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Hunt Institute was dedicated in 1961 as the Rachel McMasters Miller Hunt Botanical Library, an international center for bibliographical research and service in the interests of botany and horticulture, as well as a center for the study of all aspects of the history of the plant sciences. By 1971 the Library's activities had so diversified that the name was changed to Hunt Institute for Botanical Documentation. Growth in collections and research projects led to the establishment of four programmatic departments: Archives, Art, Bibliography and the Library.

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

Analysis of Ecosystems

Tundra Biome

TO: Barrow Workshop Invitees, other Tundra Biome personnel and informational addressees

FROM: J. Brown, Box 345, Hanover, New Hampshire 03755 (603-643-3200, Office) or (603-643-4240, Home)

SUBJECT: Barrow Workshop Arrangements, 29 October - 1 November 1969

Arrangements for the Barrow synthesis and modeling workshop are now firm. The formal workshop sessions will be held on 29, 30 and 31 October at the University of Colorado's Mountain Research Station near Nederland, Colorado. Accommodations will be at Caribou Ranch, about a 10-minute drive from the Mountain Research Station. Saturday, 1 November, will be devoted to a Biome-wide planning session at the Institute of Arctic and Alpine Research (INSTAAR) on the Boulder Campus. An informal dinner is planned for the evening of 30 October at a nearby inn. For those who would like to visit the Pawnee Site of the Grassland Biome Program, a trip can be arranged on 28 October.

INSTAAR drivers will meet incoming flights at Denver Airport. Therefore, it is necessary to return the enclosed form stating your arrival time and flight number or call Pat Webber (303-443-2211, ext. 6387, Office; or 303-444-4891, Home), INSTAAR, when your arrival time and flight number are known. If you do not find an INSTAAR representative at the airport, check with your arriving airline service desk for a message. If there is no message, call one of the above phone numbers regardless of your arrival time. Vehicles will be available for the duration of the workshop.

It is hoped to have all participants at Caribou Ranch by the evening of 28 October. Late arrivals will also be met. Be certain to bring winter clothing and a pair of boots. Visual aid equipment will be available, so do not hesitate to bring slides of data. Please be prepared to present an informal summary of your Barrow research. Also bring at least one copy of all reprints, progress reports, data reports, etc. for use at the meeting and for retention by the synthesis personnel. Each Barrow project leader is expected to bring a representative sampling of unreduced or unpublished data, particularly for the period 1961-1966. Remember that the objectives of the workshop are to evaluate existing data and their limitations and to plan the synthesis of unreduced data.

Travel advances are available for Barrow Workshop Invitees, although it will be more convenient if you claim your expenses after the workshop. Those invitees who require an advance should write directly to Dr. Harry Coulombe, Biology Department, San Diego State College, San Diego, California. If you hope to receive San Diego funds, you may use the enclosed Tax Exemption Certificate.

Looking forward to seeing you in Colorado.

DISTRIBUTION:

Barrow Workshop Invitees

Barsdate	Gersper	Martin
Benoit	Gessaman	Miller
Bliss	Goodall	Mullen
Bohnsack	Hobbie	Pieper
Boyd	Holmes	Pitelka
Britton	Ives	Rogers
Brown	Jenny	Schultz
Ciebsch	Johnson, A.	Smith
Cameron	Johnson, P.L.	Stroschein
Collier	Kadlec	Tieszen
Coulombe	Kalff	Timin
Dennis	Kangas	Untersteiner
Dingman	Kelley	Van Cleve
Douglas	Koranda	Van Dyne (or desg.)
Delwiche	Lachenbrush	Weaver
Ellis	Lewellen	Webber
Folk	MacLean	West
Gates	Maher	

Other Tundra Biome Committee Members and Informational Addressees

Auerbach	Hickok	Morthland
Benninghoff	Hoffmann	Oliver
Billaud	Hopkins	Osburn
Brewer	Laughlin	Train
Cooper	Lieth	Ugolini
Faylor	Major	Viereck
Gessel	Mooney	Welsh

I plan / do not plan to attend the Barrow Workshop.

I am / am not interested in visiting the Grassland Biome Intensive Site on 28 October.

I will arrive on Flight _____
(Airline & Flight No.)

at _____ on _____
(Time) (Date)

_____ _____
(Name) (Institution)

Taximetrics Laboratory

Armory 101

22 September 1969

Dr. Jerry Brown
Earth Sciences Branch
U. S. A. Cold Regions Research
Hanover, New Hampshire 03755'

Dear Jerry:

Thanks for your letter of 11 September. IIll keep in touch with Jack Ives for scheduling, and will talk about the information management system which we call TAXIR.

Sincerely,

David J. Rogers
Professor of Biology

DJR:gm

AIR MAIL

DEPARTMENT OF THE ARMY
U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE 03755

CRREL-RE

11 September 1969

Dr. David Rogers
Taximetric Laboratory
University of Colorado
Boulder, Colorado 80302

Dear David:

Thank you for your letter of 1 August. Please excuse the delay in answering. I have just returned to the office.

I welcome your suggestions concerning TAXIR. I suggest we discuss it at the proposed Boulder synthesis workshop in early November. You are certainly most welcomed to attend. Jack or Pat Webber have the details concerning this meeting. Would you be willing to give a short, formal presentation to the group?

Sincerely yours,

JERRY BROWN
Research Soil Scientist
Earth Sciences Branch

CF: Dr. J. Ives
Dr. G. West
Dr. H. Coulombe

22 September 1969

TO: Potential Barrow Workshop Participants, Tundra Biome Advisory Committee, and Alpine and Arctic/Taiga Steering Committees, and Informational Addressees

FROM: J. Brown, Box 345, Hanover, N.H. 03755

SUBJECT: Status Report on Tundra Biome Activities and Barrow Synthesis Workshop.

