

# CLIMATE AND THE ABORIGINAL OCCUPATION OF THE PACIFIC COAST OF ALASKA

Francis A. Riddell

## I. Introduction

In its original form this paper was a Master's thesis, submitted to a committee consisting of Drs. Ronald L. Olson, Robert F. Heizer and Erhard Rostlund. To these men I wish to express my gratitude for their generous aid and guidance in the preparation of the thesis and, ultimately, this present paper.

The major part of the region of Alaska facing the Pacific Ocean has been covered at various times in the past by vast sheets of glacial ice. Even today large areas of this section of Alaska are covered by extensive glacier systems. In most cases, however, these systems are on the retreat and are thus freeing new land areas, which are becoming covered, through a successional trend, by vegetation characteristic of the region. This floral advance permits concomitant and subsequent faunal advances. The process of faunal/floral adjustment to the changing environment in this region began with the retreat of the great mass of ice which covered the land areas at the time of maximum glaciation. Man, as an element in the faunal assemblage, has shared in this advance upon those once ice-covered regions of Alaska facing the Pacific Ocean.

Studies in glacial geology and allied fields during the last 50 years have demonstrated the complexities of the various glacial advances and retreats which have occurred in Alaska in the past. The geological events concerning glaciation as noted for southwestern and southeastern Alaska have been equated, for the most part, with similar events in other areas of Alaska and other regions of the world. These studies have provided a chronology of glacial geological events, which are of necessity closely involved with any consideration of the aboriginal occupation of the Pacific Coast region of Alaska.

It is the purpose of this paper to utilize the data presented by anthropology in conjunction with those presented by such disciplines as glacial geology, ecology, palynology, climatology, and vulcanology, in an attempt to determine when it was first possible for human beings to occupy the Pacific Coast region of Alaska. Some students have questioned the possibility of ancient native habitation in this region, because of the apparent recency of glaciation, especially in southeastern Alaska. (de Laguna, 1953, p. 57).

Archaeological evidence currently provides a longer history of aboriginal occupation for the Aleutian-Kodiak-Cook Inlet region than for southeastern Alaska. The climate of the latter region may have been recently, and for a long period in the past, of such a nature as to inhibit effective habitation of the area by aboriginal groups. Archaeological sites which could be considered as exhibiting an antiquity of more

than a few hundred years are at present unknown in southeastern Alaska. However, this may be due to the fact that there have been very few archaeological excavations and no intensive site surveys. The luxuriance of the vegetation and the rough terrain (consisting of innumerable bays, inlets, fiords, and waterways) make archaeological site survey quite difficult. This condition may be contrasted with the Kodiak-Aleutian region, which is for the most part untimbered. Here the terrain is not only more suitable for the successful observation and recording of archaeological sites, but the nature of the sites themselves is such that they may be located with ease. These untimbered sites, composed primarily of molluscan and sea mammal remains and similar kitchen refuse, may extend over an area of five to ten acres or more, with a depth of as much as thirty feet. They often may be recognized at a glance during surface or aerial survey by vegetational differences or by the numerous house pits dotting their surfaces. (Bank, 1953a, pp. 246-248, 263). Finding sites presents a very different and more difficult problem in southeastern Alaska than in the Aleutians or on Kodiak Island, particularly for those sites which might be more than 500 or 1,000 years old. Vegetational differences, however, as indicated by Drucker (1943, pp. 114-115) for sites on the Northwest Coast, may play a significant role in future archaeological site surveys in southeastern Alaska. The apparent reluctance of conifers to reclaim abandoned habitation sites seems to be useful in recording the more recent cultural deposits but not, unfortunately, the more ancient sites, which ultimately become overgrown by forests.

The following section of this paper is a brief synthesis of past and recent archaeological accomplishments in that region of Alaska with which the paper is concerned. It is believed that this section, despite its brevity, is a necessary adjunct to the rest of the paper, as it provides a certain cultural base-line for the present investigation.

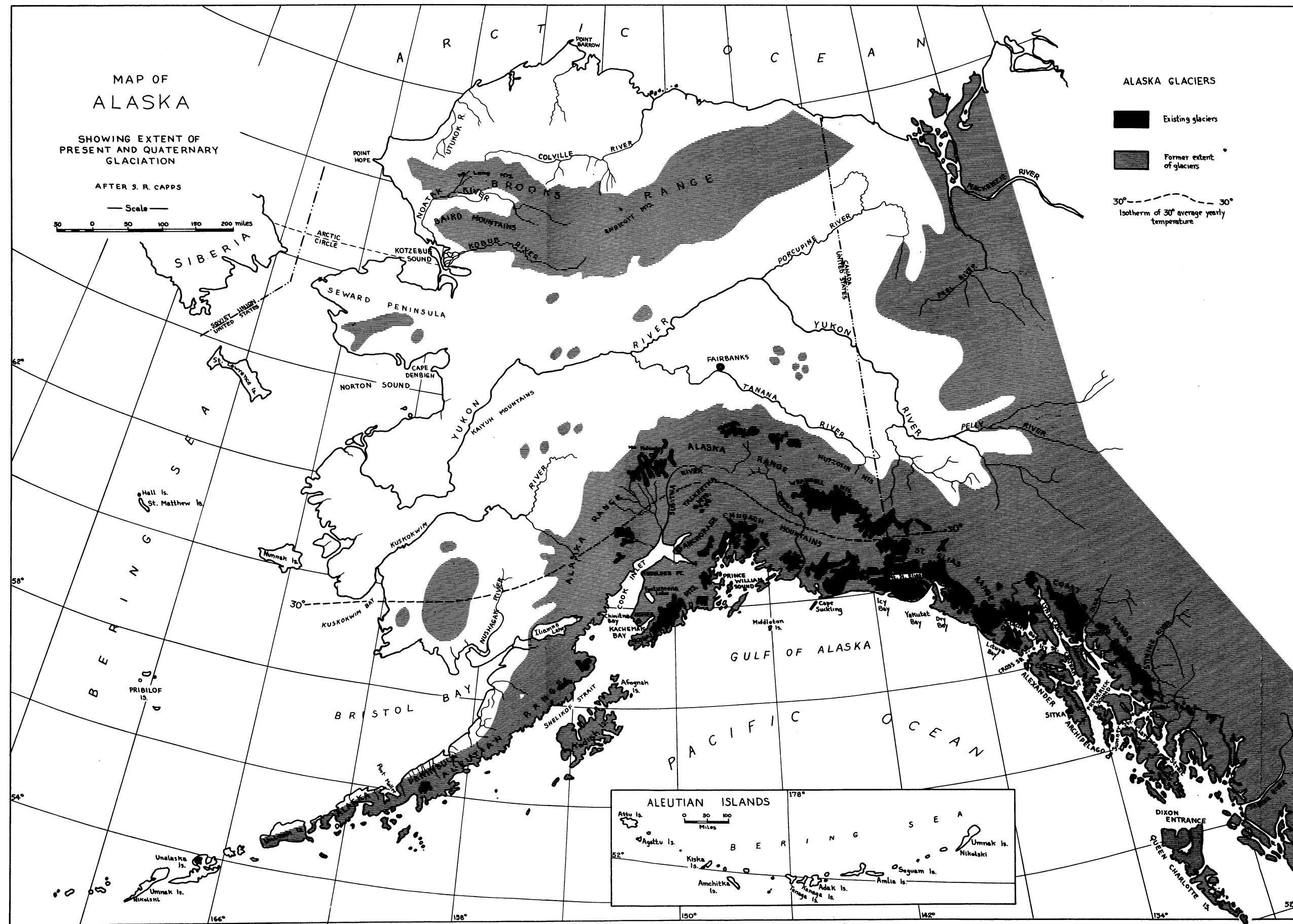
## II. Archaeological Summary

Although the Aleutians have received greater archaeological attention than southeastern Alaska, no definitive work has yet appeared for the former region. Scientific archaeological investigations in both southwestern and southeastern Alaska are yet in their infancy. Spaulding (1953) has presented an excellent summary of the status of Aleutian archaeology in which he points out that what is known of the archaeology of that region is the result of the investigations of Dall, Jochelson, Hrdlicka, and Laughlin. Dall's (1877) work led him to suggest a sequence of three successive periods, the first having a duration of 2,200 years. Subsequent investigation in the Aleutians, however, does not support Dall's interpretations.

The archaeological work done by Jochelson (1925) was a substantial improvement over that of Dall. More careful and detailed work by Jochelson demonstrated that cultural development had occurred, but not in the strict three-fold manner suggested by Dall.

PLATE I

Map of Alaska  
Showing Extent of Present  
And Quaternary Glaciation



By making physical anthropological observations on the human skeletal material recovered in his digging in the Aleutians, Hrdlicka divided the prehistoric peoples of this region into two groups, the long-headed Pre-Aleut and the round-headed Aleut. It is interesting to note that these two divisions of the prehistoric Aleuts are supported in modified form by Laughlin. Hrdlicka's findings are regarded today as of dubious scientific value (Spaulding, 1953, pp. 30-31).

Laughlin's major investigations have come about through a long-range coordinated anthropological program in the Aleutians, begun after the war. His archaeological work has been concerned primarily with the excavation of a very large and deep habitation site at Nikolski on Umnak Island in the eastern Aleutians. The radiocarbon date of about 3,000 years (Arnold and Libby, 1950, p. 13) for the base of the site seemingly attests to the antiquity of Aleut culture in this region. No final and detailed publication has yet appeared, so it is difficult to know specifically how Aleut culture is represented over this span of time at this site. Preliminary papers by Laughlin (1951; Laughlin and Marsh, 1951) do, however, give some indications of what is being determined by physical anthropological research in the Aleutians, and by excavations at Nikolski. Laughlin contends that his data support Hrdlicka's belief that the prehistoric Aleuts consisted of two groups, renamed by Laughlin as Paleo-Aleut and Neo-Aleut. It is Laughlin's belief that the Neo-Aleut spread westward along the Aleutian Chain, replacing the Paleo-Aleut both physically and culturally, but without any abrupt cultural or physical change. The changes become less noticeable toward the western end of the Aleutian Islands.

According to both Hrdlicka and Laughlin, the Paleo-Aleut and Neo-Aleut (Hrdlicka's Pre-Aleut and Aleut) were typified by long and broad heads respectively. Bank (1953b, p. 45), however, reports that broad-headed individuals are associated with the earliest levels at Amaknak on Unalaska Island. The artifact series from Amaknak is considered by Bank to be early, so there is an apparent association of a type of cranium thought by Hrdlicka and Laughlin to represent the recent Aleut with artifacts considered to be early. This difference will probably be resolved when recent archaeological work done by Laughlin and by the University of Michigan Aleutian Expedition is published.

From material salvaged from a mound at Amaknak on Unalaska in the eastern Aleutians, Quimby (1948) made an analysis of Aleutian art styles which presents Aleutian culture history as gradually changing and continuous. Cultural elements present do exhibit change, but not simultaneous change which would give specific and clear-cut periods. The change in both culture and physical type came about slowly during the total period of occupation.

Jochelson, Hrdlicka, Laughlin, and Quimby all feel that the culture history of the Aleutians has been marked by a lack of any sudden breaks or shifts.

Theodore P. Bank, II, field director of the University of Michigan Aleutian Expeditions of 1948-52, has discussed cultural succession in the Aleutians (Bank, 1953b). After summarizing the past and current status of archaeology in the Aleutians, he concludes that work has only just begun on the interpretation of Aleutian prehistory. More importantly, he emphasizes the fact that "it is conceivable that the prehistoric sequences at one site, no matter how large and ancient that particular site may be, do not necessarily reflect the prehistory of the entire Aleutians" (Bank, 1953b, p. 48). He suggests a re-examination of past archaeological data to learn more about geographical variation of the Aleutian culture, and a program of work at stratified sites throughout the entire chain of islands. It is his belief that local terms for the local cultural manifestations should be utilized instead of the generalized but restricting terms Paleo-Aleut, Neo-Aleut, and Pre-Aleut.

Under Bank's direction, since the end of the war, the University of Michigan Aleutian Expeditions have made archaeological excavations on Agattu and Unalaska Islands and, less extensively, at village sites on Tanaga, Adak, Atka, and Umnak Islands. Besides these excavations, burial cave investigations were made on four islands. Radiocarbon dates and results of pollen analyses are promised when the work of this coordinated project is published.

At the Amaknak site at Dutch Harbor on Unalaska Island, Bank found it "impossible to define any strict cultural periods marked by the synchronous appearance of a number of artifact types" (Bank, 1953b, p. 45). During the time this 20-foot-deep site was occupied no abrupt interruption of developmental trends is observable. He does note important differences between individual sites, however, and makes the statement that "----very important differences in artifact types and styles also appear in cultural assemblages from presumably contemporary levels on adjacent islands" (Bank, 1953b, p. 45). Such differences in artifact types are also expectable, considering the distance of nearly 1,000 miles between the western and eastern Aleutian islands. Bank remarks on certain cultural differences between the two ends of the chain of islands, and even between neighboring islands. He also notes a dissimilarity of artifacts between two sites on Unalaska Island separated by only a few miles of water. These various differences in cultural manifestations between sites in the Aleutians may be explained partially by non-contemporaneity. Bank feels, however, that the differences must be explained by geographical variations and maintenance of local traditions. It is for this reason that he objects to the all-inclusive terms Paleo-Aleut, Neo-Aleut, and Pre-Aleut for describing cultural remains from individual sites. As he points out, "Early Atkan and late Atkan, e.g., may or may not correspond to early Attuan and late Attuan" (Bank, 1953b, p. 49).

On Adak Island Judson (1946) noted cultural remains in the two top soil zones, overlying deposits of wind-blown sand. He believes that the deeper deposit suggests considerable antiquity for the cultural remains. In a following section, dealing with the geology of Adak Island, I give additional details of this find. Also below, I have suggested that

the wind-blown sand became stabilized at the end of a dry period and at the beginning of a more moist period. From evidence given in the following sections it seems possible that the moist period began about 4,000 years ago. The cultural remains in the lower of the two top soil zones may be about the same age as the lower levels of Laughlin's site at Nikolski on Umnak Island, i.e., about 3,000 years old.

Archaeological exploration of the Alaska peninsula, particularly on the Pacific side, has been slight and of limited value. Hrdlicka gives a list and a short description of a number of historic and prehistoric villages and sites, but gives no other details of archaeological significance (Hrdlicka, 1930, figs. 18-19, pp. 186-190). On the Bering Sea side of the peninsula E. M. Weyer, Jr. has published on archaeological work done at Port Moller (Weyer, 1930). Specimens of stone blades and points exhibiting grinding instead of chipping were quite rare at this site. The inhabitants practiced primary and secondary inhumation, and covered the burials with a red powder apparently made from an "iron-colored clay" (Weyer, 1930, p. 262).

Despite some local individualism, the site at Port Moller appears to be much like sites in the Aleutian Islands. Weyer believes that the various lines of evidence "point toward considerable antiquity" for this village site (Weyer, 1930, p. 277).

Hrdlicka notes the location of 13 sites on Afognak, Spruce, and Kodiak Islands (Hrdlicka, 1930, fig. 17, pp. 184-186) and comments on his excavations at Uyak Bay on the north side of Kodiak (Hrdlicka, 1939; 1944). Through his explorations on Kodiak, Hrdlicka determined to his satisfaction that an early long-headed population was replaced by a more recent round-headed group, as he has claimed for the Aleutians. These two differing groups of people were termed Pre-Koniag and Koniag. Hrdlicka, however, never presented a detailed account of his archaeological excavations on Kodiak, so the prehistoric cultures are relatively unknown for this island.

Until the work by de Laguna (1934), the Cook Inlet region was unknown archaeologically. Through her excavations there, she was able to present three stages of cultural development: Kachemak Bay I, II, and III. The earliest stage, Kachemak Bay I, is tentatively dated by de Laguna as terminating ca. 500 A.D. She reports that the basic pattern of Kachemak Bay III, with local modifications, also occurs at Prince William Sound, and on Kodiak Island, the Alaska Peninsula, and the Alutian Islands (de Laguna, 1947, p. 11). It is also her belief that Kachemak Bay II is present in these neighboring areas. Kachemak Bay II she dates from 500 A.D. to 1,000 A.D., and Kachemak Bay III from 1,000 A.D. to 1700 A.D. (de Laguna, 1947, p. 6).

