300 and 1,320 ± 220. A wooden meat tray was 1,146 ± 95 (Rainey and Ralph 1959; Ralph and Ackerman 1961). The site, according to Ford (1959), is considered to be early Birnirk. No further comments on these dates are offered at this time, except to state that additional efforts will be made to relate the Eskimo prehistory at Barrow to geological events and particularly sea level fluctuations.

Conclusions

Since many of the dates are based on materials that have been reworked from surface and subsurface organic layers, it is advisable to approach interpretation and correlation of local and regional events rather cautiously. However, several conclusions can be drawn from the present group of diversified samples.

The radiocarbon dates of buried peat suggest that the majority of the soils and surficial features on the present Barrow land surface are not older than 8,300 years and are perhaps considerably younger. This includes the highly polygonized tundra areas that constitute the primary surfaces such as the site of the polygon series (Fig. 2) and the sample location I-1202.

The present-day spit sediments have been shown to be approximately 1,100 years old. The upper section of the next inland raised beach is no older than 25,000 years and may be considerably younger. On this older beach, a surface horizon of a well-drained soil yields an average date of 3,000 years. This age indicates the stability and maturity of the Arctic Brown soil, and suggests that the ridge has not undergone significant surficial modification within the last 3,000 years. On the same ridge, dates of buried organic materials at depths of 0.3 to 1.0 m. represent the ages of surface horizons of soils that existed some 8,700 to 10,700 years ago.

The agents of burial of these older soils are as yet not well-established. It has been suggested that the intensive frost churning that occurred during a period of decreasing annual soil thaw caused this burial. The soils overlying the buried organic layers are poorly sorted (Fig. 3) and do not conform with particle-size distributions commonly encountered in widespread eolian deposits. Locally derived windblown material with later modification may be a possible source for some of the mineral overburden, particularly in the case of sample I-1182 with its sharp mineral contacts. The majority of the dates for organic matter at depths of 2.5 to 3.0 m. and those immediately below the seasonally thawed soil zone are within an age range of several thousand (8,300 to 10,700). These dates suggest a series of closely related events which may have included a relatively deep thaw followed by freeze back of the saturated sediments. The existence of perennially frozen ground and a tundra surface prior to this period is demonstrated by the 14,000 year age obtained from the buried ice wedge. These events of degradation of the near-surface perennially frozen ground, deposition and later refreezing occurred between approximately 3,000 and 8,300 years ago. Lack of alder pollen in the buried peat suggests that burial occurred prior to the alder maximum on the North Slope.

Acknowledgements

The author wishes to express his appreciation to Dr. John B. O'Sullivan (Allis-Chalmers), Dr. Lowell A. Douglas (Rutgers University), Paul V. Sellmann (U.S. Army CRREL) and Robert I. Lewellen (Denver University) for their valuable discussions, criticism and material assistance in the field and laboratory, and to the Arctic Research Laboratory, Barrow, Alaska for its logistical support of the several projects under which the samples were collected. The author is indebted to Dr. James D. Hume, Tufts University for permission to report his unpublished date.

References

Black, R. F. 1951. Eolian deposits of Alaska, Arctic 4:89-111.

——————1964. Gubik formation of Quaternary age in northern Alaska. U.S. Geol. Surv. Prof. Pap. 302-C, pp. 59-91.

——————Ice wedges and permafrost of the arctic Coastal Plain of Alaska (unpubl. ms.).

Britton, M. E. 1957. Vegetation of the arctic tundra, Arctic Biology pp. 26-61, 18th Ann. Biol. Coll., Corvallis, Oregon.

Brown, J. 1965? Ice-wedge chemistry and related frozen ground processes. Proc. Intern. Permafrost Conf. (in press).

Colinvaux, P. 1964. Origin of ice ages: Pollen evidence from arctic Alaska. Sci. 145:707-708.

Coulter, H. W., K. M. Hussey, and J. B. O'Sullivan. 1960. Radiocarbon dates relating to the Gubik formation, northern Alaska. U.S. Geol. Surv. Prof. Pap. 400-B, pp. B350-351.

Douglas, L. A. and J. C. F. Tedrow. 1960. Tundra soils of arctic Alaska. 7th Intern. Congr. Soil Sci. 4:291-304.