I am pleased to announce that the proposal to NSF for the Barrow synthesis and modeling has been favorably reviewed. The grant was activated by NSF on 11 September for the full amount requested ($58,700). The first order of business will be the workshop in the Boulder, Colorado, area during the last week in October. We are tentatively favoring 29-31 October for the formal meetings with the weekend of 1-2 November for other Biome business. I request that those of you who have received but have not answered our initial workshop questionnaire (1 August) to do so immediately. We would like to finalize travel and accomodation arrangements within the next two-three weeks. We believe we can fully support travel and other expenses for almost all Barrow research participants. We are also hopeful that some members of the Biome's several committees will be in attendance. However, we simply do not have adequate funds to support all committee members' travel. A memo announcing final arrangements for the workshop will be mailed by 15 October. If there are any urgent last minute questions my phone numbers are: office 603-643-3200; home 603-643-4240.

Enclosed you will find a preprint of the paper to be presented at the Tundra Conference in Edmonton in mid-October. At least Pitelka, Coulombe and I plan to attend this meeting. There will be a meeting of the International IBP Tundra Committee at that time. John Kadlec and I have decided not to hold a U.S. meeting in Edmonton.

I will be attending a meeting of the U.S. National Committee for IBP in Washington on 25 and 26 September 1969. All IRP and sub IRP directors will present status reports on their programs, as well as plan the FY 71 program and budget. I will base our report partly on the response to the Biome-wide questionnaire mailed this summer. Over 150 replies have been received, many of which indicate considerable interest in the future of our Biome program.

I have just returned from a 6-week trip in Europe. I visited tundra peat sites in both Ireland and England. Considerable field work is on-going at both sites as is the case in the Scandinavian alpine sites. We will learn more about these developments in Edmonton. I did not have an opportunity to visit any IBP projects while in Moscow and Siberia, although many Soviet colleagues are aware of the IBP program. Both David Hopkins and Bob Hoffmann have recently visited in Leningrad and they may have additional information for us on the Soviet Tundra program.

Again, Barrow workshop participants who have not replied, please let me know your attendance intentions and schedules. To those committee members who can come under their own funds, please do so.

Enclosure:

Preprint "Structure and function of the tundra ecosystem at Barrow, Alaska: A word model"

DISTRIBUTION

Barrow Workshop Invitees

Barsdate	Hobbie	Schultz	Faylor
Bliss	Holmes	Smith, F. E.	Gessel
Bohnsack	Ives	Stroschein	Hickok
Boyd	Jenny	Tieszen	Hoffmann
Britton	Johnson, A.	Timin	Hopkins
Brown	Johnson, P. L.	Untersteiner	Laughlin
Clebsch	Kadlec	Van Cleve	Lieth
Cameron	Kalff	Van Dyne(or desg.)	Major
Collier	Kelley	Weaver	Mooney
Coulombe	Koranda	Webber	Morthland
Dennis	Lachenbrush	West	Oliver
Dingman	Lewellen		Osburn
Douglas	MacLean	Other Tundra Biome	Train
Delwiche	Maher	Committee Members	Ugolini
Ellis	Martin, J.	and Informational	Viereck
Folk	Miller	Addressees	Welsh
Gates	Mullen	Auerbach	
Gersper	Pieper	Billaud	
Gessaman	Pitelka	Brewer	
Goodall	Rogers ✓	Cooper	

Structure and function of the tundra ecosystem at Barrow, Alaska: A word model

Jerry Brown
USACRREL
Hanover, New Hampshire

Frank A. Pitelka
Department of Zoology
University of California
Berkeley, California

Harry N. Coulombe
Department of Biology
San Diego State College
San Diego, California

September 1969

Preprint report for the Conference on
"Productivity and conservation in northern circumpolar lands"
15-17 October 1969
Edmonton, Alberta

Structure and function of the tundra ecosystem at Barrow, Alaska: A word model*

J. Brown, F.A. Pitelka and H.N. Coulombe

Introduction

The Tundra Biome Program of the Analysis of Ecosystems, U.S. International Biological Program, is initiating its research activities with a project designed to synthesize and model the existing Barrow, Alaska, environmental data. As suggested by Gore, we have prepared the following word model for the Barrow ecosystem. In addition this report outlines how and when this synthesis and modeling effort will be undertaken. Finally, a more detailed account of the Barrow physical setting is presented along with the previously prepared and updated bibliography.

Section 1: A WORD MODEL OF THE BARROW ECOSYSTEM*

The intensive site of the U.S.-IBP Tundra Biome Program for arctic tundra near Barrow, Alaska, is a complex of four major habitats: 1) a complex of polygonal ground; 2) ridges, divides and drained slopes; 3) meadows and marshes; and 4) large thaw lakes (see Fig. 1-1.) Associated with the first three of these, are upland tundra, meadow tundra, and bog soils; with the second, arctic brown and upland tundra soils; and with the third meadow tundra and bog soils. Included in each of these three major habitats are small ponds which are intimate components of all land habitats and show various stages of succession resulting from both filling and erosion. The fourth major habitat is represented by large shallow lakes, which in the Barrow area (71° lat. north) occupy 30% of the total surface area. The vegetation, soils and microrelief pattern within the first two are extremely complicated and form mosaics which influence plant productivity and animal population and diversity throughout the year.

The principle producer species on the terrestrial habitats are listed in the Table 1.1. Primary production is controlled by a

*Subject to revision at Barrow synthesis workshop, 28 Oct. 1969.

combination of temperature, soil moisture, day length and nutrient supply. The more productive habitats on micro- and meso-scales are near the wetter end of the soil moisture gradient (meadows and polygon troughs). All habitats are controlled by the presence of permafrost (0°C ground temperature or colder) near the surface throughout the growing season. Especially significant to the amount of seasonal primary production are the climatic conditions of the first two or three weeks of the growing season and the previous summer's stored reserves. Superimposed on this are fluctuations in nutrient cycle. On all terrestrial sites, but particularly on the wetter meso-sites, production is directly influenced by delayed effects of decay of clipped plant debris and faecal remains. It is hypothesized that the availability of nutrients to plants for growth is modulated by the lemming population through accumulation and storage of certain elements (N, K, P) in, and their ultimate release from, faecal and other dead organic matter.