A site reported by Frank Hibben (1943) at Chinitna Bay on Cook Inlet presents indications of being relatively ancient. In fact, additional investigation of this buried site might demonstrate that it is the earliest known site in the Cook Inlet vicinity. Until more data are

obtained, however, it will be possible to do little concerning its cultural and temporal placement. It will be further discussed below.

A long range coordinated project of linguistic, ethnographic and archaeological research, visualized by Frederica de Laguna for the northern Northwest Coast, was initiated in 1949 and has provided the beginning of archaeological investigation in southeastern Alaska. Reports of the site survey (during the summer of 1949) and the archaeological excavation at Angoon, Admiralty Island (the following summer) have been published (de Laguna, 1951; 1953). Preliminary reports for the work of two summers at a protohistoric village site on Knight Island in Yakutat Bay have also appeared (de Laguna and Riddell, 1952; 1953). Until the final report on the work at Yakutat Bay appears, precise information will not be available. The preliminary reports suggest Eyak, or Eyak-like, affinities in the lower levels of the site succeeded by a culture with a Tlingit orientation.

Sites with a demonstrable age greater than about 500 years are currently unreported for the northern Northwest Coast. In a following section the possibility of earlier habitation for this region will be discussed.

### III. The Chronological Sequence

We may now turn to various data that help us to reconstruct a post-glacial chronology of events, useful for suggesting the times when aboriginal occupation of the Pacific Coast region of Alaska was first possible.

#### Glacial geology

Although the glacial geology of southwestern and southeastern Alaska is as yet only imperfectly known, there has been a great deal of significant work done in recent years which has begun to clarify the numerous problems existing in this field. Glacial geologists accept, at least as a working assumption, that Pleistocene glaciation in Alaska can be temporally equated with glacial activity in other sections of western North America, and even with other regions of the world. In the following sections, information of a glacial geological nature is presented for the various component geographic elements of the Pacific Coast region of Alaska.

Attu Island. This rugged mountainous island, westernmost in the Aleutian chain, has peaks and ridges that rise to an elevation of 3,000 to 3,500 feet. Capps (1934, p. 151) noted no active volcanic vents on this island nor did he see any mountains whose contours were constructional. He did observe that the entire island had been glaciated, however. It was his opinion that the island had been heavily glaciated in Pleistocene times and that the present topography was produced by glacial modification of the preexisting stream-eroded landscape.

Kiska Island. Kiska is at least in part volcanic in origin, and has a volcanic cone some 4,000 feet high which exhibits only moderate dissection. This island is situated nearly 200 miles east of Attu Island in the Aleutian chain and also exhibits glacial erosion. Capps (1934, p. 151) states that in most places glacial scouring was not severe on Kiska.

Adak Island. Investigations on this island have been somewhat more extensive, with the result that the Pleistocene glacial record has been more clearly interpreted than for many of the other islands in the chain. According to Capps (1934, p. 150) this island was severely glaciated and was covered with a local ice cap at the time of its maximum glaciation. Glacial fiords on this island include the Bay of Islands, Three Arm Bay, and the Bay of Waterfalls. Ice has excavated basins in the volcanic rocks on the mountain slopes to form glacial lakes. The bedrock over most of the island has been scoured by the glacial ice, although the rock is now covered by material left by the ice, and by soil and vegetation.

More recent investigations on Adak by Sheldon Judson (1946) give additional data on the glaciation of the Aleutian Islands, including Adak. He states that the glaciation of Adak Island and the other islands of the Aleutian chain was local, in the sense that it was mountain rather than continental glaciation. He does not mean to infer, however, that this glaciation existed separately and apart from the major ice advances on the continents. Judson further reports that a late-glacial and post-glacial chronology exists on Adak, as exhibited by a slightly weathered till that is probably Wisconsin in age, and a marine terrace, followed by three deposits of wind-blown sand, each with a developed soil zone. From his observations on Adak, Judson suspects that this sequence "in its entirety results from climatic fluctuations and is of general distribution throughout a considerable portion of the North Pacific ..." (Judson, 1946, p. 385).

Of considerable archaeological interest is the fact that Judson found cultural evidence of the recent Aleut in the topmost soil developed on the latest blown sand. Even more interesting is his discovery, in the soil of the second oldest sand, of cultural manifestations which he presumes to be either pre-Aleut or an indication of greater antiquity for the Aleut than is usually ascribed to them. Since there were no radiocarbon dates for Aleut cultural material at that time, it was impossible for Judson to attempt to equate his earliest cultural remains with the dates revealed by radiocarbon analysis of samples from the Aleutians.

Supporting evidence concerning the glaciation of Adak is given by Charles Bradley, whose recent investigations indicate that the ice at one time must have been thick enough to bury all but a few nunataks (Bradley, 1948, pp. 232-234). He states that in the Adak-Great Sitkin group of islands there are three discernible states of vulcanism, two preglacial and one postglacial. This evidence of vulcanism can be of importance in determining a chronology of events for Adak and neighboring islands. A gradation zone between the till and the ash blanket was produced when ash from

the earlier part of the last stage of vulcanism fell upon the retreating glaciers of this island.

The postglacial stage of vulcanism on Adak appears to have been of considerable duration. Bradley (1948, p. 328) points out that the intervals of relative quiet allowed vegetation to gain foothold and to create soil horizons of humus on top of the ash. There were four or five such quiet intervals during this period of vulcanism.

Bradley also calls attention to the movement of sand during the postglacial stage, and reports that this sand became stabilized with the aid of a moist climate, and of the dying down of volcanic activity and increased growth of vegetation. This shifting of sand is probably the same phenomenon reported by Judson (1946, pp. 384-385) in his description of late- and postglacial stratigraphy.

The stratigraphic sequence noted by Bradley on Adak is well illustrated by the road cut near Red Bluff (1948, Pl. 1, fig. 2). The sequence there, from bottom to top, is as follows: a) A glacial till with a surface of old soil; b) an apparently widespread coarse ash stratum, probably deposited after a tremendous eruption of neighboring Great Sitzkin volcano; c) three strata of old soil topped by a layer of coarse ash; and d) the present surface, an old soil.

The three wind-blown sands with the developed soil zones noted by Judson may possibly be equated with the three strata of old soil noted by Bradley, or possibly with Bradley's four top strata. Such a correlation would be very useful because of the archaeological importance of the two top strata in Judson's sequence.

Unalaska Island. Unalaska, one of the Fox Islands, is situated near the east end of the Aleutian chain, and is separated from the Alaska Peninsula by several small islands and the large island of Unimak. That this island is at least in part of volcanic origin, is indicated by considerable amounts of volcanic rock and by lava flows from 200 to 500 feet thick.

Unalaska was heavily glaciated in Pleistocene times by a system of mountain glaciers which pushed out to sea in all directions. The physical aspects of the island have changed little since the retreat of the glaciers, and the strong glacial sculpturing which occurred is quite evident (Capps, 1934).

From investigations made by Capps it is apparent that at least the larger and more rugged of the Aleutian Islands were subjected to glaciation during the Pleistocene. The islands visited had developed individual ice caps, "in which only the higher peaks and ridges stood above the glacial ice, and the glacial movement was radially away from the divides toward the sea" (Capps, 1934, p. 147). Capps did not visit other large islands such as Unimak, Akun, Akutan, Umnak, Kanaga, Tanaga, Amchitka, and Agattu, but he feels certain that they underwent the same sort of

glaciation described for those he did visit.

Alaska Peninsula. During the Pleistocene glaciation, all areas reaching an elevation of as much as 2,000 feet or more were capable of holding perpetual snows and of generating glaciers. These pushed down into the sea on the Pacific side and produced a rugged coastline with many fiords. The precise limits of the glaciers on the Bering Sea side are not known, but that they extended into the lowlands is attested by the numerous large lakes so conspicuous in that region. "Throughout this area, however, including both the peninsula and Aleutian Islands, the glacial ice was of local origin, and as the distance to the sea was nowhere great, the ice streams never reached great length" (Capps, 1934, pp. 146-147).

Kodiak Island. The occurrence of pebbles of volcanic rocks on a beach on the southwest shore of Kodiak Island suggests to Capps (1937, p. 164) the possibility that they were transported there by glacial ice from volcanic regions of the Alaska Peninsula. This is evidence which indicates that at one time there was a probable merging of the glacial ice from the peninsula with the local ice cap on Kodiak. In any event the island was the site of an extensive local center of glaciation.

Capps assumes that the blue, unoxidized till soon at so many places on Kodiak and neighboring islands is of Wisconsin age, and coeval with the last widespread glaciation noted elsewhere in Alaska, which has been correlated with the Wisconsin period.

Alaska Range--Cook Inlet--Kenai Peninsula Region. The last great glacial advance, which occurred in late Wisconsin time, was very similar in most respects to all the preceding ice advances that took place in the Pleistocene. Ice built up in the Alaska Range and pushed down both slopes of the main range, forming a continuous piedmont ice sheet upon the joining of the ice streams from adjacent valleys.

The great glacier that poured down the Susitna Valley was fed by ice streams coming down the south and east sides of the Alaska Range, and by tributary ice streams flowing from the Chugach and Kenai Mountains to the east. This great glacier may have extended southward to the mouth of Cook Inlet (Capps, 1935, pp. 77-78).

The glaciers flowing out from the westward slope of the Southern Alaska Range were almost as vigorous as the ones on the east, but pushed out onto an unglaciated lowland rather than into salt water. The basin of Iliamna Lake was excavated by the movement of ice from this range. A terminal moraine 7 miles below the present outlet of this lake indicates the extent of the great ice tongue that formed the lake basin. That the glacial activity throughout the entire region of the southern Alaska Range was quite severe, is borne out by the abundant evidence of glaciation noted by Capps.

The Naknek district just southwest of Iliamna Lake has undergone four successively less extensive glaciations during the Pleistocene. "Moraines of the latest major glaciation are correlated with similar moraines in the Cook Inlet lowland and parts of the Alaska Range, on the basis of relative topographic prominence, preservation, and physiographic position" (Muller, 1952, p. 72).

According to Karlstrom (1952, p. 57), the last recognized glaciation did not fill the trough of Cook Inlet. The moraines of this glaciation reached only to the mouth of Matanuska Valley and up to 15 miles out from the Alaska Range and Kenai Mountain fronts. Karlstrom states that the last glaciation advanced between 14,000 and 8,000 years ago, and the previous glaciation more than 19,000 years ago. He believes that the oldest two may be early Wisconsin or pre-Wisconsin in time as noted in the Cook Inlet region.

Investigations on the Kenai Peninsula by D. B. Krinsley (1952) produced evidence of glacial activity that is correlated with Karlstrom's sequence of glacial activity for the Cook Inlet area. Krinsley believes that the southwest Kenai piedmont was probably covered during the second recognized glaciation. During the last glaciation, ice came down from the Kenai Mountains and filled the trough of Tustumena Lake and Kachemak Bay. During the last major deglaciation at least three readvances or stillstands are recorded by concentric morainal loops in the Tustumena trough. Two moraines within a mile of the present glacier fronts indicate more recent glacial fluctuations in the Kenai Mountains (Krinsley, 1952, p. 60).

It will be noted from the preceding evidence by Capps and Karlstrom that the former investigator places end moraines in the Cook Inlet area considerably in advance of those by Karlstrom. These moraines evidently were from an earlier glaciation than those observed by Karlstrom, probably from early Wisconsin times. Those noted by Karlstrom are from the latest major glaciation (Péwé, 1953, p. 5), which occurred not more than 14,000 and not less than 8,000 years ago, as indicated by radiocarbon dates (Karlstrom, 1953).

St. Elias Range. The glaciers of the Wolf Creek area, on the interior (Canadian) side of the St. Elias Range, appear to have undergone transitions quite similar to those of the coastal glaciers, whose history during post-Wisconsin times is one of initial glacial retreat of great magnitude, followed by a relatively recent glacial growth, followed by another retreat. After the initial extensive retreat, the ice-free areas were covered with vegetation. The later glacial expansion engulfed forests which had grown up after the initial retreat. Upon the recession of this later advance the remnants of the engulfed forests were revealed.

Though the evidence is not particularly clear, R. P. Sharp (1951, p. 105) is inclined to believe the Wolf Creek glaciers experienced the same post-Wisconsin recession as did the other glaciers on the interior

side of the St. Elias Range. The sequence as outlined above for the Wolf Creek glaciers--initial glacial growth followed by another retreat--is shared with a number of coastal glaciers.

Prince William Sound. The whole Prince William Sound was occupied by a great piedmont glacier during the stage of maximum Pleistocene glaciation. The distance to which this mass of ice extended into the sea is not precisely known. However, it is very likely that it extended as marine shelf-ice as far as Middleton Island (Péwe, 1953, p. 2).

Late Wisconsin glaciation in this region was probably much less extensive than the maximum Plioistocene glaciation, a condition thought to be true, in general, for the entire territory (Péwe, 1953, p. 9).

Yakutat Bay. Glaciation in the Yakutat Bay region has been best studied and reported upon by Tarr and Martin (1914), though this work now has become somewhat obsolescent. Their findings are briefly this: glaciation in this area dates back to the Pleistocene and at its maximum literally flooded the mountain valleys with a system of mighty glaciers. This condition prevailed from the Alaska Peninsula along the Alaskan coast to British Columbia. After this great period of advance, at which time Yakutat Bay and Russell Fiord were completely filled by glaciers, the initial great post-Pleistocene recession set in. By the end of this recession the glacier fronts had retreated to a point behind that at which they now stand, and the regions vacated by the ice became covered with forest or other vegetation.

After the recession of the maximum glaciation another advance took place, but of lesser magnitude. In Yakutat Bay the advance extended the glaciers only into Russell Fiord and Disenchantment Bay. Tarr and Martin regarded it as a local phenomenon, but sufficient glacial geological information has been obtained since that time to allow Lawrence to state that "The same chronology has been reported from Glacier Bay, Alaska, from Garibaldi Park, British Columbia, from Mt. Hood, Oregon, and even from Norway and Iceland" (Lawrence, 1950, p. 222).

This brief advance at Yakutat Bay was followed by a recession that was still in progress ca. 1905. Subsequent to that time, according to Tarr and Martin, there has been some advance due to the earthquake of 1899, which threw fields of snow and ice down on the glaciers from bordering steep mountain slopes (Tarr and Martin, 1914, pp. 168-197).

Future work of a glacial geological nature in the Yakutat Bay area will probably show that Tarr and Martin are correct in their basic assumptions, but that considerable refinement is also necessary.

Juneau Area. Pleistocene glaciation in this area and in the numerous islands to the south is clearly indicated by evidence on all sides. Great streams of ice flowed to the sea from the heights of the coast range, gouging out such features as Lynn Canal and Chatham Strait, Icy Strait, and Cross Sound, Frederick Sound, Sumner Strait, Clarence

Strait, and Dixon Entrance. Ice from the mainland probably coalesced with the expanding local ice caps on Prince of Wales, Baranof, Chichagof, and neighboring islands. In short, the story of glaciation in southeastern Alaska closely parallels the history of Pleistocene glaciation in other sections of southern Alaska.

The degree of emergence of the higher peaks above the last ice sheet is quite difficult to determine, because of the severe weathering that has taken place at higher elevations. Concerning this, Péwé states, however, that the ice during the last major glaciation "covered the land up to an altitude of about 3,000 feet near Juneau but descended to an altitude of about 2,000 feet on Admiralty Island, and perhaps to 1,500 foot on Prince of Wales Island" (Péwé, 1953, p. 4).

An interesting and significant phenomenon, occurring with the retreat of the Mendenhall Glacier and other glaciers in the Juneau area, is the uncovering of remnants of a mature forest that had been overwhelmed and engulfed in the last advances of these glaciers (Wentworth and Ray, 1936, pp. 888, 891). Remains of overwhelmed forests have been noted also in the Taku and Stikine river district (Kerr, 1948a; 1948b), at Glacier Bay (Cooper, 1931, pp. 61-95; Reid, 1892, p. 39), and at Disenchantment Bay near Yakutat (Russell, 1893). Future investigations will probably reveal that the occurrence of remnants of forests overwhelmed by post-Pleistocene glacial advance is quite widespread in southern Alaska. It is also interesting to note that forest beds were observed at two stratigraphic levels at Muir Inlet at Glacier Bay. This would suggest a fluctuation in the ice front in post-Pleistocene times which permitted an advance in the forest with each retreat of the ice (Heusser, 1952, p. 348).