Drew, J. V. and J. C. F. Tedrow. 1957. Pedology of an Arctic Brown profile near Point Barrow, Alaska. Soil Sci. Soc. Am. Proc. 21:336-339.

Drew, J. V., J. C. F. Tedrow, R. E. Shanks and J. J. Koranda. 1958. Rate and depth of thaw in arctic soils. Am. Geophys. Un. Trans. 39:697-701.

Faas, R. W. 1964. A study of some late-Pleistocene estuarine sediments near Barrow, Alaska. Ph.D. Thesis, Iowa State Univ.

Ford, J. A. 1959. Eskimo prehistory in the vicinity of Point Barrow, Alaska. Anthropol. Pap. Am. Mus. Nat. History Vol. 47, pt. 1, 272 p.

Hopkins, D. M., F. S. MacNeil and E. B. Leopold. 1960. The coastal plain at Nome, Alaska. A late Cenozoic type section for the Bering Strait region. 21st Intern. Geol. Congr., Copenhagen. Pt. 4, Sec. 4, Proc. pp. 46-57.

Hume, J. D. 1964. Shoreline changes near Barrow, Alaska, caused by the storm of October 3, 1963. Science in Alaska. Proc. 15th Alaskan Sci. Conf. pp. 20-21.

Koranda, J. J. 1954. A phytosociological study of an uplifted marine beach ridge near Point Barrow, Alaska. M.S. thesis. Mich. State Univ.

Lachenbruch, A. H. 1957. Thermal effects of the ocean on permafrost. Geol. Soc. America Bull. 68:1515-1530.

——————1962. Mechanics of thermal contraction cracks and ice-wedges polygons in permafrost. Geol. Soc. Am. Spec. Pap. 70, 69 p.

Livingstone, D. A. 1957. Pollen analysis of a valley fill near Umiat, Alaska. Am. Jour. Sci. 255:254-260.

Moore, G. W. and D. W. Scholl. 1961. Coastal sedimentation in northwestern Alaska. U.S. Geol. Surv. TEI-779, pp. 43-65.

Olson, E. A. and W. S. Broecker. 1958. Sample contamination and reliability of radiocarbon dates. N.Y. Acad. Sci. Trans. 20:593-604.

——————1959. Lamont natural radiocarbon measurements V. Radiocarbon Supplement 1:1-28.

——————1961. Lamont natural radiocarbon measurements VII. Radiocarbon 3:141-175.

O'Sullivan, J. B. 1961. Quaternary geology of the arctic Coastal Plain, northern Alaska. Ph.D. thesis, Iowa State Univ., 191 p.

Péwé, T. L. and R. E. Church. 1962. Age of the spit at Barrow, Alaska. Geol. Soc. Am. Bull. 73:1287-1292.

Porter, S. C. 1964. Late Pleistocene glacial chronology of northcentral Brooks Range, Alaska. Am. Journal Sci. 262:446-460.

Rainey, F. and E. K. Ralph. 1959. Radiocarbon dating in the Arctic. Am. Antiquity 24:365-374.

Ralph, E. K. and R. E. Ackerman. 1961. University of Pennsylvania radiocarbon dates IV. Radiocarbon 3:4-14.

Rex, R. W. and E. J. Taylor. 1953. Uplifted beach ridges and first generation lakes in the Barrow, Alaska area. Unpubl. Final Rept. Contr. NONR 225(09).

Rubin, M. and C. Alexander. 1958. U.S. Geological Survey radiocarbon dates IV. Sci. 127:1476-1487.

——————1960. U.S. Geological Survey radiocarbon dates V. Radiocarbon Supplement 2:129-185.

Sellmann, P. V. and J. Brown. 1963. Near-surface lithology of the Barrow, Alaska area, a preliminary report. 14th Alaskan Sci. Conf. Proc. pp. 231-232.

Sellmann, P. V., J. Brown and R. I. Lewellen, 1964. Near-surface stratigraphy, Barrow, Alaska: Core analyses. Prog. and abstrs., 15th Alaskan Sci. Conf. pp. 39-40.

Tedrow, J. C. F. 1965? Arctic soils. Proc. Intern. Permafrost Conf. (in press).