Long-term rates of total decomposition in most of the habitats are approximately equal to production; there is no net accumulation of organic matter, and biological functions of the land habitats are in apparent equilibrium with this cold-dominated, permafrost-controlled environment. A dominant acceleration effect in the decomposition process is the amount of standing dead plant matter prostrated by lemming grazing. Prominent saprovores are dipterous larvae, collembolans, and oribatid mites. Although the rate of organic decomposition is slow, wetter habitats show higher rates of nutrient loss through decomposition compared to better-drained, drier habitats. Microbial activity appears to be several order of magnitude below that of lower latitude wet ecosystems and, furthermore, is confined to the upper 10 centimeters or so of the soil.

Important for the assessment of production on tundra is the distinction between above and underground components of plants. Biomass ratios below to above are of the order 5:1 or greater. Annual production rates below to above are approximately equal.

Annual production rates for the tundra ponds are the lowest on record for fresh water. Many of these small ponds receive seasonal influxes of organic matter (clippings, faeculs, soluble organic), especially during spring runoff. During the summer, thermal erosion of organic-rich permafrost also contributes to lake and pond filling. Melt of the ice cover in larger lakes is not completed until the first half of July; however, production is initiated early in both ice-free moats and beneath the ice. Approximately 25% of the total seasonal production occurs beneath the ice following snow cover dissipation.

Plant consumption is dominated by the brown lemming (Lemmus trimucronatus), which utilizes standing living tissue on a year round basis. Other vertebrate herbivores typical of tundra elsewhere are here negligible (e.g., a second microtine, Dicrostonyx; caribou; geese) or absent (ground squirrels). The herbivory of arthropods is probably lower than in other ecosystems due to the dominance of the cold climate and the overriding effect of lemmings. The vegetation-lemming interaction is cyclic on a "short term" basis, the period being three to five years.

Carnivory is conspicuously associated with the lemming cycle, and several bird and mammal predators can be present in significant densities. These include jaegers, owls, weasels, foxes, and gulls. Other carnivory is that of insect predators, mainly birds, but also that of shrews, arachnids, and other arthropods. Most prominent beside that of lemming predators is the carnivory of shorebirds, mainly on aquatic Diptera larvae. Both of these categories of carnivory occur prominently in all land habitats on both micro- and meso-scales.

Dominating all terrestrial and aquatic processes is the shortness of the growing season, varying between 45 and 90 days. Short growing season is partially compensated for by uninterrupted diurnal light.

Table 1.1 Principle vascular plant species and their occurrence on the Barrow landscape

Species	Principle Habitat
Arctophila fulva	deepest pond water
Carex aquatilis	shallow pond waters, wet polygon centers and troughs
Eriophorum scheuchzeri	shallow water
E. angustifolium	shallow water
Dupontia fisheri	saturated soils
Alopecurus alpinus	saturated soils
Luzula confusa	drier ridges and polygon tops
L. nivalis	
Poa arctica	
Potentilla hyparctica	
Saxifraga cernua	
S. foliolosa	
Salix pulchra	
S. phlelophylla	
S. rotundifolia	
Petasites frigidus	

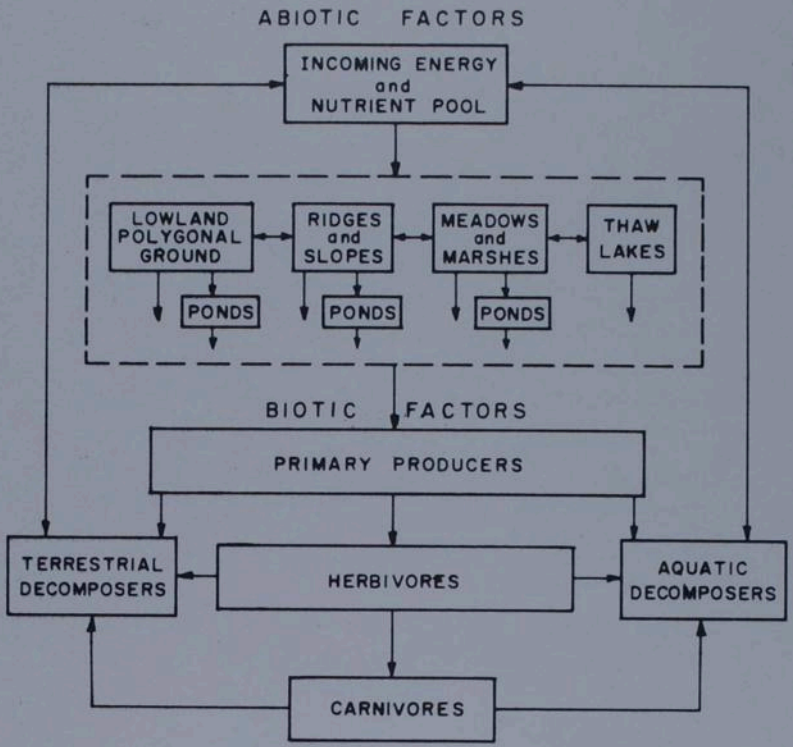

Figure 1.1. A simplified representation of the Barrow ecosystem emphasizing the functional relations of the four component biotopes.

SECTION 2*

The synthesis of the Barrow, Alaska
data base and a discussion on ecosystem modeling

Harry N. Coulombe and Jerry Brown

*Insert section 2 when available.

SECTION 3

Environmental Setting, Barrow, Alaska

Jerry Brown

Geographic Setting

Barrow is situated at the northern extremity of the Coastal Plain Province of the Arctic Slope (Figure 3.1). The area reported upon is restricted to the land mass north of 71° 15' latitude. As such, it is a triangular-shaped land mass bounded by the Chukchi Sea on the west, the Arctic Ocean on the north, and Elson Lagoon and the Beaufort Sea on the east. The area is characterized by low relief, patterned ground dominated by ice-wedge polygons and shallow, oriented lakes and drained lake-basins. The depth of seasonal soil thaw averages 40 cm and is underlain by perennially frozen ground to several hundred meters. Elevations at the northern part of the Barrow area are less than 5 meters along wave-cut cliffs and rise to 20 meters in the southern part. Relief is rarely greater than 5 meters on the undulating inland areas. This northernmost tip of land is the most recently emergent part of the Coastal Plain and is late Pleistocene in age.