Summary. The investigation of glaciers and glaciation in southwestern and southcentral Alaska has shown that, in its broader aspects, Pleistocene and post-Pleistocene glacial activity has been quite uniform over the entire region subjected to glaciation. According to Péwé (1935), the glacial advances of recognized pre-Wisconsin age were considerably more extensive than the Wisconsin advances. Because of this, any reference to the maximum Pleistocene glaciation deals with a feature of pre-Wisconsin events. Evidence from the Fairbanks area in central Alaska suggests to Péwé that the warm period preceding the Wisconsin was warmer than the present climate and that permafrost was absent. Concerning the Wisconsin period he states that "there has been recognized a prominent twofold division of the Wisconsin deposits: two well-developed glacial or cold periods separated by a glacial retreat or warm period" (Péwé, 1953, p. 3).

The two broadest climatic variations recorded in post-Wisconsin times, according to Péwé, are the following: "(1) the warm and perhaps drier period of 3,500 to 4,000 years ago, which was followed by (2) a colder and perhaps wetter period that climaxed 200 to 400 years ago" (Péwé, 1953, p.8).

The stabilization of the sand on Adak Island noted by Bradley and by Judson probably may be equated with the colder and wetter period as presented above. The fact that wind-blown sands appear to have been stabilized at least three times suggests a certain climatic fluctuation during the post-Wisconsin period. To so equate the stabilized sand deposits would give an age of at least several thousand years to the cultural remains noted by Judson from the soil above the second oldest sand.

Muller notes that the Naknek district near Iliamna Lake has undergone four successively less extensive glaciations during the Pleistocene. The moraines of the latest major glaciation are correlated with similar moraines in parts of the Alaska Range and in the Cook Inlet lowland. The latest major glaciation is dated by Karlstrom as occurring between 8,000 and 14,000 years ago. It did not fill the trough of Cook Inlet as some preceding advances had done. Evidence from the Kenai Peninsula has been correlated by Krinsley with the sequence of glacial activity noted in the Cook Inlet area by Karlstrom. During the last major deglaciation, Krinsley also notes at least three readvances or stillstands. Even more recent glacial fluctuation is shown in the Kenai Mountains by two moraines within a mile of the present glacier fronts.

In basic outline, the chronological sequence presented by Sharp for the Wolf Creek glaciers is the same as given above by Pévé. Sharp's sequence is as follows: Initial glacial retreat of great magnitude, followed by a relatively recent glacial growth, followed by another retreat. This same sequence of events for post-Wisconsin times is given by Tarr and Martin for the Yakutat Bay area. Sharp has chosen to call the period of initial glacial retreat the post-Wisconsin xerothermic interval, to avoid using such general terms as "post-Pleistocene" and "postglacial". He also chooses to use the dates of 7,000 to 8,000 years ago as the beginning of this period, and 4,000 years ago as the approximate end (Sharp, 1951, p. 104).

At the present stage of knowledge of glacial geology for southwestern and southeastern Alaska, it appears that both the pattern of Pleistocene glaciation and the post-Wisconsin climatic changes were, by and large, synchronous and/or equatable within these regions as well as with other sections of the northern Hemisphere.

#### Pollen analysis

A method of attempting to gain greater detail concerning post-Wisconsin climatic changes is the technique of pollen analysis (Fagri and Iverson, 1950). The results of the pollen analysts' investigations into plant succession and climatic change in post-Wisconsin times in the Pacific Coast region of Alaska and neighboring areas are in close agreement, for the most part, with the sequence of climatic change presented by the glacial geologists.

Pacific Northwest. On the basis of 70 peat or sediment sections, Hansen (1947) has been able to make a reconstruction of postglacial-postpluvial climate and vegetation for this region. The areas from which these samples were obtained include the Puget lowland, the coastal strip of Washington and Oregon, the Willamette Valley, eastern Washington, northeastern Washington and northern Idaho, Oregon Cascades, and the northern Great Basin in south-central Oregon. The importance of the investigations in these areas to the present study is the fact that they present such a large body of pertinent material from a neighboring region.

From analyses of pollen profiles, Hansen has assigned a chronological position to various levels in a number of his sediment columns. Since all of the columns obtained rested upon glacial drift or its chronological equivalent, Hansen arbitrarily calls the period, during which these columns formed, the Postglacial, "regardless of glacial movements and time of final dissipation of ice sheets in various parts of the continent" (1947, p. 113). This Postglacial period has been divided by Hansen into four component parts on the basis of the recorded forest succession. Period I extends from the last glacial maximum to 15,000 years ago. Period II dates from 15,000 to 8,000 years ago and was a period of increasing warmth and dryness. Period III was from 8,000 to 4,000 years ago and reached a stage of maximum warmth and dryness. Period IV, from 4,000 years ago to present, exhibits a return to a more moist and cool climate (see Table 1).

Glacier National Park. The results of the investigation of two sphagnum bog sections taken in Glacier National Park reveal a sequence of postglacial forest succession fairly consistent with what has been determined from the many pollen profiles from other areas of the Pacific Northwest. "Climatically, the forest sequence denotes an initial cool, moist period, a second period of warming and drying, a third stage of xerothermic maximum, followed by a final period of cooler and moister climate which in general has persisted to the present" (Hanson, 1948, p. 152).

These four stages of forest succession are chronologically equatable with the four-stage sequence noted for the Pacific Northwest as presented above.

Vancouver Island. Pollen profiles recently taken from three separate areas on Vancouver Island apparently fail to show any trends denoting climatic fluctuations, according to the analysis by Hansen (1950a). He feels that the forest succession shown by these three sections is due to a normal response to "a general amelioration of the climate and modification of the sterile mineral substratum left in the wake of glaciation" (Hansen, 1950a, p. 276). Because of this situation there has not been any strict correlation of these columns with the chronological sequence determined for the Pacific Northwest and Glacier National Park regions.

British Columbia. An important development of Hansen's (1950b) pollen investigations along the Alaska Highway in British Columbia is his suggestion that ice-free areas may have existed in western Alberta during the late Wisconsin glaciation. These areas could have served as refuges at this time for the forests, and thus have acted as centers for their migration northwestward during the early part of postglacial times. Evidence of an abundance of spruce and pine in the lowest horizons of peat bogs of the region suggests to Hansen that these ice-free areas were forested during Late Wisconsin time, or a short time thereafter. On the strength of this, Hansen even suggests the possibility of an ice-free corridor existing between the Keewatin and Cordilleran ice during the Late Wisconsin (Hansen, 1950b, pp. 420-421). This ice-free corridor could have served as an early migration route for the first movement of people into the continent of North America. This is in agreement with a theory held by Antevs (1935). Other students believe that it may have been possible for groups of people to enter during the interstadial between the first and second Wisconsin glacial substages, and again during the interstadial between the second and third glacial substages (Wormington, 1949, pp. 152-153).

The investigations by Hanson in British Columbia along the Alaska Highway, however, do not seem to indicate the presence of these open, ice-free corridors earlier in the Wisconsin (Hansen, 1950b). Nor do his investigations in Alberta give evidence of early Wisconsin ice-free corridors. This does not exclude the possibility, however, that these ice-free corridors may have existed during the first and second interstadial periods. Subsequent glaciation may have destroyed all easily observable evidence, particularly any accumulation of sediment from which samples could be obtained for use in pollen analysis.

Alberta, Canada. From the Grande Prairie-Lesser Slave Lake region, Hanson (1952) took eleven peat sections for study. From his investigations in this region it appears that owing to numerous large lakes, and possibly ice, forest development was retarded until post-Pleistocene times. In fact, muskegs may not have developed until subsequent to the warm, dry maximum. Hanson indicates, however, a vegetational invasion of subalpine Cordilleran forest, boreal forest and grassland, but is unable to fit it into a chronology.

Southeastern Alaska. Recently, peat sections have been obtained from southeastern Alaska for use in making pollen analyses. This research was undertaken by C. J. Heusser, who took 17 peat sections during the summers of 1950 and 1951 from the region between Ketchikan and Juneau. From these sections, obtained from muskegs, he was able to construct peat and pollen diagrams which have allowed him to make an interpretation of post-glacial forests, climate, and chronology.

The post-Mankato recession pollen profiles show the importance of lodgepole pine (Pinus contorta) as an early regional postglacial invader (Heusser, 1952). This tree appears to have been of general occurrence at this time, although today the lodgepole pine is primarily restricted to

muskeg areas, or occasionally to areas recently freed from ice.

Through the interpretation of his pollen profiles, Heusser has divided the post-Mankato time span into five periods (see Table I).

Period I from 8,000 to 6,000 years ago was cool and moist. Floristically it was represented by regional predominance of lodgepole pine. Period II from 6,000 to 5,000 years ago was characterized by a warmer and drier climate and almost complete replacement of lodgepole by Sitka spruce and later by the western hemlock-spruce climax. Period III is from 5,000 to 2,000 years of age. It is represented by continued warming and drying to a maximum (postglacial optimum). During this interval, western hemlock and spruce comprised the forest complex with hemlock constantly increasing. Period IV from 2,000 to 200 years ago marked the return of wetter and cooler climate. In the pollen profiles, Period IV reflects the disturbance of the climax forest by glacial advance. The coincident increase of pine is attributed to wetter conditions which brought about an expansion of muskeg at the expense of the forest. Period V is considered as the interval of the last 200 years when glaciers began to retreat (Heusser, 1952, p. 350).

Heusser obtains the age of 8,000 years since deglaciation of the earliest sites of pollen sedimentation, or at least since the sediments first began to collect, by certain comparisons with dated peat sections taken in Minnesota (Heusser, 1952, p. 349). His origin dates for the southeastern Alaska pollen bearing sediments were obtained by a comparison with the Cedar Creek Bog near Minneapolis, whose pine period has been dated by means of the radiocarbon method at about 8,000 years ago. Below the pine period in the Cedar Creek Bog is the peat of the initial spruce-fir period of an unknown age, but resting upon Mankato till. The Two Creeks deposit on the shores of Lake Michigan in Wisconsin has a C14 date of nearly 14,500 years, and is pre-Mankato; the Mankato has been dated at about 11,000 years (critical discussion of these dates is given in a later section). Since the radiocarbon date for the pine period at the Cedar Creek Bog is about 8,000 years and the Mankato is approximately 11,000 years, the intervening 3,000 years (approximately) have been accounted for by Heusser by allowing about 1,000 years for the recession of ice and about 2,000 years for the accumulation of one meter of eutrophic gyttja which formed during the spruce-fir period at the base of Cedar Creek Bog. Pollen sedimentation began at the Cedar Creek Bog at 10,000 years, or just as soon as the ice had retreated beyond the site of the bog.

Heusser does not automatically transfer this date (10,000 years) to the earliest pollen bearing sediments in southeastern Alaska without modification. His reason for reducing the number of years before applying them as a date for Alaskan sediments is as follows:

Owing to the position of Cedar Creek Bog, rather distantly removed from the Laurentide ice center on the Canadian shield,

the ice was presumably thinner and wasted away more rapidly than it did in Southeastern Alaska, where the nearby Cordilleran center resulted in a greater thickness of ice. Southeastern Alaska, as a result, was probably deglaciated at a later time, and the earliest postglacial pollen bearing sediments are dated at about 8,000 years (Heusser, 1952, p. 349).

Heusser also gives additional data to substantiate his estimate of 8,000 years for the age of the oldest southeastern Alaska sediments as shown by pollen analysis. This substantiation is in the form of estimates on sediment deposits in British Columbia and near Russell Glacier in the interior. He also makes comparisons with peat deposits in neighboring regions that have been dated by the C14 method.

Substantiation of the glacial advance of about 2,000 years ago, as postulated by Heusser, is obtained by a C14 date of forest debris overridden by the latest significant advance of the Mendenhall Glacier near Juneau. It was at this advance that Tide Lake near Stewart, British Columbia, is thought to have originated. Varved sediments have been estimated to date back about 2,000 years, when the lake was first formed by ice blocking during a period of advance, and by subsequent moraine building. This estimate of 2,000 years for a period of ice advance is utilized by Heusser to lend substantiation to his finding a glacial advance reflected in his pollen profiles in Period IV.

Kodiak Island. Pollen analysis of peat from two bogs on Kodiak Island has not been interpreted as indicating any chronology such as presented by Heusser in his investigations in southeastern Alaska. Evidence does show, however, "that the edge of the forest at Kodiak has advanced from a point many miles to the east of the location of these two bogs to a point a mile or more to the west of them during the accumulation of the upper three feet of peat" (Bowman, 1934, pp. 98, 100).

Aloutian Islands. Several hundred samples of humus, ash, till and charcoal have recently been gathered by Anderson and Bank (1952) from recently exposed stream banks and road cuts on Kodiak, Unalaska, Umnak, Atka, Adak, Tanaga, and Agattu Islands. Preliminary analytical investigation of Bank's two samples from Tanaga, and a sample from Unalaska, have already been undertaken by Anderson. Two entirely different plant communities are indicated by the two samples from Tanaga. One sample was from the upper part of the profile, the other from the lower section. The Unalaska profile is peculiar in that it is completely dominated by a fern. Anderson and Bank believe, however, that samples obtained from archaeological sites can be correlated with one another. This correlation, coupled with radiocarbon dating, should provide a picture of "climate and living conditions prevailing by the time of the ancient Aleut settlements" (Anderson and Bank, 1952, pp. 85-86).

Important to future investigations in the Aleutians is the fact that the samples obtained by those two investigators were from soils that were not composed of peats and mucks, but were from terrestrial deposits. Due

to the great amounts of annual rainfall in the Aloutians, combined with low temperatures, the pollen and spores have not oxidized. Possibly this same condition will be found in at least part of the Northwest Coast.

The non-archaeological profiles obtained by Anderson and Bank exhibit alternating bands of humus and ash, with some sand and occasional lenses of weathered till. The sand layers, which may vary from one inch to 30 feet in thickness, are usually noted close to the shore. When glacial till is noted it is near the bottom of the profile. "A ferruginous band, possibly caused by leaching from above, shows up in the middle soil zone and may prove to be a dependable point of departure for correlation" (Anderson and Bank, 1952, p. 84).

Summary. The work of the pollen analysts in northwestern North America has been closely integrated with the results obtained by the glacial geologists. These students of pollen analysis have presented what seems to be a very comprehensive picture of post-Wisconsin climate and vegetational succession, and present chronologies which have been at least partially substantiated by the radiocarbon method of dating. Except for a considerable difference in dates, the postglacial climatic sequence presented by Heusser for southeastern Alaska is in essential agreement with what has been presented by Hansen for the Pacific Northwest. The differences in dates may be partially explained by the fact that Hansen's area was released from glaciation much earlier than was Heusser's. This difference is observable even today, since glaciers are common in southeastern Alaska.

Heusser's postglacial climatic sequence begins with a cool and moist period from 8,000 to 6,000 years ago, followed by a period of continued warming and drying up to 2,000 years ago. From 2,000 to 200 years ago there was a marked return to a wetter and cooler climate. In the last 200 years there has been a very marked retreat of the glaciers.

The fundamental principles of pollen analysis appear to be simple and obvious at first glance. "Further consideration, however, reveals a complex of factors, many of them immeasurable and some even intangible, that influences the picture of forest succession and climate. The results and conclusions of pollen analysis, at best, can be interpreted in only general and relative terms" (Hansen, 1947, p. 6).

Both Hansen and Heusser seem to realize the manifold problems involved in making interpretations of their pollen investigations, and they therefore use data from other fields to aid in the substantiation of their findings.

#### Vulcanism

In the recording of geological stratigraphy and in the examination of peat profiles, during the course of preparing samples for pollen analysis, it is sometimes possible to obtain critical information concerning

vulcanism. Volcanic eruptions often leave evidence of activity in the form of ash strata observable in stratigraphic profiles.

Aleutian Islands. According to Bradley (1948) there were two pre-glacial and one postglacial stages of vulcanism in the Adak-Great Sitkin group of islands. Ash falling upon the retreating glaciers on Adak produced a gradation zone between the till and the ash blanket. This occurred during the earlier part of the last stage of vulcanism. This postglacial period of vulcanism was of considerable duration, with intervals of relative quiet which allowed vegetation to grow and to create soil horizons of humus on top of the ash. During this period of vulcanism there were four or five quiet intervals.