Tedrow, J. C. F. and L. A. Douglas. 1958. Carbon 14 dating of some arctic soils. Rutgers Univ. (mimeo, note).

Trautman, M. A. 1964. Isotopes, Inc. radiocarbon measurements IV. Radiocarbon 6:269-279.

Trautman, M. A. and A. Walton. 1962. Isotopes, Inc. radiocarbon measurements II. Radiocarbon 4:35-42.

can be estimated that a *standing crop* of at least 10-12 mg./m.^{2} or 25x10^6 kg. Chl. *a* exists during about two months. A conservative carbon to chlorophyll ratio of 30:1 suggests a standing crop of 750x10^6 kg. C on the ice.[14] There is no quantitative information on the actual utilization of this food but since it is found at high concentrations throughout the spring and disappears as a result of increased light intensities, it is probable that little of it is assimilated into a higher trophic level.

It is unlikely that the algal growth described by Meguro[1] occurs to any significant extent in the Arctic since it is evidently dependent upon a snow layer remaining on broken sea-ice. The below-freezing air temperatures of the Antarctic permit this, but it is normal in the Arctic for the snow cover to melt and disappear before the ice breaks. There are apparently no reports of such a development in arctic ice, nor have I seen it while observing sea-ice in five different regions of the north.

Acknowledgements[15]

I am indebted to Drs. M. J. Dunbar and I. A. McLaren and Mr. A. S. Bursa who kindly read this manuscript and offered helpful comments.

Mr. A. S. Bursa, Arctic Unit, Fisheries Research Board of Canada, has kindly examined preserved samples from the ice and has identified over 60 species of algae, of which diatoms are dominant. Mr. Bursa expects to prepare a separate report on the results of his examination.

S. Apollonio
Rockport, Maine

References

[1]Meguro, H. 1962. Plankton ice in the Antarctic Ocean. Antarctic Record, 14: 1192-1199.

[2]Bunt, J. S., and E. J. F. Wood. 1963 Microalgae and antarctic sea-ice. Nature, 199: 1254-1257.

[3]Bunt, J. S. 1963. Diatoms of antarctic sea-ice as agents of primary production. Nature, *199*: 1254-1257.

[4]Apollonio, S. 1961. The chlorophyll content of arctic sea-ice. Arctic, 14: 197-200.

[5]Parsons, T. R. 1963. Suspended organic matter in sea water, *in* Progress in Oceanography. New York: Pergamon Press. Col. 1, 205-239.

[6]Collin, A. E. Personal communication. 15 August 1961.

[7]Thomas, C. W. 1963. On the transfer of visible radiation through sea ice and snow. J. Glaciology, 4: 481-484.

[8]Strickland, J. D. H. *1960*. Measuring the production of marine phytoplankton. Fish. Res. Bd. Canada, Bull. No. 122.

[9]Parsons, T. R. 1961. On the pigment composition of eleven species of marine phytoplankters. J. Fish. Res. Bd. Canada, 18: 1017-1025.

[10]English, T. S. Unpublished ms. Primary production in the central north polar sea, Drifting Station Alpha, 1957-1958.

[11]Mohr, J. L., and J. Tibbs. 1963. Ecology of ice substrates, *in* Proceedings of the Arctic Basin Symposium October 1962, Arctic Institute of North America, Washington, D.C.

[12]Weeks, W. F., and O. S. Lee. 1958. Observations on the physical properties of sea-ice at Hopedale, Labrador. Arctic, 11: 135-155.

[13]Sverdrup, H. U., M. W. Johnson, and R. H. Fleming. 1942. The oceans, their physics, chemistry and general biology. New York: Prentice-Hall, 1087 pp.

[14]Steele, J. H., and I. E. Baird, 1961. Relations between primary production, chlorophyll and particulate carbon. Limmol. Oceanog., 6: 68-78.

[15]The Devon Island Expedition received financial and material support from many sources. These are listed in Arctic, 14: 252-265.

Corrigendum (Radiocarbon Dating, Barrow, Alaska)

Arctic, Vol. 18, No. 1, page 36. Footnote to second column of Table 1 — *Age*[1] *(yrs. B.P.)* — should read: "... no corrections are made for new half life or *1950* reference year."