The largest Eskimo population in the state is located within this area at the village of Barrow. Several government-operated facilities including the Naval Arctic Research Laboratory are situated some 8-10 kilometers north of Barrow village (Fig. 3.1). In addition to the food resources derived from migrating birds and the ocean by the natives, the only other natural resources presently being exploited at Barrow are the underground gas which is pumped from several wells south of the village and fresh water derived from several lakes and ice. As a result of earlier oil exploration and the present-day

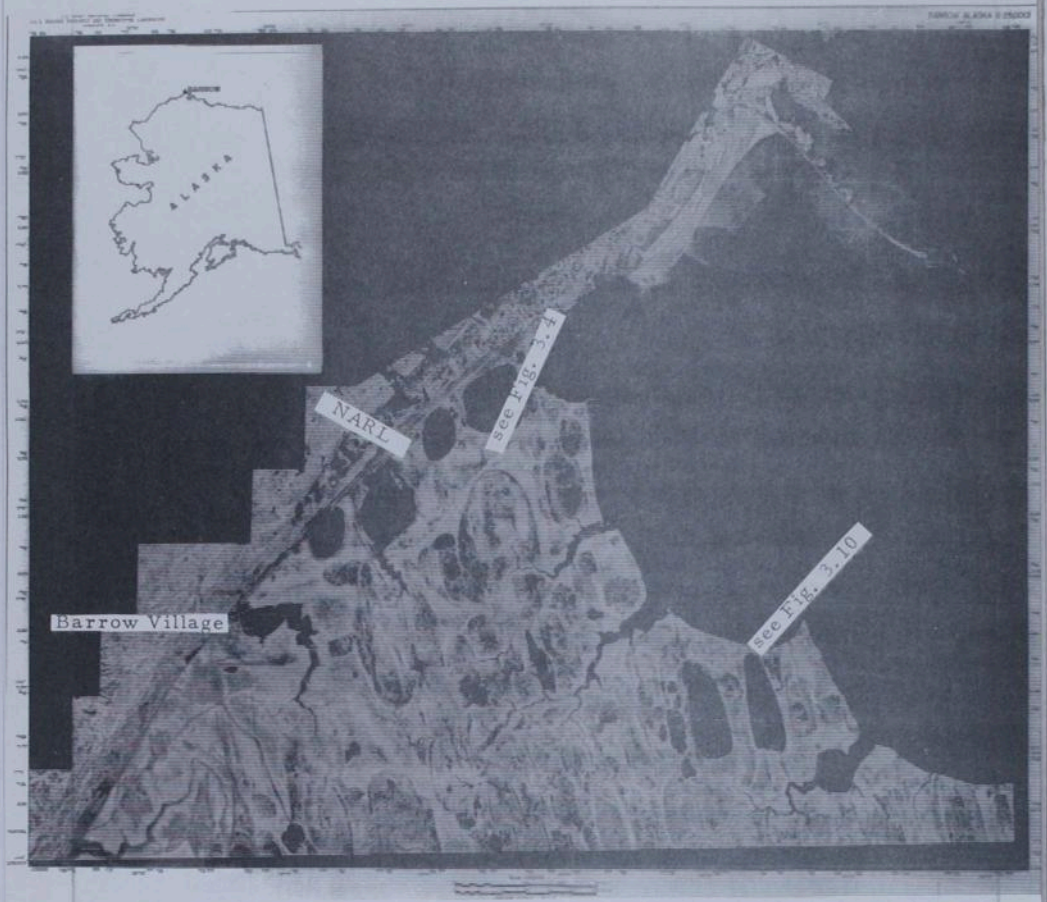

Figure 3.1 Photo mosaic of Barrow, Alaska and location map.

cultural activities, the immediate Barrow tundra landscape has been modified by vehicular tracks and occasional debris.

Climate

The regional climate can be briefly described as consisting of long, dry, cold winters and short, moist, cool summers. Temperatures remain below freezing through most of the year. Daily maxima are higher than 0C on an average of 109 days. Freezing temperatures are observed every month of the year. February is generally the coldest month, having a mean of -28C. Temperatures begin a gradual warming trend in April with a definite transition to summer during May, accompanied by an average of 5 days above freezing in that month. July is the warmest month with a monthly mean of approximately 4C. The end of summer is reached by mid-September and by November one-half of the daily mean temperatures are -18C or below. Mean precipitaion is 116 mm. The months of March, April and May are the driest, and July and August are the wettest. The heaviest portion of the precipitation season extends into October with the highest average snowfall occurring in that month. Winter snow cover is generally melted by mid- to late-June, although late snow patches can remain well into the summer. Summer snowfalls occur occasionally. The annual mean hourly wind speed is 21.6 km/hr and the prevailing direction is easterly. October has the highest monthly mean hourly wind speed of 24.6 km/hr and March and December the lowest with 19.8 km/hr. Fogginess and cloudiness persist through the summer with maximum cloudiness occurring in the transition to winter during September and continuing through October and November. The presence of ice-free ocean from mid-July onward to freeze-up is a moderating factor resulting in cooler summertime temperature and in more cloudiness and fogginess than in the adjacent inland areas. Table 3.1 presents the normals, means and extremes from the first order weather station at Barrow (U.S. Dept. Commerce). For purposes of comparison, the