Alternating bands of humus and ash, with some sand and occasional lenses of weathered till, were noted by Anderson and Bank (1952) in the non-archaeological profiles obtained from islands in the Aleutian chain.

Cook Inlet. Hibben (1943) reports a three inch layer of ash near the top of a deposit of muck. The muck varied in thickness from four to twenty-two feet, and was superimposed upon a humus/occupation layer, and was capped by a peat deposit from one to six feet thick. Hibben suggests the likelihood that the ash came from nearby Mt. Iliamna, which still exhibits some volcanic activity.

Southeastern Alaska. The eruption of Mt. Edgcumbe near Sitka produced ash which was observed by Heusser (1952) in his Sitka sections. Since this volcanic ash appeared in his Period II, he has assigned an eruption date of about 5,500 years ago to this activity.

Volcanic ash in the vicinity of Wrangell has been found in the peat sections taken there. The depth of the ash in these sections suggests to Heusser that vulcanism has occurred within the last 500 years. In none of the peat sections studied by Heusser, however, was there any evidence of volcanic ash from the Mt. Katmai eruption of 1912. This is not too surprising, since this volcano is located on the Alaska Peninsula a considerable distance from southeastern Alaska, where the sediment columns were obtained.

Pacific Northwest. Hansen encountered volcanic ash in a number of the sediment columns he obtained in the Pacific Northwest. The volcanic ash strata in his Washington profiles are placed near the middle of the warm, dry middle postglacial stage (Hansen, 1947, p. 119). Ash from the Mount Mazama eruption was also encountered in a number of his sediment columns. This ash fall has subsequently been dated by the radiocarbon method at  $6,453 \pm 250$  years (Arnold and Libby, 1951, p. 117). Newberry Crater, which is about 70 miles northeast of Crater Lake (Mount Mazama) is thought to have erupted subsequent to the Mount Mazama eruption (Heizer, 1951, p. 23).

Excellent points of departure for archaeological correlation are provided by the volcanic ash strata recorded by Hanson (1953) along the

Alaska Highway in British Columbia, the Yukon Territory, and Alaska. Archaeological work of a preliminary nature undertaken by Johnson (1946) has already suggested the usefulness of volcanic ash strata in cultural correlation within this extensive area. The archaeological chronologies established in the interior regions in the future may be quite important in the interpretation of archaeological data found in the coastal regions and vice versa.

Ash from volcanic eruptions often spreads over a localized area, thus providing stratigraphic interruptions over only relatively small areas. This is well illustrated by the fact that the Mount Mazama and Newberry ash deposits are only regional manifestations. The significance of these ash deposits, however, is not to be minimized; the determination of dated sequences in local regions can be very helpful in providing some sort of a sequence for a much larger area, through various correlations.

Summary. Layers of volcanic ash occurring in stratified deposits are reported from the Aleutians, Cook Inlet, southeastern Alaska, and the Pacific Northwest. A number of these layers of volcanic ash have been tentatively dated by their relative position in the soil profile in which they were encountered, or by means of the radiocarbon method.

Postglacial vulcanism on Adak Island in the Aleutian chain appears to have been of a relatively extended nature, with intervals of quiet which allowed vegetation to grow on top of the ash previously deposited. The major ash deposit of this series was laid down in early postglacial times, while the remaining three (?) occurred at intervals throughout the postglacial deposition of soil. No strict dates, to my knowledge, have yet been applied to these ash deposits on Adak, or to the one noted by Hibben at Chinitna Bay on Cook Inlet.

The assignment of a date of 5,500 years to ash from an eruption of Mt. Edgecumbe near Sitka, and 500 years for volcanic ash near Wrangell, may be of considerable importance to future archaeology undertaken in those areas.

The C14 date for the eruption of Mount Mazama in Oregon has already been of importance, both archaeologically and by providing an excellent time marker in the sediments from which pollen samples have been obtained in the affected region.

The importance of having at least one stratum dated in any stratigraphic sequence is obvious, and has been noted by the pollen analysts, geologists, and archaeologists in the Pacific Northwest, and southeastern and southwestern Alaska.

#### Changes in land elevation

The raising of land in some regions of the Alaskan Pacific coast, and the lowering in others, may possibly have been a factor in, and/or

a consequence of, the advance and the recession of the glaciers in that part of Alaska. Twenhofel (1952) has given the maximum apparent change in altitude for a number of localities on the Pacific Coast of Alaska. The greatest of these is a rise of about 500 feet recorded in the Juneau area. Other changes in altitude are as follows: Lituya Bay to Yakutat Bay, raised 100 feet; Yakutat Bay, raised 47 feet; Icy Bay to Cape Suckling, raised 200 feet; Wingham Island, raised 100 feet; Copper River Delta, dropped 40 feet; Port Gravina in Prince William Sound, dropped 10 feet; Columbia Bay in Prince William Sound, dropped 5 feet; Anchorage and vicinity, raised 60 feet; Canvass Point at west end of Kodiak Island, raised 50 feet; Aniakchak on the Alaska Peninsula, raised 100 feet. Twenhofel is unable to ascribe a principal cause to these shore-line changes on the basis of available data. He is of the opinion, however, that orogenic movements may be the major cause. He also considers the factor of deglaciation, which could allow the land, once rid of its burden of ice, to rise. Also involved in this problem is the possibility of a general lowering of the sea level.

Some changes in shore-line elevations in the Juneau area have been dated by Heusser by means of the examination he has made of the peat sections obtained there. "From this information, the sea level lowering from 150 ft. to as low as approximately 10 ft. (at Lemon Creek muskog) occurred in less than 1,000 years, or between 6,000 and 5,000 years ago. High tide level has only been lowered about 10 ft. since, as evidenced from the difference between the base of Lemon Creek muskog (no. 9) and the present sea level" (Heusser, 1952, p. 347).

Heusser is inclined to believe that the peat sections from the other areas he tested reveal similar sea level trends.

Buddington (1927) states that there has been a succession of post-glacial uplifts in southeastern Alaska totalling at least 600 feet. Below altitudes of 200 feet, well-marked platforms and benches occur. A relatively recent and conspicuous platform is at about present high tide level. Buddington's observations were made south of Icy Straits and Cross Sound.

Five intervals of crustal movement, with corollary intervals of stability, which extend over the entire postglacial period of time in eastern North America, are used by Lougee (1953) as a framework for a chronology. He states: "Through the use of carbon-14, marine stages in eastern North America eventually may be found to correlate with marine stages in British Columbia and Alaska, or in such distant glaciated regions as Fennoscandia" (Lougee, 1953, p. 263).

Mathiasson (1927, pp. 8-10) has noted that the land is rising along the Arctic coast and that some of the Eskimo village remains lie considerably back from the present shoreline. He was unable to determine how rapidly this rise in land has occurred, but overturned stone pillars, presumably kayak supports, were found a considerable distance from the shore and 17 or 18 meters above sea level.

As with volcanic ash layers, marine terraces and similar manifestations of changes in shoreline elevations will be useful time markers if they can be fitted into a chronology of Pleistocene and post-Pleistocene events.

### Radiocarbon dating

Radiocarbon dates from Alaska are not yet very numerous, particularly from the area with which this study is concerned. Of particular importance to glacial studies are the dates obtained from vegetation overrun by glacial readvance in the post-Wisconsin period. Precise information concerning the collection of the samples used for C14 dating is not always obtainable. This condition makes interpretation of the dates more difficult than if one knew the circumstances of the collecting of the samples.

Because of the light they shed on the past climate of Alaska as a whole, C14 dates from other sections are reviewed, not just those from southwestern and southeastern Alaska.

Sample L-117K:  $400 \pm 150$ . "Wood from end moraine within 1,000' of the present front of Tustumena Glacier, Kenai Peninsula. Deposit represents one of the most recent glacial advances in the Cook Inlet area, following a warmer period during which Tustumena Glacier was much less extensive than at present" (Kulp, et al., 1952, p. 412). This date apparently temporally places the advance of a glacier which may correlate with the advanced position of many other glaciers noted by the first explorers to reach the coast of this region of Alaska. This sample demonstrates the conservative nature of this advance.

Sample L-117D:  $450 \pm 100$ . "Wood and peat 3' beneath surface in a peat layer interbedded with muck at head of Coffee Creek. Deposit indicates that accumulation of mucklike material has taken place during last few hundred years. The peat layer was formed at a time when the climate was not perceptibly different from the present" (Kulp, et al., 1952, p. 412). This date from the Seward Peninsula is self-explanatory and agrees with what is presented in Unit 9 of Table 1.

Sample L-106C:  $1,790 \pm 285$ . A sample of forest debris recovered from the recent recession of the Mendenhall Glacier near Juneau has a C14 date of almost 1,800 years (Kulp, et al., 1951, p. 568). Heusser (1953, p. 640) feels that this sample dates the whole valley segment of the "little ice age", in regard to the Mendenhall Glacier.

Sample L-117B:  $3,200 \pm 150$ . "The spruce root was deposited toward the end of the depositing phase of one of the numerous extensive alluvial fans that spread over Homer Beach..." on Kenai Peninsula (Kulp, et al., 1952, p. 412). Could the "end of the depositing phase" have coincided with the retreat of a manifestation of the Cochrane advance?

Sample L-106B:  $3,500 \pm 250$ : "Wood from bottom of muskeg in outwash, or possibly lateral moraine, of nearby Lemon Glacier" (Kulp, et al., 1952, p. 412). Lemon Glacier is near Juneau in southeastern Alaska. Housser (1953, pp. 637-640) tentatively considers this sample as dating the thermal maximum in southeastern Alaska. He reasons that conifers invaded the muskeg during the thermal maximum but lost out to sedges and mosses when the muskeg was reactivated in the following cooler and more moist period.

Sample L-117H:  $3,750 \pm 200$ . "Wood 6' beneath the surface in an organic layer at Eva Creek 10 mi. W. of Fairbanks. The deposit was formed at a time when the climate was slightly warmer than at present" (Kulp, et al., 1952, p. 412). This may be a reflection of the thermal maximum, or a cooling period just before the Cochrane advance (if the latter manifests itself in this region of Alaska).

Sample L-117N:  $3,800 \pm 400$ . "Spruce log near base of 5' peat section overlying lake silts deposited on till, near Boulder Point, Kenai Peninsula. Dating of the basal peat permits evaluation of rate of accumulation during the past 4,000 years in the Cook Inlet area" (Kulp, et al., 1952, p. 412). The previous warm period ending with the thermal maximum may have dissipated the water of the lake sufficiently to allow vegetation to grow which produced a deposit 5 feet thick over a period of about 4,000 years. The till underlying the lake silts may possibly be correlated with the last major glaciation in the region, the Mankato.

A radiocarbon sample collected from near the bottom of an 8-foot deep deposit near Anchorage has a date of about 5,000 years (Kulp, et al., 1951). This date suggests the possibility that this deposit accumulated at a rate of one foot in 600 years. The dating of sample L-117N (above) at 3,800 years implies an accumulation rate of about 800 years per foot. If these two rates of accumulation are applied to the thickest of Hansen's (1953) sediment sections in the Anchorage area (6.9 meters) the dates of 13,000 and 18,000 years respectively, are obtained. The implication made here is that deglaciation in the Anchorage area had progressed sufficiently to allow peat and sediment to accumulate between 13,000 and 18,000 years ago. This is, of course, assuming that the rate of accumulation at one muskeg can be applied with validity to a neighboring deposit. According to Hansen (1953, p. 538), however, the rate of peat accumulation may vary as much as 9 to 1 in a single region.

Sample L-117G:  $4,200 \pm 200$ . "Wood 6' beneath the surface in muck at Wilbur Creek near Livengood. The deposit was formed at a time when the climate was slightly warmer than at present" (Kulp, et al., 1952, p. 412). Livengood is a short distance north of Fairbanks. This date fits well into the thermal maximum, or possibly shortly after when the climate had become a little more cool.

Sample L-117C:  $8,350 \pm 200$ . "Wood 10' beneath the surface in interbedded peat and muck at Coffey Creek, a tributary of Kougarok River, Seward Peninsula. The deposit was formed at a time when the climate was

warmer than at present and is underlain by undated silt deposited at a time when the climate probably was colder than at present" (Kulp, et al., 1952, p. 412). This sample seemingly provides a date for the warming period after the last major glacial advance.

Sample W-49:  $10,560 \pm 200$ . A recently dated sample from McKinley Park "should date from just slightly after Riley Creek Glacier maximum advance" (Suess, 1954, p. 471). This sample probably dates the end of the last major glaciation.

Sample C-301:  $12,622 \pm 750$ . "Wood from 30 to 60 feet deep on Fairbanks Creek, Alaska. Associated with extinct animal bones" (Johnson [assem.], 1951, p. 9). If the association is primary and not one of redeposition of the extinct faunal remains, this date informs us that extinct forms of animals lived in central Alaska at the time of the last major glacial advance. This region of Alaska, however, did not come directly under the dominance of glacial ice, thus it could serve as a refuge for plants and animals. Along these lines Pówe (1953, p. 6) states that "Evidence from central Alaska reveals that extinct Quaternary mammals not only lived until fairly recently, but apparently lived in abundance during both glacial and interglacial intervals".

Sample L-117I:  $13,600 \pm 600$ . "Wood from fossil beaver dam in muck at Fairbanks Creek, 20 miles NE of Fairbanks. Deposit formed when climate was slightly warmer than at present" (Kulp, et al., 1952, p. 412). This warm period may represent a period preceding the last major glaciation.

Lignitic peat from the Eagle River north of Anchorage has a  $C^{14}$  date of about 14,300 years (Kulp, et al., 1951) and is thought to have formed during the Cary-Mankato interstadial. The glacial till overlying this peat deposit is thought to be of Late Wisconsin origin. A possibility, not brought out by Hansen (1953) in his studies in the Anchorage area, is that the glacial till may have been a local manifestation of the Cochrane oscillation as presented by Antevs (1953). It will be elaborated in a later section that Antevs does not consider the  $C^{14}$  date of about 11,000 years for the Mankato to be correct. If he is right then the date given for the peat from the Eagle River vicinity would not apply to the Cary-Mankato interstadial. At this time, however, there are not sufficient data even to be sure that the Cochrane oscillation was felt in this region of Alaska. This date does suggest, however, that some time after about 14,000 years ago there was a glacial advance in the Anchorage area. The implied dates above of 13,000 and 18,000 years ago for the beginning of peat accumulation suggest that the peat deposit lay outside of the area of the glacial advance of post-14,000 years ago, or that the implied dates were somewhat excessive.

Summary. The reliability of the radiocarbon method of dating has been discussed by numerous students, including Antevs (1953). Cognizance of this will be taken in a later section. Tentative acceptance of all the above  $C^{14}$  dates indicates a climate suitable for man for at least part

of the Pacific Coast of Alaska 4,000 years ago, or more. The climate apparently became more severe since that time, but not sufficiently to prevent human occupation of at least the Aleutians. A deep habitation site at Nikolski on Umnak Island in the eastern Aleutians has a C14 date of  $3,018 \pm 230$  years (average of two dates) (Johnson, 1951). This is the earliest date obtained by the C14 method for cultural material in the Pacific Coast region of Alaska.

Radiocarbon dates in other areas of the Territory indicate a suitable climate, in portions of Alaska, for aboriginal occupation as long ago as 8,000 years, and even longer.

Of importance in obtaining a postglacial chronology in the Pacific Coast region of Alaska is the tentative acceptance by Heusser of the C14 date of  $3,500 \pm 250$  years as the approximate date for the thermal maximum in southeastern Alaska. This date agrees with his previously estimated date obtained through examination of sediment columns and pollen analysis (Heusser, 1953, p. 639).

There simply are not enough C14 dates from the Pacific Coast portion of Alaska at this time to allow the presentation of any detailed chronology of Pleistocene and post-Pleistocene events. At this stage, the dates presented are so few and widespread that they exhibit a number of isolated events which are difficult to integrate with any certainty.

#### Vegetation as a time and climate indicator

Vegetation has been used by various students as a time and climate indicator, in an attempt to interpret aspects of postglacial history in a number of regions of Alaska. In the investigation of timberlines as indicators of climatic trends, Griggs (1937) feels that Alaskan climate has become mild so recently that the trees have not been able to keep up with the change and occupy all suitable territory. He illustrates this point of view by the following statement: "...we find a general belief among botanists, not very well supported by evidence, to be sure, but conforming fairly well with many facts, that tree growth is limited by the isotherm of  $10^{\circ}$  C ( $50^{\circ}$  F.) for the warmest month. It is interesting to observe that in southwestern Alaska the isotherm stands 250 miles beyond the edge of the forest (Griggs, 1937, p. 253)."