Table 3.1 Climatological normals, means, and extremes, Barrow, Alaska

NORMALS, MEANS, AND EXTREMES

Month	Temperature °F: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days: Base 65°F	Precipitation in inches: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: 2 AM	8 AM	2 PM	8 PM	Wind & Fastest mile: Mean hourly speed	Prevailing direction	Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover: sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet .1 inch or more	Thunderstorms	Heavy fog	Temperatures Max. 70° and above	32° and below	Min. 32° and below	0° and below	Average daily solar radiation - langleys
																					Standard time used: ALASKAN																							
(a)	(b)	(b)	(b)	48		48		(b)	(b)	48		48		47		48	48		48		24	24	24	24	39	14	9	9		26	34	34	34	48	24	48	27	48	48	48	48	12
J	- 9.4	-23.0	-16.2	35	1963	-53	1951	2517	0.18	1.04	1962	0.00	1939+	0.70	1937	2.4	11.9	1962	5.4	1962	64	65	64	65	11.2	ESE	49	09	1962		8	3	5	2	4	1	0	2	0	31	31	29	2
F	-12.2	-24.4	-18.3	32	1960	-56	1924	2332	0.17	0.81	1959	0.00	1936	0.36	1959	2.3	9.4	1944	3.6	1959	62	63	62	62	11.0	E	45	11	1960		5.3	12	6	10	4	1	0	1	0	28	28	27	39
M	- 8.1	-21.1	-14.6	33	1967	-52	1923	2468	0.11	1.49	1963	0.00	1928	0.71	1963	2.0	19.8	1963	7.1	1963	64	64	66	65	11.2	ENE	58	27	1960		5.0	14	7	10	4	*	0	1	0	31	31	30	177
A	7.4	- 7.0	.2	42	1926	-42	1924	1944	0.11	1.36	1963	0.00	1938	0.42	1963	2.2	15.4	1963	4.2	1963	72	72	73	73	11.6	NE	40	25	1961		5.9	10	7	13	4	1	0	3	0	29	30	23	390
M	23.5	13.3	18.4	45	1927	-18	1922	1445	0.12	0.81	1933	T	1939+	0.30	1923	1.9	12.9	1933	4.5	1923	87	87	84	86	11.7	ENE	39	25	1968		8.4	4	4	23	4	*	0	8	0	26	31	4	527
J	37.5	28.7	33.1	70	1942	8	1933	957	0.36	1.15	1955	T	1937+	0.82	1955	0.5	6.6	1933	2.9	1954	94	92	89	91	11.3	E	35	23	1961		8.0	4	4	20	4	*	*	12	*	5	25	0	545
J	44.9	33.3	39.1	78	1927	22	1936	803	0.77	2.44	1922	T	1937	0.86	1954	0.7	9.0	1922	6.0	1922	95	91	88	91	11.6	E	35	23	1961		8.2	3	7	21	9	*	*	13	*	*	14	0	437
A	42.7	33.1	37.9	76	1968	20	1925+	840	0.90	2.81	1963	T	1934	0.83	1960	0.6	2.9	1933	2.5	1936	95	93	89	93	12.6	E	36	23	1963+		8.9	2	3	26	10	*	*	11	*	2	15	0	262
S	33.8	27.2	30.5	62	1957	1	1957	1035	0.64	1.56	1958	0.02	1927	0.56	1959	3.0	7.9	1925	5.0	1950	92	91	89	91	13.2	E	37	07	1961		9.2	2	2	26	9	1	0	4	0	13	26	0	120
O	21.4	11.8	16.6	43	1954	-21	1963	1500	0.50	1.65	1925	0.12	1936+	1.00	1926	7.1	21.2	1925	15.0	1926	84	85	84	85	13.5	E	55	27	1963		8.7	2	4	25	11	2	0	6	0	28	31	6	41
N	5.3	- 6.7	- .7	39	1937	-40	1948	1971	0.23	1.15	1965	T	1936+	0.41	1925	3.8	19.0	1929	6.0	1925	77	76	76	75	12.7	E	54	26	1966		8	4	4	10	6	1	0	2	0	30	30	21	5
D	- 5.0	-17.4	-11.2	34	1932	-55	1924	2362	0.17	0.76	1967	0.00	1936+	0.26	1930	2.8	9.7	1929	5.0	1922	66	66	66	66	11.4	E	44	09	1960		8	8	8	8	9	1	0	2	0	31	31	29	0
YR	15.1	4.0	9.6	78	JUL. 1927	-56	FEB. 1924	20174	4.26	2.81	AUG. 1963	0.00	JAN. 1939+	1.00	OCT. 1926	29.3	21.2	OCT. 1925	15.0	OCT. 1926	79	79	78	79	11.9	E	58	27	MAR. 1960			60	53	184	74	8	*	65	*	256	323	169	212

& Sun below horizon continuously November 19 to January 23.
Data entered in columns headed "Clear, Partly Cloudy, and Cloudy" in both tables are for period sun above horizon.
Means and extremes in the above table are from the existing and comparable locations. Annual extremes have been exceeded at another location as follows:
Maximum monthly snowfall 26.5 in April 1916.

(a) Length of record, years.
(b) Climatological standard normals (1931-1960).
* Less than one half.
+ Also on earlier dates, months or years.
T Trace, an amount too small to measure.
Below-zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Degree day totals are the sums of the negative departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3; partly cloudy days 4-7; and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter. Averages in the lower table for some months may be for more than the listed number of years.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. A figure appears in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

monthly air temperatures and annual precipitation for Barrow and several Siberia coastal stations which have a somewhat similar climate are presented in Table 3.2.

Black (1954) contended that precipitation at Barrow is greater than actually recorded by standard gaging methods; perhaps by a factor of 2 to 4 times. This discrepancy between recorded and indirect observations such as snow depths and densities and soil moisture was thought to be a result of gaging inefficiencies caused by high winds during rain storms and snowfall. Recent data by USA CRREL, in which summertime precipitation was gaged over a small watershed, agreed reasonably well with the Barrow weather station data on a seasonal basis, but demonstrated considerable variability within and between storms (Brown, Dingman, and Lewellen; 1968). Mather and Thornthwaite (1956, 1958) proposed that these differences in measured precipitation were due to random variations. Benson (1962) has conducted a detailed snow survey on the North Slope of Alaska to provide a more accurate approximation of snowfall. These measurements are based on snow density and drift patterns.

Both Clebsch (1957) and Mather (1956, 1958) have engaged in evapotranspiration studies at Barrow, and the general conclusion has been that precipitation equals or only slightly exceeds total evapotranspiration during the summer period at Barrow (Britton, 1957). The four-summer hydrologic study (1963-1966) is essentially in agreement with these conclusions (Brown, Dingman, and Lewellen; 1968). It revealed that about 5% of the thaw-season precipitation runs off, but that considerable variation exists in runoff from year to year between similar storms (1 to 70%). This is a reflection of the summer precipitation record and other antecedent conditions. Therefore, since essentially all the meltwater runs off prior to the initiation of soil thaw, the precipitation period most important to the soil moisture regime occurs during the summer months.

Table 3.2 Climatic comparison of Barrow with several Siberian coastal stations.

Location	Lat.	Long.	Elev. (ft.)	Years of Record	Monthly Mean °F												Ann. (°F)	Ppt. (in.)
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Barrow	71° 18'	156° 47'	31	46	-15.3	-18.7	-15.5	-0.5	18.8	33.7	39.4	38.1	30.4	16.3	0.3	-11.4	9.7	4.6
Siberian Stations																		
Bely, Ostrov	73° 20'	70° 02'	20	7	- 6.5	-10.1	-10.1	1.8	18.3	30.9	39.7	41.4	35.4	24.4	10.4	- 1.3	14.5	6.6
Dvoryancy, Mys	72° 40'	70° 55'	171	7	-10.3	-11.3	- 8.9	1.4	19.4	32.5	40.8	43.5	35.8	23.5	8.2	- 5.3	14.2	5.9
Diksona, Ostrov	73° 30'	80° 23'	79	11	-18.4	-14.4	-13.9	-0.8	16.9	30.7	37.8	39.7	32.5	16.9	- 4.5	-11.0	9.1	6.5
Preobrazheniya, Ostrov	74° 38'	112° 48'	16	7	-17.7	-13.4	-16.1	-1.1	18.9	32.9	37.6	36.5	31.6	14.9	- 5.8	-14.8	8.6	4.5
Nordvik	73° 38'	110° 50'	102	7	-20.9	-22.0	-22.4	-3.1	16.3	34.2	41.0	39.6	33.6	13.5	-10.1	-20.0	6.6	4.8
Pronchishchevoi, Bukhta	75° 33'	113° 27'	16	7	-17.7	-14.3	-17.0	-2.0	17.2	32.7	39.2	36.7	29.1	-12.2	- 8.5	-17.9	7.5	5.9
Vankarem, Mys	67° 50'	184° 04'	16	7	-11.9	-13.0	-11.6	2.8	17.2	34.9	40.3	40.3	33.8	21.9	5.7	- 6.2	12.9	4.8

Vegetation

In general the vegetation of the Coastal Plain is meadow-like in character with an abundance of sedges, grasses, herbs and a few dwarf shrub species. Detailed accounts of species distribution and community structure have been written by Britton (1957, 1958), Spetzman (1959), Cantlon (1961), Wiggins (1951, 1962), Korando (1954) and Brown and Johnson (1965) for the area including Barrow. Hulten (1961) observed 106 species of vascular plants in the Barrow vicinity and Wiggins and Thomas (1962) enumerates 435 species on the Alaskan Arctic Slope. Britton (1957) describes the vegetation of the Coastal Plain as being less complex than the Foothills or Brooks Range because of the fewer species which are distributed over a lesser number of habitats. Northward across the Coastal Plain to Barrow, there is a general increase in the wet grassland type of vegetation with a conspicuous increase in grasses and sedges, parallelled by poorer drainage and a reduction in the woody species, particularly heat (Britton, 1957; Clebsch, 1957). Cantlon (1961) has distinguished a narrow zone including Barrow which borders the Arctic Ocean as Littoral. The vegetation strongly reflects the moderating and cooling effect of the ocean.

The vegetation at Barrow occurs primarily on drained lake basins and their gently sloping divides which are the characteristic land surfaces of the area. An understanding of species population is based upon geomorphic processes and the ages of land surfaces (Britton, 1957) which will be discussed later. Superimposed on these large scale features is the distribution of vegetation across microenvironments, particularly polygonal ground, frost scars and hummocks. These features, generated by cryopedological processes, create microhabitats that within distances smaller than a meter result in extremes of vegetation. These microstructures of vegetation have been described and mapped by Wiggins (1951) for a series of four sites that represent

different stages of polygonal ground development at Barrow. Others have described and graphically illustrated the edaphic control of vegetation across moisture and microgradients (Brown and Johnson, 1965; Drew and Tedrow, 1962; Tedrow and Cantlon, 1958; and Britton, 1957; see Fig. 3.2.)

For the purposes of this report the distribution and structure of vegetation in the Barrow area can be briefly summarized as being a predominantly wet, low grassland or tundra with abrupt spatial changes in species distribution, the results of cryopedologic and geomorphic processes peculiar to the Arctic. In addition, the moderating effect of the maritime climate at Barrow is reflected by the vegetation, in size, phenology, and species distribution. These differences in vegetation can serve as criteria for evaluating regional and local difference in the less easily observed pedologic and geomorphic parameters of the substrate.

Soils

The soils of the Barrow area have been described, classified and mapped by Drew (1957). The classification corresponds to one presented by Tedrow et al. (1958) for Arctic Alaska and includes the genetic soils termed Arctic Brown, Tundra and Bog. Brown (in press) has demonstrated that the depth to the underlying, impervious perennially frozen ground is a function of soil moisture content. The wetter and more organic soils possess the shallower depths of thaw.

The Arctic Brown soil is formed on coarse grained material; the depth of the seasonal thaw is usually in excess of a meter, and drainage is generally unimpeded. This combination results in a well-drained, brown-colored, somewhat acid soil which is considered the zonal soil of northern Alaska (Tedrow et al., 1958). At Barrow, this soil occupies only a limited area, specifically on top of the raised inland beach ridge where drainage conditions are optimum for its

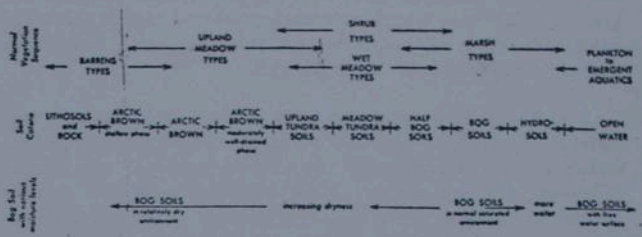

Figure 3.2 Vegetation-soil relationships along a moisture gradient characteristics of the Barrow area (Tedrow and Cantlon, 1958)

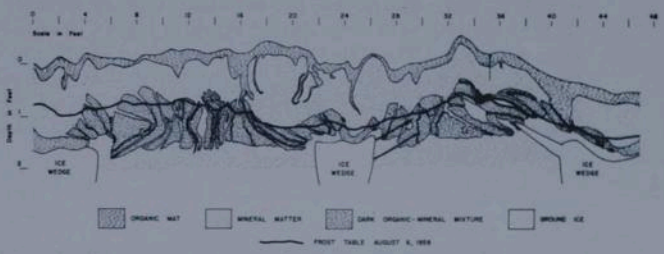

Figure 3.3 Cross section of tundra soil, Barrow, Alaska (Douglas and Tedrow, 1961).

development (Drew and Tedrow, 1957). Shallow, normal and imperfectly drained phases are recognized but were not mapped at a scale of 1:20,000. Regosols are present on gravelly deposits which are excessively drained and which have undergone virtually no soil development. Beach gravels can be considered in this type soil.