Kodiak Island. The rate of advance of spruce forests into Kodiak Island grasslands is of the order of one mile per century, according to Griggs. Application of this rate of advance to the evidence presented by Bowman (1934) might give a date for the beginning of the accumulation of the upper three feet of peat on the two bogs from which he obtained pollen samples on Kodiak Island. Since Bowman speaks of "many miles", only an approximation of the time involved could be reached on the basis of his published report (1934, pp. 98, 100).

The automatic application to other areas of the rate of advance determined by Griggs for Kodiak Island would not, however, be wise, unless investigation of the local conditions should warrant it. The rate of forest advance has been swifter than one mile per century for the Glacier Bay area, as demonstrated by Cooper (1939).

Glacier Bay, Southeastern Alaska. The principal subject of Cooper's (1939) studies in Glacier Bay is the contemporaneity of vegetational advance with the steady recession of the ice fronts during recent times. His work shows that the advance of vegetation is taking place in three stages. The first is the pioneer community in which a moss (Racomitrium canescens), two perennial herbs (Epilobium latifolium and Equisetum variegatum), the mat-plant (Dryas drummondii), and the prostrate willows are the most important species. The second stage is the willow-alder thicket, composed of various species of bushy willows and Alnus sinuata. The dominants of the final and climax phase are the Sitka spruce (Picea sitchensis), and the two hemlocks (Tsuga heterophylla and T. mertensiana). "These three communities are displayed in consecutive order upon the shores of Glacier Bay. The pioneer group is found in scattered fashion in the upper reaches, the willow-alder thicket clothes the slopes of the middle bay and the young climax forest mantles the mountain sides and forelands surrounding the lower bay" (Cooper, 1939, p. 133).

This study in Glacier Bay is of particular interest because it demonstrates the possible rate of growth of vegetation on a recently deglaciated area. Glacier Bay was entirely filled with ice about 200 years ago, according to historical and ecological evidence (Cooper, 1939, p. 132).

Cooper and Field (1936, p. 45) caution, however, that the absence of forest is no certain criterion of recent ice recession as willow-alder thicket or alpine turf-mat may have as great an age as a forest of mature trees.

#### Dendrochronology

Dendrochronology, another method of using vegetational growth as a time indicator, has been used to but a limited degree in the Pacific Coast region of Alaska. In northern Alaska, however, Giddings (1941, 1944, 1953) has used this method quite successfully. Tree growth ring counts have been made in southeastern Alaska by Lawrence (1950, p. 202) and Wentworth and Ray (1931, p. 886). Those growth ring counts were made primarily for the determination of minimal ages of terminal moraines of various glaciers, especially in the Juneau area.

It is scarcely to be expected that dendrochronological investigations will obtain a chronological sequence for any great distance into the past, e.g., the immediately postglacial period of time. It is possible, however, that a sequence of a thousand years, or more, may eventually be obtained for southeastern Alaska. This would be valuable for

climatological and archaeological interpretations for a considerable time beyond recorded history.

#### IV. Correlation Of Sequences

Evidence presented in the foregoing sections strongly suggests that sufficient work has not been done in archaeology, glacial geology, paleontology, ecology, and other related fields to present an accurate and comprehensive chronology of Pleistocene and post-Pleistocene events for the Pacific Coast region of Alaska. The chronologies which have been presented often are in agreement in their basic features, but usually show a discrepancy in the assignment of dates. From a study of these several chronologies, however, one is struck by the fact that they all note a climatic change closely comparable with Antevs' Neothermal (cf. Antevs, 1948). Their records show that there has been an amelioration in the climate since the last major glaciation. The warming and drying of the climate reached a climax and was followed by a more moist and cool climate, which has very recently changed to a warmer climate.

At this point it is worth while to review briefly the chronologies which have been given in some detail in the preceding sections.

Any chronology so far obtained by archaeology can be dismissed, since such a system has reference to the last few millenia and expresses only the terminal phases of a chronology of Pleistocene and post-Pleistocene events.

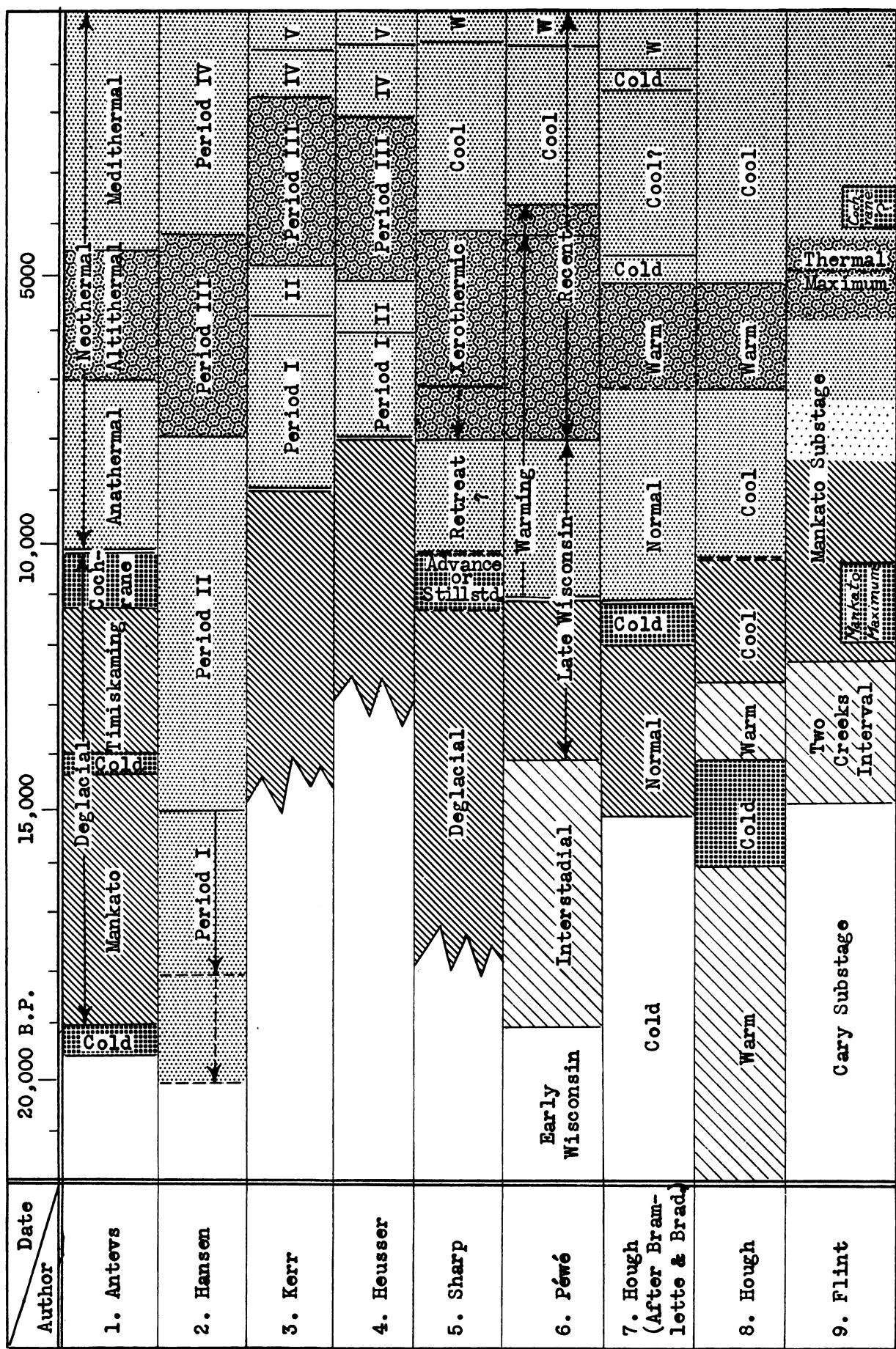
In Capps' investigations of the Alaska Peninsula and the Aleutians (1934), of Kodiak and adjacent islands (1937), and of the Southern Alaska Range (1935), he is inclined to speak in general terms. He does not attempt to present a refined chronology, but merely notes whether or not glaciation had taken place during the Pleistocene in these regions. It was his opinion that in Late Wisconsin times the glacial advance was quite similar to all the preceding ice advances that had taken place during the earlier portions of the Pleistocene. Pévé's exceptions to this view will be noted below.

From Capps' point of view, Pleistocene glaciation in the region under discussion was of an extensive nature with the various glaciations being of nearly equal vigor. In its broadest aspects this view is acceptable, but is not particularly useful when refinement is desired in order to present a detailed chronology.

Tarr and Martin's (1914) studies in Yakutat Bay present a four-fold system of glacial activity. They speak of the maximum glaciation occurring during the Pleistocene, followed by the great post-Pleistocene glacial recession. Following this recession an advance of lesser magnitude occurred. This advance ultimately began a retreat which ended with a readvance ca. 1905. This sequence of events, it must be remembered, was for

PLATE II

Table I  
Proposed Sequences  
Of Climatic Succession



the region of Yakutat Bay.

In the light of more recent work it is evident that Tarr and Martin's investigations lack certain detail. This is in no way a criticism of their excellent pioneer work. Despite the lack of specific details, the work by Tarr and Martin presents a sequence which, in its basic outline, is in partial agreement with recent studies in southeastern Alaska.

Investigations of the Wolf Creek glaciers, on the interior side of the St. Elias range, by R. P. Sharp (1951) allowed him to present a sequence of events quite similar to that of Tarr and Martin. During post-Wisconsin times there was an initial glacial retreat of great magnitude followed by a relatively recent growth. This, in turn, was followed by another retreat. Sharp (1951, p. 104) calls the post-Wisconsin period of warming and drying climate the post-Wisconsin xerothermic interval in order to avoid the terms "post-Pleistocene" and "postglacial". It is Sharp's choice to take 7,000 to 8,000 years ago as the beginning of this period, and 4,000 years ago as the approximate end (see Table 1). This terminal date is apparently obtained from an estimate of the age of climax forests overwhelmed by glacial advance, subsequent to the end of the post-Wisconsin xerothermic interval. The date of 8,000 years is an estimate of the probable time involved in the deglaciation process at the end of the Wisconsin period. That is to say, by about 8,000 years ago the deglaciation period was at an end and the xerothermic interval was beginning.

Sheldon Judson (1946) reports a late-glacial and postglacial sequence for Adak Island in the Aleutian chain. The sequence is manifested by a slightly weathered till which is probably Wisconsin in age, and a marine terrace, followed by three deposits of wind-blown sand. Each sand deposit has a well-developed soil zone. Cultural remains were noted in the two top soil zones.

Additional work on this island by Bradley (1948) also calls attention to the movement of sand. Bradley believes that the sand became stabilized in postglacial times due to an increase in moisture, a dying down of volcanic activity, and an increased growth of vegetation.

Neither Judson nor Bradley express their geological events in terms of a temporal scale. The stabilization of the sand by a more moist climate suggests the possibility of an equation with the end of the dry period called by Sharp the post-Wisconsin xerothermic interval. Using Sharp's dates this would put the beginning of the period of sand stabilization at approximately 4,000 years ago.

Utilizing data from existing literature, including that by Muller (1952) for the Naknek district, Karlstrom (1952) for the Cook Inlet area, and Krinsley (1952) for the Kenai Peninsula, Troy L. Péwé (1953) has presented a review of Pleistocene and post-Pleistocene events and climatic changes in Alaska. Also available to him was information on studies in progress by personnel of the U. S. Geological Survey. By virtue

of the fact that he has access not only to the published literature but to data on work so recent that it has not yet been published, Péwé's review can be considered the most up-to-date work presented on this subject. He makes a two-part division: the Wisconsin period for which the most abundant and clearest information is available, and the pre-Wisconsin period for which there is less detailed information. Following Hough (1953), Péwé (1953, p. 1) dates the Wisconsin as "the last 80,000 years or so". Post-Wisconsin time is apparently dated sometime after about 10,000 years ago (Péwé, 1953, p. 8).

Péwé (1953, p. 9) speaks of the existence of at least two prominent pre-Wisconsin glaciations, separated by a warm interval. In the Seward Peninsula of western Alaska this interval was much warmer than anything recorded in Wisconsin or post-Wisconsin times. Throughout Alaska, both glaciated and unglaciated areas, these two cold periods have left a record. According to Péwé the intervening warm period was warmer and lasted longer than the post-Wisconsin period.

Referring to late Wisconsin glaciations in Alaska, Péwé states that they "were restricted to mountain valleys in northern ranges; however, in southern ranges glaciers extended beyond the mountains and spread terminal bulbs in the lowlands" (1953, p. 9). Significantly, he also states that in general the glaciers of late Wisconsin time advanced a shorter distance and were smaller than previously believed. In a preceding section of this paper it was pointed out that Capps' (1935, pp. 77-78) interpretation of the extent of glaciation in Cook Inlet in late Wisconsin time was excessive, in view of the results of Karlstrom's (1952) recent investigations in the region.

The post-Wisconsin period is divided by Péwé into a warmer and perhaps drier period of 3,500 to 4,000 years ago, and a colder and probably wetter period that reached a climax from 200 to 400 years ago. The warm period would seem to correspond to Sharp's post-Wisconsin xerothermic interval, although Péwé does not give a beginning date for it. He does date the latest major glaciation at 11,000 years ago (Péwé, 1953, p. 10). His warm dry period would, therefore, come after this date.

A section of Péwé's tentative correlation of glacial sequences in Alaska is given in the following (Péwé, 1953, p. 14).

	Kenai Peninsula	Alaska Peninsula
<u>Recent</u>	<u>Unnamed</u>	<u>Unnamod</u>
	Nikolai Creek	Iliuk
<u>Late Wisconsin</u>		
	Naptowne (older than 8,000 years, younger than 14,000 years)	Brooks
<u>Early Wisconsin</u>	Swan Lake (older than 18,000 years)	Mak Hill
<u>Pre- Wisconsin</u>	Caribou Hills	Johnston
	Mt. Susitna	Earliest

These named periods for the Kenai Peninsula and the Alaska Peninsula are also tentatively correlated with other regions of the Territory.

Kerr (1936) postulates a warm period with attendant glacial recession in northern British Columbia and southeastern Alaska, beginning approximately 5,500 years ago and continuing until about 1,500 years ago. He obtained the date of 4,500 years from a computation of the rate of advance of the deltas of the Stikine and the Taku Rivers. Between 5,500 and 4,500 years ago the climate was moderating, while from 4,500 to 1,500 years ago the climate was warmer than at the present time. "Between 9,000 and 4,500 years ago conditions of intense alpine glaciation prevailed" (Kerr, 1936, p. 681). The date of 9,000 years was accepted from a date presented by Antevs (1928) concerning the retreat of the ice sheet in eastern North America. The sequence of events presented by Kerr is in keeping with those presented by other investigators (see Table I).

Sequences of Pleistocene and/or post-Pleistocene events and chronologies covering these events have been presented not only by geologists but by palynologists as well. Hansen's (1947) investigations in the Pacific Northwest have allowed him to present four periods from the last glacial maximum. Period II was a period of increasing warmth and dryness which lasted from 15,000 to 8,000 years ago. Period III reached a stage of maximum warmth and dryness by 4,000 years ago. Period IV, from 4,000 to present, exhibited a return to a more moist and cool climate.

Heusser (1952), on the basis of his pollen analyses, has divided the post-Mankato period into five sections. Period I from 8,000 to 6,000 years ago was cool and moist. Period II, from 6,000 to 5,000 years ago, was a time when the climate was beginning to become warm and dry. Period III, from 5,000 to 2,000 years, saw a continuation of the warming and drying to a climax. During Period IV, 2,000 to 200 years ago, there was a return to a wetter and cooler climate. Glaciers retreated during Period V, which he dates as beginning 200 years ago.

Although the sequence of events presented by these two palynologists correspond quite well, the dates they give these events do not. Hansen tends to follow the chronology presented by Antevs (1948) while Heusser accepts the recent radiocarbon date of about 11,000 years for the Mankato (Johnson, 1951). Heusser uses the C<sub>14</sub> date as a point of departure for his chronology, after some modifications. More will be said later concerning Antevs' chronology and the radiocarbon date for the Mankato.