The wetter mineral soils are divided into two types: Upland Tundra and Meadow Tundra. The Upland Tundra, for which a dry and normal phase are recognized, are moderately to poorly drained and occur on predominantly fine-grained parent materials. The depth of thaw is generally less than 0.5 meter. The upper portion of the thawed soil is strongly mottled with orange-brown colors that grade into more bluish grays. A weak platy structure is observed under a thin peaty organic mat of less than 7.5 cm and is probably a reflection of the occurrence of seasonal ice lens. A semi-continuous buried organic layer is ubiquitous just above and penetrating into the perennially frozen ground. This is illustrated in Figure 3.3 (Douglas and Tedrow, 1961). The occurrence and origin of this layer will be discussed later. The Upland Tundra soils occupy an intermediate drainage position between Arctic Brown and Meadow Tundra on the silt covered uplands. The Meadow Tundra soils which are divided into dry, normal and wet phases have a peaty organic mat (7.5 to 15 cm) over a grayish brown to bluish gray wet mineral soil. The depth of the seasonal thaw is less than in the Upland Tundra and reducing conditions are dominant. These wet tundra soils correspond qualitatively to the gley soils of the northern frost zones (Douglas, 1961; Douglas and Tedrow, 1961).

Bog soils occur where surface peat has accumulated to depths in excess of 15 cm and generally do not exceed 30 cm in the Barrow area. A thaw zone of saturated, gray mineral

soil with some organic inclusion generally underlies the organic mat which in turn overlies the perennially frozen ground. Where the wet peat has been effectively drained by erosion or thawing of ice wedges, the peat is dry and the depth of thaw is considerably less than in wet organic soils. This dry phase is associated with high-centered polygons.

An idealized spatial relationship of these genetic soils are illustrated in Figure 3.4 Details of the relationship of soils, moisture regimes and vegetation are presented in Figure 3.2.

Drew's approach to soil mapping involved the classification of the ice-wedge polygons (non-sorted types) so that local microtopography and surface drainage could be related to the major soil units. The mapping legend consists of two parts: a soil classification and a polygon classification. Three types of parent materials were recognized:

1. Beach gravel along the coast.

2. Surface gravels, sand and silts of the inland beach ridge.

3. Sand, silts, clays and peats that mantle the surfaces of drained lake basins and interfluves.

A sequence of polygon types is designated dependent upon the degree of ice-wedge formation and ground deformation. An example of a polygon field containing polygons with slightly raised edges is illustrated in Figure 3.5 (see also Brown and Johnson (1965) for other examples of the Barrow pattern ground). In areas where more than one kind of polygon is present, a combination of types are mapped along with the dominant soil type. Planimeter measurements on this map yield the following distribution of soils and polygon: Soils: 75% Meadow Tundra, approximately 10% Bog soils, 5% Upland Tundra and only minor occurrence of Arctic Brown and the remainder of the land surface comprising gravel beaches and recently exposed lake alluvium. Polygons: approximately 40% of the ground surface contained polygons with flat tops, and about 20% contain polygons with distinct raised edges.

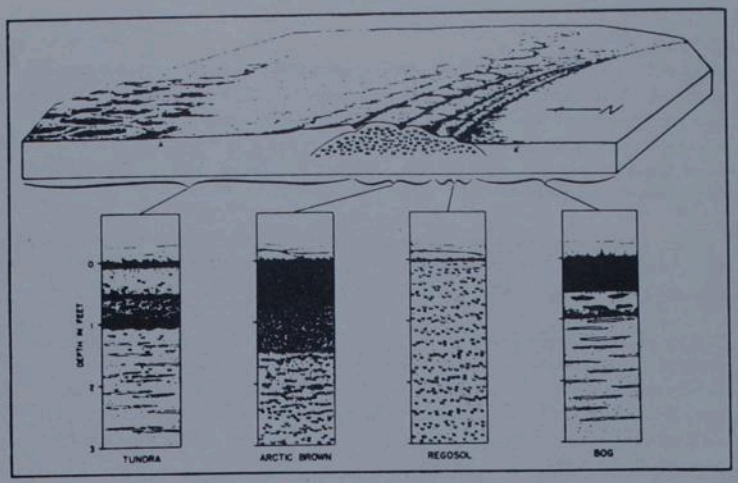

Figure 3.4 Diagram of soil conditions from a tundra landscape at Barrow, Alaska (Drew et al., 1958).

Figure 3.5 Polygon field in which edges are slightly raised. Troughs are water covered. Photo taken after light snow fall in mid-summer.

Douglas and Tedrow (1959) investigated the rates of organic matter decomposition in the different soil types. Soil temperature, moisture and type govern the rate of decomposition. Decomposition during the summer was shown to be least in the Arctic Brown, intermediate in the Upland Tundra and dry Half Bog, and greatest in the wet phase of the Half Bog. The production of organic matter probably parallels the rates of decomposition in each soil; consequently, thick peat deposits do not form. Van Cleve (1967) found that decomposition of peat at Barrow was considerably less than for more southerly latitude and amounted to only 1% of the total per year. The microbiology of the Barrow soils and near-surface permafrost has been investigated (Boyd, 1958; Boyd and Boyd, 1964). Bacteria and other microorganisms are present in the seasonally thawed soil in significant number and several viable organisms were found within the upper several meters of permafrost.