The utilization of vulcanology, changes in land elevation, and vegetation as time and climate indicators in the Pacific Coast region of Alaska have not as yet been developed sufficiently to give any extensive chronology of Pleistocene and post-Pleistocene events. The data presented by these studies may be considered at the present time to be of a supporting nature to those chronologies developed by other means.

Since the various chronologies presented in this paper tend to bear out Antevs' presentation of a three-part climatic sequence for that period of time which he calls the Neothermal, it seems justifiable to attempt to chronologically equate the elements of these separate sequences with the corresponding elements of Antevs' Neothermal period (see Table I). In Table I eight chronologies are marked so as to show my interpretation of them relative to Antevs' Neothermal periods. It will be noted that Hansen's Periods II and III are considerably in excess of Antevs' Anathermal and Altithermal periods. This may be explained by the fact that Hansen has taken the estimate of 18,000 to 20,000 years ago as the end of the Pleistocene (Hansen, 1947, p. 113), and since the location of sites from which his sedimentary columns were obtained are, for the most part, outside of the range of continental glaciation, it is expectable to get a record of vegetational growth relatively sooner after the beginning of the post-Pleistocene deglaciation than in those areas originally covered by continental ice. In other words, it is expectable for local glacier systems to diminish and die, and for vegetation to extend over the once glaciated areas, much earlier in the Pacific Northwest than in northern British Columbia or southeastern Alaska. The difference could be in terms of thousands of years.

The difference of 1,000 years between Antevs' Altithermal and Hansen's Period III cannot easily be explained, except to point out that Hansen's dates are only estimates. Since they are not based directly upon varve counts, or upon C<sub>14</sub> dates, a shift to 1,000 years later would not seem to make any significant difference in the chronology. Antevs (1948, p. 175) also points out that the age of maximum temperature need not have been

fully contemporaneous in various parts of the world.

In Table I Kerr's Periods I and II have been correlated with the Anathermal, even though Period I is supposed to be a period of intense alpine glaciation. Since Period I is followed by a warm and dry period, the two periods are equatable with the Anathermal, which begins cool and moist, but grades into a warm and dry climate. Kerr's Period III, in which the warm and dry climate reached a maximum, clearly corresponds to Antevs' Altithermal. The rather extreme discrepancy in the dating of these two periods, however, presents a problem. This difference in dates might be explained by the difference in geographic location, and Kerr's lack of any precise method of obtaining his dates. It is expectable, in my opinion, to find a lag in deglaciation in northern British Columbia and southeastern Alaska behind deglaciation in central and eastern North America. This factor is elaborated upon by Heusser and is presented below.

The use of the C<sub>14</sub> date of about 11,000 years ago for the Mankato has allowed Heusser to claim a lag in deglaciation in southeastern Alaska behind that of the retreat of ice toward the Laurentide center. This was done on the ground that the Cordilleran center was close to southeastern Alaska and was much thicker than the edge of the Laurentide sheet in eastern North America. The point is that the thin ice cap would retreat at a greater rate than the thick Cordilleran cap. Heusser estimates that it would take about 3,000 years before pollen sedimentation could begin in southeastern Alaska after the Mankato peak. If Antevs (1953, p. 219) is correct in dating the Mankato at about 19,000 years ago, Heusser must be dealing with some glacial advance subsequent to the Mankato. It might be that, instead of speaking of the Mankato, he is in reality considering a local manifestation of the Cochrane advance, which Antevs dates at slightly more than 10,000 years ago. Only continued investigations in the area can resolve this problem.

Heusser's chronology presents another problem when an attempt is made to correlate his Period III with Antevs' beginning date for the Medithermal. Heusser's Period III ends 2,500 years after Antevs' Altithermal comes to an end and the Medithermal begins. It is not difficult to visualize the lag in deglaciation but it is less easy to understand why there should be such a lag in a return to a cool and moist climate. Heat and dryness are not unaffected by a reversal of climate to the same degree as is a tremendously thick ice cap. This is particularly true when the change to a warmer and drier climate (i.e., the Anathermal) came about slowly, while the change to a more moist and cool climate (i.e., the Medithermal) was much more rapid. It is, therefore, difficult to see how Heusser's Period III could have continued to be warming and drying 2,500 years after the maximum had been passed, as determined by Antevs and represented by his Altithermal period. It does not seem likely that southeastern Alaska should continue to have a warm, dry climate while the remainder of North America had long since undergone a reversal of temperature and moisture conditions. In the light of the foregoing, it would seem advisable for Heusser to review

his Period III and see if it could not be reduced to a duration of 1,000 years, or less. This would extend his Period IV back in time and allow it to coincide temporally with Antevs' Medithermal.

Heusser (1953) interprets the C14 date of  $3,500 \pm 250$  years (Kulp, et al., 1952) from wood buried in a muskeg near Juneau as dating the thermal maximum in southeastern Alaska. According to Heusser this date does not, however, indicate the termination of this period. If one assumes, nevertheless, that this C14 date expresses the approximate end of the thermal maximum, then the beginning of Heusser's Period IV, if set at this date, more nearly coincides with the beginning of Antevs' Medithermal. The beginning date for this period, according to Heusser, is not provided by the C14 date of  $1,790 \pm 285$  years (Kulp, et al., 1951) for buried wood from the outwash of the Mendenhall Glacier; it merely dates the valley segment of the "little ice age" for this vicinity.

If the C14 date of about 3,500 years ago is accepted as the beginning of Heusser's Period IV, there is still a gap of about 1,000 years between it and the beginning of the Medithermal. One cannot expect an exact correlation, since local climatic conditions in southeastern Alaska at the present, and in the past, could account for a discrepancy of this magnitude. That local climatic conditions must be taken into account is attested by the present extent of glaciation in southwestern and southeastern Alaska. This is, in fact, probably one of the major considerations which must be kept in mind when one attempts to make correlations of the past climates of the Pacific Coast region of Alaska with other regions of the northern hemisphere.

The chronological outline of Wolf Creek glacial history presented by Sharp (1951, p. 100, Table I) closely follows Antevs' division of the Neothermal. He speaks of a late Wisconsin glaciation followed by a latest Wisconsin, or possibly post-Wisconsin advance. It is likely that these glacial advances represent manifestations of the Mankato and Cochrane advances, respectively. It can be assumed that the period between corresponds to Antevs' period of deglaciation. If, however, the two glacial periods with a deglacial interval are so equated, the period between the later glaciation and the warming and drying period (the xerothermic interval) must be accounted for. It can be accounted for, however, in the same way that Heusser accounts for a lag in the initial postglacial pollen sedimentation of his Period I, as has been described in a foregoing section. Sharp's xerothermic interval is thus equatable with Antevs' Anathermal and Altithermal. If the lag of several thousand years in deglaciation is accepted, Sharp's period agrees temporally quite well with Antevs' first two periods of the Neothermal. The cool period following the xerothermic interval is in near temporal agreement with Antevs' Medithermal period.

The chronology presented by Péwé (1953) dates early Wisconsin as older than 18,000 years, and the early phase of the late Wisconsin as being older than 8,000 years, and younger than 14,000 years. The recent period then would extend back to about 8,000 years ago. Péwé considers

the latest major glaciation to have occurred about 11,000 years ago; subsequent to that time the climate was warming until about 4,000 years ago, when it became cool. Pówe thus ends the Wisconsin at about 8,000 years ago but begins the period of warming after the last major glaciation about 11,000 years ago. His warming period equates rather closely with Antevs' Anathermal and Altithermal, while his cool period equates closely with the Medithermal. The fact that there is a difference of about 3,000 years between the beginning of Pówe's warming period and Heusser's period of initial pollen sedimentation may be explained as before. The climate could be warming slowly for several thousand years before the ice thinned and retreated sufficiently to allow vegetation to grow and produce pollen for a sedimentary record. The geographic location of the pollen sediment stations would, of course, have some bearing upon when the ~~area~~ investigated was first capable of producing a pollen record. It has been pointed out in a previous section that this was possible, according to Heusser, about 8,000 years ago in southeastern Alaska. We have also seen that the postglacial warm period began shortly after 11,000 years ago, according to Pówe. The fact appears to be that the two phenomena need not be mutually exclusive for areas such as southeastern Alaska. The problem with this reasoning, however, is that one must accept the date of 11,000 years for the date of the last major glaciation. Since Pówe apparently accepts this date and does not consider Antevs' date of 19,000 years for the Mankato, the reasoning seems sound. If, however, one accepts 19,000 years ago as the date of the last major glaciation, he must account for about 11,000 years before Heusser's pollen sediments begin collecting. This can be done by equating the "last major glaciation" mentioned by Pówe and the "later glaciation" noted by Sharp with some manifestation of Antevs' Cochrane interval. If the Cochrane can be equated with a similar event in Scandinavia (Antevs, 1953), it seems possible to note the equivalent in Alaska. Possibly current observers have mistaken this interval for the Mankato.

In Table I two chronological sequences have been added to the list in order to provide a wider perspective on the ordering of climatic events in post-Wisconsin times. One is a record of climatic events obtained from sediment core samples taken from the ocean floor in the North Atlantic (Bramlette and Bradley, 1940). The other is a climatic record obtained in the same manner from the Southeastern Pacific (Hough, 1953). Hough (1953, Fig. 3) has made a comparison of these two records which I have presented with little modification in Table I.

The correlation between these two records is quite consistent both as to chronology and temperature. The record of the last 10,000 years for both series apparently can be divided into three component elements which closely correspond temporally and climatically to the three parts of Antevs' Neothermal period. Since these two records obtained from the ocean floor come from points greatly distant one from the other, their relatively close correlation in regard to time and type of climate for the last 10,000 years is significant. These records demonstrate that climatic changes may be synchronous over great distances. These records give support to the other sequences discussed in this paper, i.e., those

sequences having a correspondence with Antevs' three-part Neothermal period.

For a future refinement and substantiation of these two records it seems imperative, however, that a series of ocean bottom sediment core samples be taken in various strategic places throughout the oceans of the world.

The presentation of a precise chronology of Pleistocene and post-Pleistocene events in the Pacific Coast region of Alaska depends upon which authority one chooses to endorse. It is apparent that a system based on the C14 date of about 11,000 years for the Mankato advance is not compatible with that system based on Antevs' determination of the Mankato at about 19,000 years through varve counts and compilations. One may choose the radiocarbon findings, or one may accept the reliability of varve counts and compilations.

It has been my personal inclination to use Antevs' Neothermal period with its three-part division as a method of delimiting the post-Pleistocene period, because I find its divisions useful for descriptive purposes, even though some of its limitations can be recognized. Quimby (1954) also uses Antevs' three-part Neothermal period for orientation and descriptive purposes, but he does not consider it to be post-Wisconsin in time as evidenced by his discussion of "Wisconsin glaciation" up to 500 B. C. (Quimby, 1954, p. 329). In this latter respect he follows Flint's (1947, pp. 208-210) ideas with regard to the extent of the Pleistocene into recent times. I feel that Quimby's compromise is a good one for the purposes to which he has put it.

From a variety of reports in a number of related fields, a chronological sequence of climatic events has been pieced together for the Pacific Coast region of Alaska (Table 1). In basic outline the climatic events agree with the sequence presented by Antevs, especially for his Neothermal period. Most authorities agree that a glacial advance occurred in northeastern North America about 10,000 years ago, and that this same cold period was noted in other parts of North America including the West and Northwest. This same period of glacial advance and/or colder climate has been noted in Europe as well. It has been dated by the radiocarbon method (Libby, 1952, pp. 675, 678-679; Arnold and Libby, 1951, pp. 117-118) and except by Antevs is generally considered as dating the Mankato period of glacial advance. Antevs recognized a cold period at about this time, but he associates it with the Cochrane advance and relegates the Mankato to a time of about 19,000 years ago.

As noted above I have presented an eight-unit table of post-Wisconsin climatic events and chronologies. The table is so constructed as to attempt an equation of the events and chronologies of seven of these units with the chronology of events presented by Antevs. Differences in the chronologies can be accounted for, at least in part, by the fact that the investigators are often reporting from distinct geographical regions, and none but the basic elements of the chronologies could be

expected to approach agreement. All-in-all, however, the relationships of the various sequences to each other are clearly apparent and are meaningful. In other words, climatic changes can be demonstrated to have occurred throughout widespread areas at about the same time. Once this is demonstrated it is possible to transfer certain knowledge from known areas to lesser known regions. That is to say, known glacial chronologies and events of northeastern North America or Europe can, for example, be equated with considerable surety with similar events in northwestern North America. This is useful for obtaining a comprehensive picture of post-Wisconsin contemporaneous climatic activities in all regions of North America.

It has been disturbing in my investigations to note a major difference of opinion between two of the leading authorities on glacial geology--Ernst Antevs and Richard F. Flint. It has been disturbing because if one intends to temporally correlate certain climatic events in the Great Lakes region and northeastern North America with events in the Pacific Coast region of Alaska, the dates those men assign to the Mankato, for example, show a discrepancy of about 9,000 years! If one is interested in that region of Alaska a difference in time of that magnitude is serious. Simply stated, Antevs dates the Mankato and the later Cochrane advances by means of varve counts and compilations (Antevs, 1953). His correlation of the Cochrane advance with the Fenno-Scandian advance of the Younger Dryas-Salpauselka ago, which has been dated by varve counts as ending 10,150 years ago, seems reasonable in the light of the data he presents. His dates and correlations, however, can express only the degree of accuracy one can obtain through use of this system. Antevs (1953, pp. 225-226) believes that a careful and competent investigator can obtain excellent results from varve analysis and correlation. Flint, on the other hand, is somewhat more reserved and states: "The whole matter of the reliability and usefulness of varve correlation is at present in an unsatisfactory state" (Flint, 1947, p. 397). It would seem that it is here we find the basic difference of opinion between these two men with regard to dating the Mankato substage and the Cochrane advance.

Those students who consider the Mankato to have a date of about 10,000 years, instead of the 19,000 proposed by Antevs, obtain one of their dates from the Two Creeks forest bed in Wisconsin, which has a radiocarbon date of approximately 11,000 years (Arnold and Libby, 1951, pp. 117-118). The Two Creeks interval was a warm period between the Cary substage and the Mankato substage of the Wisconsin. Antevs has the following to say about the C14 date for the Two Creeks bed:

The date of 11,000 implies that the maximum was a correlative of the Fenno-Scandian moraines (the Salpauselka stage). It implies that the North American ice sheet still extended into the Great Lakes when the European ice sheet had entirely disappeared, for this ice did so 2,000 or more years after it departed from Salpauselka II, judging from the fact that it had withdrawn to Stugun, [450 km. north of Stockholm] 1,364 years after that departure. Finally, since 5,025 varves have been

counted between the Valders maximum and the Cochrane stage and since estimates raise the minimum duration of the interval to 7,700 years, there would be less than 3,300 years left for the Cochrane oscillation, the subsequent 575-miles retreat to the Labrador ice center, and the time since the center became ice-free. Since all of these implications are unreasonable, we conclude that the radiocarbon date of the Two Creeks forest bed cannot be correct" (Antevs, 1953, p. 219).

With respect to the Two Creeks interval, Quimby interprets three radiocarbon dates of wood obtained from glacial deposits on Skunk River, Iowa, and one of wood from sediments of Lake Agassiz near Moorehead, Minnesota (samples C-664, C-653, C-596, and C-497 respectively) as placing "The Mankato moraine and the Des Moines lobe... earlier than the Valders climax, and earlier than the end of the Two Creeks interval as registered in Wisconsin" (Quimby, 1954, p. 320). One of the samples (C-664) by this interpretation is about 3,000 years older than the Two Creeks sample (C-497). This is a rather great span of time considering that the Two Creeks interval is generally thought to precede the Mankato. Another sample (C-596) considered by Quimby to be of Mankato times is, however, only about 500 years earlier than the Two Creeks sample. A third sample (C-630) considered to be of Mankato times is about 600 years younger than the Two Creeks sample. We thus see that by Quimby's interpretation the Mankato substage (or portions of it) antedates the Two Creeks interval by as much as 3,000 years, and postdates it by as much as 600 years.

As noted above Antevs and Flint are not in agreement on the date for the Cochrane advance, which occurred sometime after the withdrawal of the Mankato ice. Flint speaks of peat and inorganic sediments found between two tills in the area southwest of James Bay (on Hudson Bay). He suggests that the overlying till was deposited by a very late readvance of the northward shrinking glacier margin and that it "may date from late in the Wisconsin age" (Flint, 1953, p. 914). It will be recalled that Flint considers the Wisconsin to extend up until present time. It can be supposed that this top till is a manifestation of the Cochrane advance. Flint would apparently give a tentative date of about 2,000 years ago, or less, for the age of this till (Flint, 1953, pl. 3). Antevs, on the other hand, has given a date of about 10,000 years ago to the Cochrane advance.

In line with the basic difference of opinion between Antevs and Flint as to the date of the Mankato and Cochrane periods of glacial advance, the following quote from Flint is given:

Radiocarbon dating has established beyond reasonable doubt the equivalence of the Two Creeks peat horizon in the Lake Michigan region to the widespread Allerod horizon in Europe. It follows that the climatic fluctuation that resulted in the Allerod-Two Creeks interval of relative warmth was common to both North America and Europe. The basis of belief that Pleistocene

climatic changes in general were contemporaneous over both continents is thereby strengthened.

Comparison of stratigraphic sequence within the Wisconsin glacial stage in America with those of the Newer Drift in Britain and the Weichsel drift in Continental Europe, its presumed equivalents, reveals striking similarities. These constitute a reasonable basis for the belief that the same sequence of glacial substages characterizes both continents. It is likely, therefore, that the same series of climatic fluctuations affected both continents simultaneously during the Wisconsin glacial age (Flint, 1951, p. 1438).

Antevs would not quarrel with the fact that the same sequence of glacial substages can be observed both in Europe and in North America. However, since he believes the Cochrane to correlate with the Fenno-Scandian advance of the Younger Dryas-Salpauselka age it would be impossible for him to consider the C<sub>14</sub> date for the Two Creeks bed to be correct. If he considers this radiocarbon date to be in error he cannot equate the Two Creeks bed with the European Allerod age. What he actually does is to place the Allerod at a point in time shortly before the Cochrane (as he defines the Cochrane).

That there has been some uncertainty as to the validity of the C<sub>14</sub> dates for the Two Creeks beds and other similarly derived geological dates, is demonstrated by the recent release of a series of radiocarbon dates by the U. S. Geological Survey. Suess (1954, p. 467) states specifically that "The ages of most of the samples were determined for the purpose of dating pre-Mankato substages of the last Glaciation". Presuming that the deposits from which the samples have been collected are correctly geologically identified, the C<sub>14</sub> dates (e.g., W-88, W-92, W-91) suggest a date of 18,000 to 21,000 years ago, or longer, for the Tazewell substage. Late Cary (the following substage) samples (W-57, W-58) from different counties in Indiana have the same C<sub>14</sub> date of slightly more than 12,000 years.

The U. S. Geological Survey has also made two determinations on wood obtained from the type locality of the Two Creeks forest bed, in order to make a "direct comparison with samples from the Allerod-Younger Dryas boundary in Denmark" (Suess, 1954, pp. 471-472). The average date of the two samples is 11,307±100 years which is almost identical to the average of five samples dated by Arnold and Libby (1951, pp. 117-118) from the same organic deposit. If the Two Creeks bed has been correctly identified as to its geologic position the case appears quite strong in favor of the date of 11,000 years for the age of this bed and, thus, for the interval just preceding the Mankato substage.

The Geological Survey has also tested "two samples from the pollen-zone boundary II/III denoting the beginning of the colder climate of the Younger Dryas and the end of the relatively warm Allerod fluctuation" in Denmark (Suess, 1954, p. 472). Their results are closely comparable to

those of the Danish Geological Survey (Anderson, et al., 1953, p. 8). From these investigations it would seem that there is a climatic and temporal correlation between the Two Creeks Forest bed deposits and the Danish Allerod-Younger Dryas boundary as revealed by the radiocarbon dates.

In accepting C14 dates for geological dating one must also be aware that not all of the dated samples find close agreement with the geological determinations. An honest investigator must not accept only those dates which "fit" but he must also be aware of those dated samples which do not "fit". For example, a sample collected near central Ohio in Licking County has a date of  $16,100 \pm 850$ . "All indications are that the logs were swept up and deposited by the Tazewell advance and the surface covered with thin outwash from the Johnstown Moraine in Cary times" (Libby, 1954, pp. 13-14, sample C-893). The recency of this date suggests that either the sample was improperly identified as to geologic placement, or that the sample was erroneously dated in the laboratory. Probable errors such as this are to be expected in the disciplines of glacial geology and radiocarbon dating, because of inherent complexities. However, one must be aware of the fact that such errors are apt to occur, and that one should use considerable discretion in the use of the radiocarbon dates. The casual investigator from outside the field of glacial geology can hardly hope to make precise interpretations of dates for which he has but slight data.

What has been done in the immediately preceding sections is to show that there is not complete harmony between two authorities on matters of glacial geological dating. One is inclined to agree with Quimby who states that "geologists are just as confused and confusing as archaeologists" (Quimby, 1954, p. 319).

Possibly the presentation by Quimby (1954) is a good example of the use of the radiocarbon dates (and other data), with the three divisions of the Neothermal, to provide a sort of synthesis of the two systems. The last, or ninth unit of Table I is along the same lines as Quimby's exposition, and is adapted after Flint (1953). In viewing unit 9 (Table I) it will be seen that the Cary substage and the Two Creeks interval temporally replace Antevs' Mankato deglacial period. The advance of the Mankato after the Two Creeks interval temporally replaces Antevs' Cochrane and relegates it to a period of about 2,000 and 3,000 years ago. But from the end of the Mankato climax on to the thermal maximum, the amelioration of climate can be correlated with Antevs' Anathermal and Altithermal. The Cochrane advance and subsequent cool (modern) climate fit with Antevs' Medithermal.

In adding the ninth unit to Table I the consequent correlation between it and the four Alaskan units (titled Kerr, Heusser, Sharp, and Pówe) can be observed. For those favoring the Antevs system correlations can be made with it from the top down; and those favoring a system based upon the radiocarbon dates (and other data) may view the chart from the base upward (see Table I).

In conclusion it is possible to state with assurance that glacial geological investigations in the Pacific Coast region of Alaska, like those in palynology and archaeology, are in their infancy. Even Péwé, with all available published work at his disposal, and with access to as yet unpublished work, is not able to produce any precise chronology of Pleistocene and post-Pleistocene events for the Territory of Alaska. There can be little doubt, after having reviewed considerable recent literature concerned with this problem, that we are now on the threshold of obtaining a much more complete and coordinated sequence of these events for Alaska, and for North America as a whole. Until this goal is attained, however, we must utilize present information to form tentative chronologies.

## V. Conclusion

The original problem with which this paper was concerned was to attempt to obtain a chronology of climatic events in late glacial and post-glacial times, in order to suggest when it was possible for human beings to take up residence in southwestern and southeastern Alaska. The results of investigation have demonstrated that the sequence of climatic events in the various regions of the Pacific Coast of Alaska has been the same in its broader aspects, but the chronology of these events has not always been closely comparable. Differences in the chronologies can be ascribed primarily to the difference in latitude of the regions for which the various chronologies have been obtained. An example is the difference in age of the earliest post-Wisconsin pollen sediments obtained outside the limit of continental glaciation in the Pacific Northwest, as compared to those obtained near Juneau, in southeastern Alaska. According to the palynological authorities for the respective regions, the Pacific Northwest began its record of pollen sediments about 7,000 years before those of the Juneau area.

The importance of latitude in the preservation of accumulations of glacial ice is clearly demonstrated on the Pacific Coast of North America by the tremendous residue of ice still in existence between Latitudes 58° and 62° in Alaska and Canada. In comparison, the Pacific Northwest area of the United States exhibits glaciers on only a few large mountain peaks. This is true even though the precipitation for each season in both regions is closely comparable.

Once it is evident that differences in time of deglaciation on the Pacific Coast of Alaska and British Columbia are due primarily to latitude, it becomes much easier to understand why it is necessary to construct a separate chronological sequence of climatic events for each of the various regions involved.

There can be little doubt that the pattern of the previous deglaciation in post-Wisconsin times was identical, or very closely comparable, to the present pattern in southeastern and southwestern Alaska, as

exhibited by the extent of glaciation currently observable. The farther southwest, and southeast, one goes along the coast from the vicinity of Prince William Sound, for example, the fewer glaciers and ice fields one can see. As one might expect, the more southerly regions were first to become free of the Wisconsin ice, while the region farthest north on the Pacific Coast of Alaska is still heavily covered with fields of glacial ice.

It must be remembered, however, that the present ice fields in the Pacific Coast region of Alaska are not remnants of the Wisconsin advances, but are the residue of a relatively small ice advance of approximately 3,000 years ago. This period of ice advance is sometimes referred to as the "little ice age". Before this advance, the glaciers in Alaska had retreated a greater distance than have the present glaciers (see "Juneau Area" in Section III above). It may also be recalled that the last glaciation of Wisconsin times was not very extensive when compared to those of early Wisconsin times. It was, however, of greater magnitude than the advance of 3,000 to 4,000 years ago.

Approximately 10,000 years ago there was a glacial advance in Alaska which some students consider to be the last major advance of Wisconsin times, i.e., the Mankato. They base their considerations upon the results of radiocarbon dating. Other students believe that the Mankato advance occurred about 19,000 years ago, basing their belief upon varve counts and compilations. These latter believe that the glacial advance of 10,000 years ago was the Cochrane oscillation, or some manifestation of it. Since the physical remains of these two advances are quite distinct and separate in eastern North America, there can be no confusion as to their physical identity. The error has been in the dating of the remains. So far there has been no consideration of the Cochrane advance in the glacial geological investigations in the Pacific Coast of Alaska; consequently the last major glacial advance has been considered to be related to that of the Mankato. Radiocarbon dates for this advance indicate that it occurred about 10,000 years ago. There still remains a question as to whether it was related to the Mankato or was some manifestation of the Cochrane advance. Regardless of terminology, however, it is important to know that there was an advance at this time and that it can be made to serve as a point from which chronologies of events of deglaciation may begin.

It has been repeatedly pointed out in preceding sections that the glacial advance of about 10,000 years ago was a relatively conservative advance. For example, it is believed that Cook Inlet was not filled with glacial ice, and that the glaciers were only extensive enough to fill Tustumena Lake and Kachemak Bay on the Kenai Peninsula. Remains of this advance, in the form of moraines, indicate that the glaciers extended only about 15 miles out from the Alaska Range and Kenai Mountain fronts, and only to the mouth of the Matanuska Valley northeast of Anchorage.

Due to the conservative aspects of this advance, it is to be expected that, although much of the vegetation of the Pacific Coast region was

destroyed by the ice advance, the various forms were able to maintain themselves, though possibly in refugia. These remnant floral assemblages would serve as points of dispersal when the ice again began its retreat. The coincident retreat of the ice and the advance of the vegetation occurred at different times in the various areas of the Pacific Coast. It has been pointed out above that latitude is a major factor in providing a difference in time for the retreat of the ice in the various regions of the Pacific Coast.

From the data presented in the foregoing sections of this paper and from the chronologies presented in Table I, it is possible to present the following chronologies for the various regions of the Pacific Coast of Alaska, and for several neighboring areas. It is obvious that these chronologies can be only tentative arrangements owing to the fact that the scientific investigations bearing upon this topic are in their infancy in the Territory of Alaska.

Deglaciation can be considered to be significant in a region when the ice has receded sufficiently to allow vegetation to grow in the once glaciated areas and allow pollen to be deposited to record its presence. Peat or similar vegetal material will also, of course, give a record of deglaciation or climatic change.

Because of its position south of the limit of continental glaciation (at least the major portion of it) the Pacific Northwest began and/or continued its history of pollen deposition at a time when the regions farther to the north were still glaciated. Bogs and marshes which came into being due to the deglaciation of ice-covered areas of the Pacific Northwest began trapping pollen about 15,000 years ago. This, then, is the date for the recession of the last major glaciation in this region. The advance of about 10,000-12,000 years ago, so important farther north, appears to have been of slight significance in the Pacific Northwest of the United States. Although the glacial systems were rejuvenated at this time in the Pacific Northwest, it is not recorded in the chronology of events presented by Hansen (1947).

Although precise data are lacking, it is possible that the entire region of the Pacific Coast became deglaciated, at least to a degree equal to the present position, before the time of the last extensive glacial advance of about 10,000 years ago. This cannot be determined, however, until the various students interested can reach agreement on the dates and occurrence of the several most recent glaciations.

Deglaciation from the advance of about 10,000 years ago probably occurred about 9,000 years ago on the southern Northwest Coast and about 8,000 years ago in southeastern Alaska. In the Yakutat Bay area and in the Prince William Sound region the deposition of pollen sediments may not have begun until about 6,000 years ago.

From evidence presented previously, there is some reason to believe that near Anchorage local conditions prevailed which allowed a record of

peat deposition to begin as long ago as about 13,000 years, or possibly even earlier. This would suggest that the advance of ice of about 10,000-12,000 years ago often did not engulf local regions such as those in the vicinity of Anchorage. It would be from areas such as those that vegetation in refugia could spread out over adjacent areas after they were released from the retreating ice.

The Cook Inlet region may have become deglaciated sufficiently to record pollen deposition by 8,000 or 9,000 years ago. In view of the fact that the glacial advance of about 10,000 years ago was relatively conservative it is quite likely that at the lower elevations the vegetation was not overrun by the advance of the ice. This would also quite likely be true for areas of southeastern Alaska, and particularly so for the southern Northwest Coast.

Kodiak Island and the Alaska Peninsula underwent deglaciation and floral advance at about the same time as the Cook Inlet area, or even earlier. The Aleutian Islands recovered from the glacial advance at about the same time as the southern Northwest Coast, if present lack of glaciers and latitude may be taken as criteria. It has even been suggested (Bank, 1953c) that some of these islands escaped complete Pleistocene glaciation and served as refuges for the flora which has subsequently spread over the other islands, which were glaciated.

It is realized that these dates for the deglaciation of the various regions of the Pacific Coast are not too precise, but under the circumstances I believe they are currently valid and are quite useful for obtaining a clearer picture of post-Wisconsin climatic events.

With the retreat of the ice, a successional trend in vegetation occurred upon the ice-free land. The rate of advance and the rate of successional change would depend upon a multitude of factors, but under normal conditions a climax forest of spruce and hemlock could be expected in southeastern Alaska, for example, within a period of several hundred years, or possibly within 500 years. Reforestation would be greatly facilitated if the forest assemblage continued within the region in refugia.

With the expansion of the flora one would normally expect an influx of animals. With both plants and animals of suitable quantity and type, the scene is set for the entrance of humans into the Pacific Coast of Alaska. Man's entry into any of the various regions of the Pacific Coast of Alaska, however, probably depended upon one very important factor. This factor is the previous arrival of the various species of salmon. The arrival of the salmon, in turn, must depend upon an important factor. Salmon will not spawn in glacial streams which are carrying silt in any appreciable concentrations. The water must be clear or they will not ascend the streams to spawn. Without the salmon all those animals so dependent upon them will not occur.

It is quite probable that soon after deglaciation began, some streams were of such a nature that they did not carry loads of silt, and were thus

suitable for salmon. Possibly many streams on the Pacific Coast of Alaska and British Columbia never ceased to be salmon streams during the advance of ice of 10,000-12,000 years ago. These would, in a sense, serve as refuge streams for the salmon.

There is no reason to believe that humans could not have occupied at least parts of the Pacific Coast of Alaska before the glacial advance of 10,000 years ago. When more data are obtained for this period they might show that habitation was possible for the entire region; however, the data are more precise since about 10,000 years ago, so it is possible to suggest more precise dates since then for the human occupation of the various areas of this region. Even the currently most heavily glaciated region of the coast, of which Yakutat Bay is the approximate center, probably was sufficiently deglaciated and populated with necessary types of flora and fauna to allow human occupation by about 6,000 years ago. It must be kept in mind that not all areas are even yet suitable for human habitation. These areas do, however, border habitable areas. The Aleutian Islands and the southern Northwest Coast were probably habitable about 8,000 or 9,000 years ago and possibly, like the Anchorage area, during and before the advance of about 10,000 years ago.

In a previous section dealing with archaeology it was pointed out that the oldest known cultural manifestations on the Pacific Coast of Alaska are from Nikolski on Umnak Island in the Aleutians. The lower levels have been dated by the radiocarbon method and have an age of about 3,000 years. Earlier remains have not been recorded for one of two obvious reasons: they have not been found; or they do not exist. As it has been demonstrated that it is possible for earlier remains to be present, it might be profitable to discuss why they have not been found.

As previously noted, archaeological investigation in the Pacific Coast region of Alaska is in its beginning stages. So far, only the more obvious archaeological sites have been recorded, and only a relatively small number of these dug. Early sites will be more easily located in the Aleutian Islands for reasons previously given, viz., they are less obscured and more readily observable. On the northern Northwest Coast postglacial activity such as erosion and deposition may have contributed to the destruction of early camp and village sites. The raising of the land during the last few thousand years may have elevated former beach sites, which have then been heavily covered with timber. The rank growth of vegetation on the entire Northwest Coast makes the finding and recording of even relatively recent archaeological sites difficult. The fact that no early sites have been recorded for southeastern Alaska is no reason to assume that sites with considerable antiquity may not eventually be found when archaeological work is expanded in the region. Visiting likely spots on raised beach lines on the Northwest Coast might produce sites of greater antiquity than presently recorded.

The discovery of the oldest sites in southeastern Alaska is yet in the future. The method that will probably have to be used to find them is the method suggested by Banks for the Aleutian Islands. "It is

entirely possible that future reconnaissance will uncover the oldest sites on...uplifted beaches, and it may be that here is where the true beginning of Aleut culture will have to be sought" (Bank, 1953c, p. 502).

Investigations of a preliminary nature can be undertaken without going into the field by studying aerial photographs prepared by the Federal government (if available). From the aerial photographs an itinerary can be developed for a terrestrial archaeological site survey. It would be necessary for each student working in an area to utilize the photographs for this purpose so that the tremendous task could be expedited. When each student had prepared an itinerary for his local area, region, or island, he could further eliminate the necessity of terrestrial observation by first flying over the critical areas to be checked. Upon closer observation from the air it might become obvious that areas which seemed likely habitation areas from the aerial photographs (usually taken from high altitudes) would not be worthwhile visiting from the ground. In this manner the seemingly impossible task of intensively surveying southwestern and southeastern Alaska for archaeological remains becomes more feasible. Larson (1950, p. 177) has found this method of site survey to have "many advantages".

Although archaeological sites of an antiquity of more than about 3,000 years have not as yet been recorded in the Pacific Coast region of Alaska, it has been demonstrated in this paper that it is quite likely that humans could have occupied the region by about 6,000 years ago, and probably much earlier in some areas. Since no body of archaeological data exists which has reference to the postglacial period previous to about 3,000 years ago, one can only speculate on the type of culture and the method and route of entry of the first humans to the Pacific Coast region of Alaska.

Not only is evidence of ancient man nearly lacking for the Pacific Coast of Alaska, but his presence is poorly documented in the other regions of the Territory. Sellards notes only four localities which can be classified as exhibiting possible manifestations of "early man" (Sellards, 1952, p. 5). The first is the one investigated by Frank Hibben at Chinitna Bay on Cook Inlet. This site, which is being washed away by wave action, is composed of a humus layer containing artifacts, bone and charcoal. Imbedded in the humus are the remnants of a forest, including upright stumps which appear to be resting in their original positions. Above the humus layer is a stratum of muck which varies from four to twenty-two feet in thickness, and has a loess-like consistency. Near the top of the muck layer is a 3-inch-thick band of volcanic ash. The muck layer is capped by a deposit of peat varying from one to six feet in thickness. The entire deposit has as a base an iron-stained clay. It is from the surface of this blue clay and the immediately superimposed humus layer that the artifacts are said to occur. The clay may possibly represent a sediment deposition during a period of glacial advance. The humus layer with the forest remnants certainly indicates a relatively warm period. The rather thick deposit of muck lying above the humus and forest debris is a possible indication that the local climate had coased to be relatively

warm and dry and had become more cool and moist. The top layer (peat) suggests a continuance of the cool and moist period, but possibly with some amelioration of the climate. Interpreted from a conservative point of view, the cultural remains can be placed temporally during the period of maximum warmth and dryness which occurred after the last major glaciation. This period has been equated with Antevs' Altithermal period in another section of this paper. If the artifacts were actually deposited by man upon the blue clay, they would antedate the warm, dry period, or at least correlate with its beginning. It is possible that the artifacts, in some cases, attained the level of the blue clay through a process of working downward. This is suggested by the fact that the artifacts occur in the humus deposit and on top of the blue clay. A conservative estimate of the age of the artifacts from this site would be about 4,000 years. Additional investigation at the site might suggest a more ancient date, but for the present the data do not clearly support a greater antiquity. The chipped stone blades illustrated as having come from this site (Hibben 1943, pl. 15) are not unlike modern Eskimo specimens, a point which Hibben presents after suggesting a "Yuma" affinity for the specimens. If further work were carried on at this site, a cultural and temporal relationship might be demonstrated between it and the lower levels of Laughlin's Nikolski site.

The second area noted by Sellards with a possible occurrence of early man is in the vicinity of Fairbanks at various localities in the Tanana and Yukon River valleys. A Folsom-like point and a fragment of what Hibben believes to be an Eden Yuma point have been illustrated (Hibben, 1943, pl. 15). They are said to have come from muck deposits in central Alaska. Although these mucks contain the remains of extinct and fossil fauna, Sellards points out that "it is not possible to determine the contemporaneity of the artifacts and fossils" (Sellards, 1952, p. 121). If early man used the ice-free Yukon River valley as a route of entry into continental North America (Wormington, 1949, p. 152) then it is not strange that artifacts possibly attributable to him have been recovered. As Wormington points out, however, "incontrovertible proof is still lacking" (Wormington, 1949, p. 152) that early man did utilize the Yukon River valley as a route of entry.

In passing, it might be well to suggest a further possibility concerning the site reported by Hibben at Chinitna Bay. If the site is actually older than about 4,000 years there is a possibility that it might eventually be correlated with the cultural remains which have been recovered from the mucks of central Alaska. Early man undoubtedly could have come down the Susitna River valley to the head of Cook Inlet. This is especially true if conditions were as they have been suggested by this present study, that is, unglaciated areas in the vicinity of Anchorage and in the lowlands about portions of Cook Inlet. It has also been pointed out repeatedly in previous sections that the last major glacial advance is believed to have been quite conservative relative to previous Pleistocene advances. In early postglacial times, then, it might have been possible for contact to be made with the Cook Inlet area from central Alaska via the Susitna and Nenana Rivers.

A third early man find from Alaska noted by Sellards is a fluted point found on the upper reaches of the Utukok River in the northwest corner of Alaska. This surface find was reported by Raymond Thompson (1948) and probably demonstrates that early man had been in that vicinity at some time in the past. Until more evidence is turned up one can do little more than speculate upon the occurrence of this artifact.

The Cape Denbigh flint complex is the fourth early man site discussed by Sellards for Alaska. Although Giddings (1951) does not intend to imply cross-dating of the Denbigh flint complex material with any of the Old World phases of prehistory, he does point out that a number of artifact types from this complex resemble Aurignacian work. One of the most important traits of the Denbigh flint complex is the occurrence of burins, an artifact type common in Aurignacian times in Europe. With regard to the Denbigh flint complex, Collins states that it is "an early microlithic culture with definite Mesolithic affinities, older than and possibly ancestral to both Eskimo and Siberian Neolithic, and also connected in some way with Folsom and Yuma" (Collins, 1951, p. 459). Collins also believes that some sort of a cultural relationship existed between the Denbigh flint complex and the later Eskimos who occupied the same region. More specifically, he sees a certain relationship between the Denbigh flint complex and Ipiutak.

According to David Hopkins (1952, p. 513) the climate was warm at Cape Denbigh during the time the site was first occupied. He suggests that this warm period might be the same period dated at about 8,500 years ago from muck north of Nome. This period was preceded and followed by colder intervals. Hopkins also suggests the possibility that the Denbigh flint complex existed, instead, during a pre-Mankato warm interval more than 10,000 years ago. This warm interval is suggested to him by dated muck near Fairbanks. If the date of about 8,000 years is taken, however, the Denbigh flint complex is coeval with the Mesolithic of Europe (Kroeber, 1948, p. 662). Upon temporal grounds, therefore, it would be possible for Collins to suggest a relationship between the two, as well as between the Denbigh flint complex and the Folsom culture and the "Yuma" manifestations. Upon these same temporal grounds, however, it is difficult to see any relationship between the Denbigh flint complex and Ipiutak, which has a C14 date of about 1,000 years. Possibly giving the true age of the Denbigh flint complex, however, are radiocarbon samples C-792 and C-793 (Libby, 1954, p. 140). The samples are dated  $3,509 \pm 230$  (average of two) and  $4,658 \pm 220$  (average of two), respectively. A comparison of these dates with unit 9 of Table I (infra) points out that the Denbigh flint complex on Norton Sound existed during the thermal maximum, and possibly into the following period of glacial advance. This agrees with what Hopkins has said (see above) with regard to the climate before and after the occupation of the lower (Denbigh flint complex) portions of the Iyatayet site; that is, it was preceded by a cool period and followed by another, and occupied during a warm period. The site, therefore, would be located on the edge of the bay, as it is today, and not far from salt water as it would have been if the site had been occupied during a cold period when the sea level was lower (due to the fact that so much

water was locked up in the form of glacial ice) (cf. Collins, 1953, pp. 199-200).

The recent C14 dates for the Denbigh flint complex indicate that it was not coeval with the European Mesolithic, but that it still temporally precedes Ipiutak by possibly as much as 2,000 years. In this case it might be postulated that the Denbigh flint complex was a descendant of the Mesolithic and ancestral to Ipiutak. It might also be that the Denbigh flint complex and the Folsom culture and the "Yuma" manifestations all had a common antecedent.

Other archaeological sites having a cultural affinity with the Denbigh flint complex have been reported by Larsen (1953). One of these sites is on the Kukpowruk River, which flows into the Arctic Ocean about 40 miles south of the Utukok River in northwestern Alaska. Another site is located on the Kugururuk River, an upper branch of the Noatak River. The headwaters of the Kukpowruk and the Kugururuk Rivers are near one another and rise in the Brooks Range. A third site which is said to produce material of the Denbigh flint complex is situated in the Anaktuvuk valley, 245 miles west of the site on the Kugururuk River.

Of the four early man sites discussed by Sollards, it will be noted that only the Chinitna Bay site falls within the province of the Pacific Coast region of Alaska. What the possible relationships are between the other three early sites and the Pacific Coast region is difficult to say. It has been suggested above, however, that there may have been a relationship between the early man remains (artifacts) from the central Alaska region and the site at Chinitna Bay on Cook Inlet. With so little archaeological data upon which one may draw it is difficult even to speculate about the possible relationships.

Now, in the light of the above discussions, certain general conclusions can here be drawn.

1) It is presumed that the route of early man into continental North America was along the Yukon River--a presumption which seems most valid at the present time. The Pacific Coast region of Alaska is peripheral to the Yukon River route and, unlike the latter, is not particularly conducive to overland travel. The insular and fiorded coast line of the Pacific Coast region would certainly not be attractive to people oriented to an interior land mammal hunting economy. Good water craft and specialized hunting techniques are necessary for those people desiring to live permanently on the coast. Due to the ruggedness and peripheral nature of the Pacific Coast it seems quite likely that early man did not occupy the region, although he may have visited it upon occasion.

2) Until people with a marine and coastal orientation began appearing in the New World, it is probable that the Pacific Coast of Alaska was only occasionally visited and probably not continuously inhabited. When

people with an economy much like that of the historic Eskimos entered the region they found it to their liking, because of the abundance of available food which could be obtained through use of their specialized equipment and techniques.

3) The lower levels of the Nikolski site on Unalak Island apparently contain a culture with a content closely resembling that of the upper levels. In other words, the oldest dated cultural remains noted from the Pacific Coast of Alaska are in most respects quite similar to the more recent remains. The base of the Nikolski site has a date of more than 3,000 years. Since there is no reason to believe that this will be the most ancient site ever to be found in this region, it is possible to suggest that people with an Eskimo-like culture were in the Aleutian-Alaska Peninsula area more than 4,000 years ago. From a climatic and ecological point of view, there is no reason to believe that these people could not have been in that area 6,000 years ago, or even longer. It is not expected, however, that these people will have been the typical hunters of extinct forms of land mammals of continental North America, but probably a somewhat later group with a more maritime orientation. This is not to say, however, that there may not be some ultimate ancestral relationship between the two.

4) Due to a lack of any extensive body of evidence, one can only speculate about the movement of these Eskimo-like people into southeastern Alaska, and possibly further south. They probably spread out along the coast and islands both to the east and the west, with the extremities being the last to be occupied. Kodiak Island, the Cook Inlet area, Prince William Sound and areas to the southeast were occupied in that order a relatively short time after the Alaska Peninsula and the eastern Aleutians. These people and/or elements of their culture may possibly have extended as far south as the Puget Sound area. At the same time that these Eskimo-like people were spreading out along the coast to the southeast and south it is probable that Indian groups were moving up the coast toward British Columbia and southeastern Alaska. These movements were probably of a rather complex nature in that they consisted of advances, halts, and retreats as well as a coalescence of peoples and cultures. There were probably pressures which pushed people from the coast into the interior, and vice versa. From these movements and mixtures a basic sort of culture emerged which differed from the original Eskimo-like culture found quite early in the Aleutians. Additions to this basic Northwest Coast culture were probably made from time to time from the north and the south, and from the interior. It was from this background of numerous influences that the protohistoric Northwest Coast culture developed. As it became more developed it appears to have expanded both to the north and the south as well as to the peripheral interior.

5) The spread of the Eskimo-like people and/or their cultural traits into southeastern Alaska and probably into British Columbia, or further south, could have occurred as long ago as 4,000 years, or earlier. The movement of Indian groups from the south along the coast toward the north could have begun even earlier than the southward movement of the Eskimo-like

people. Movement from the coast to the interior, or the reverse, was possible quite early and may have been almost continuously possible in British Columbia since the retreat of the last glaciation some 6,000 or 8,000 years ago.

6) It is not within the stated scope of this paper to discuss in detail the ultimate origin of the Eskimo. Such a discussion has been undertaken by numerous students including Steensby (1917), Hatt (1934), Mathiassen (1927), Kroeber (1939), Collins (1937), de Laguna (1934), and Pirket-Smith and de Laguna (1938). It has been suggested that Eskimo culture originated inland in the Mackenzie drainage (Steensby, 1917); other students more strongly favor the Bering Strait route as a point of entry of Eskimo culture into America (Kroeber, 1939). The likelihood of cultural exchange between Asia and America via the Aleutian Islands has been supported by de Laguna (1934), Birket-Smith and de Laguna (1938), and Collins (1937). These various viewpoints need not necessarily be mutually exclusive. During a span of time of 4,000 years or longer, a variety of cultural influences from numerous sources can be expected to have presented themselves to those human groups occupying the Pacific Coast region of Alaska.

More recently, on the basis of his glottochronology studies, Hirsch has made suggestions that may be of interest here: "the proto-Eskimo-Aleut stock was present in south Alaska over 3,000 years ago, and... the proto-Eskimo stock was between the latter area and the Bering Strait region between 3,000 and 1,000 years ago when it split into the two major groups found at the present time" (Hirsch, 1954, p. 835).

7) The suggestion above of a possible southward movement of Eskimo-like people and/or elements of their culture into southeastern Alaska, and possibly further, need not in any way invalidate Kroeber's statement that "the Northwest Coast culture was originally a river or river-mouth culture, later a beach culture, and only finally and in part a seagoing one" (Kroeber, 1939, p. 28). It is probable, however, that cultural contacts from the northern Northwest Coast to Puget Sound were possible in ancient times as well as during recent times.

It has been the aim of this paper to show the time at which it was possible, following the last major glacial advance, for humans to spread out and occupy the Pacific Coast region of Alaska. From these present investigations suggestions can be made concerning the movement of these humans into the region, and the probable coalescence of peoples and traits entering the region from both the north and the south. The soundness of the speculations concerning the aboriginal occupation of the Pacific Coast region of Alaska as presented in this paper can scarcely be demonstrated conclusively until much more investigation of an archaeological and glacial geological nature is undertaken in this region in the future. The tempo of scientific investigation of this sort is steadily increasing in the Territory of Alaska, so it is almost certain that the problems with which this paper has been concerned will be greatly clarified in a relatively short time.

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