Thermal Regimes

The thermal regimes of ground and water masses in northern Alaska have received considerable attention for both the solution of engineering problems and natural surface phenomena. In the following sections geothermal gradients, soil temperatures and ground temperatures below water bodies are discussed separately.

Geothermal Gradients: Negative mean annual ground surface temperatures over a period of time result in the downward growth of perennially frozen ground. In northern Alaska, the maximum depth of perennially frozen ground that has been measured is 320 meters, while an extrapolation of the geothermal profile indicates a maximum depth of 405 meters located 12.8 km south of Barrow (Brewer, 1958). Figure 3.6 illustrates the geothermal profile at Cape Simpson Well 28, located to the southeast of Barrow (Brewer, 1958). The inverse temperature gradient of 23.7 m/C remains essentially unchanged from 76 meters through to 530 meters. Based upon rigorous analysis of these geothermal gradients, Lachenbruch and Brewer (1961) have demonstrated an

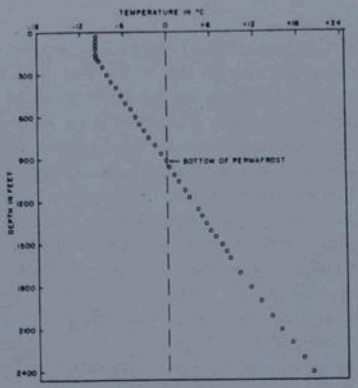

Figure 3.6. Geothermal profile for Cape Simpson Well 28, Northern Alaska (Brewer, 1958).

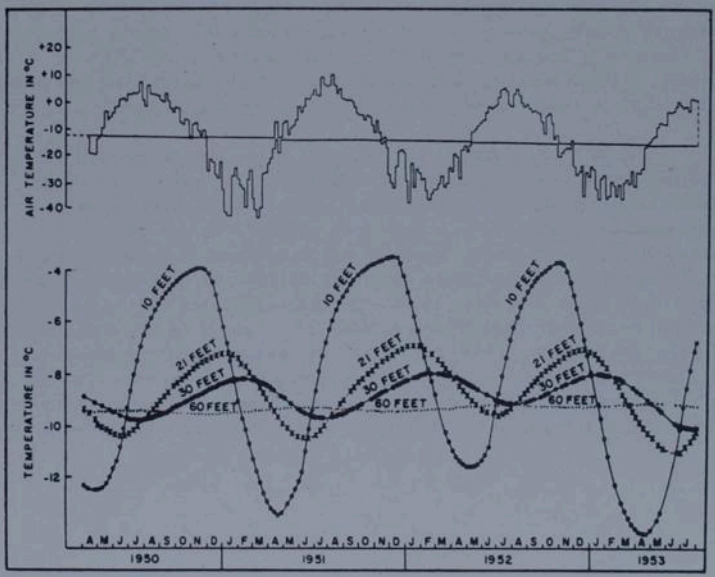

Figure 3.7. Time-temperature curves for various depths in permafrost near Barrow, Alaska (Brewer, 1958).

increase of approximately 4C in the mean annual ground surface temperature since about 1850, one-half of which occurred since 1930.

Figure 3.7 is a time-temperature curve for various depths in perennially frozen ground and the five-day average air temperature (Brewer, 1958). In general, the curves are sinusoidal with pronounced assymmetry near the ground surface. The lowest measured temperature below the maximum depth of measurable seasonal change on the North Slope is -10.6C and is located near Barrow.

Soil Thermal Regime: The characteristics of the annual temperature wave through a wet tundra soil are illustrated schematically in Figures 3.8 and 3.9 (Lachenbruch et al., 1962; Brewer, 1958). Thawing of the soil commences when spring temperatures rise above freezing (time = t). Under normal conditions thawing proceeds to the top of the perrennially frozen ground by the time autumn surface temperatures fall below freezing ($t = t_3$). From t_3 to t_5 the seasonally thawed soil freezes and the surface temperatures drop to near the annual low. Temperatures throughout the unfrozen soil drop to 0C soon after initial freezing (t_3). As freezing progresses downward and occasionally upward, a steadily decreasing slab or sandwich of soil remains isothermal as the latent heat of fusion is being extracted. The result is the "zero curtain" or the period during which temperatures at a given depth remain at the freezing point (t_3 to t_4). The lower part of the seasonally thawed soil freezes between t_4 and t_5. Once it is totally frozen the cold wave can penetrate into the perennially frozen ground. The zero curtain phenomenon is of little significance in the spring thaw period. Figure 3.9 presents the time-temperature curve for the 25-cm depth in a wet tundra soil at Barrow. The average annual temperatures at the top of the perennially frozen ground at Barrow ranges between -7.0 and -9.5C.

The rate and depth of seasonal thaw has been measured across the soil gradient illustrated in Figure 3.4 (Drew et al., 1958).

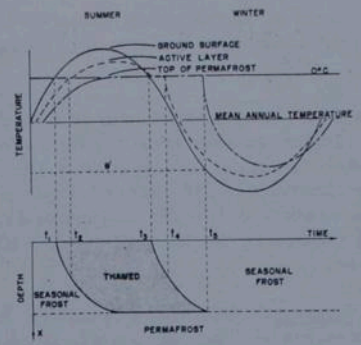

Figure 3.8. Diagram illustrating the passage of the annual temperature wave through a wet tundra soil (Lachenbruch et al., 1962).

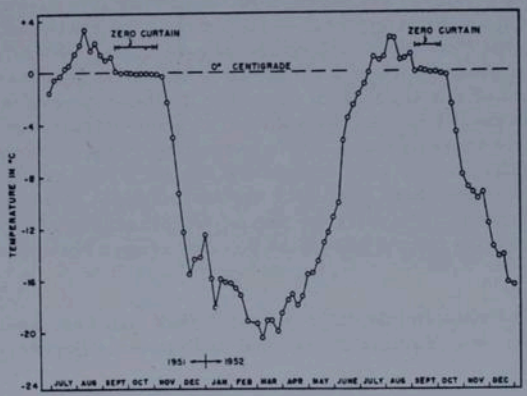

Figure 3.9. Time temperature curve at a depth of 25 cm for a tundra area near Barrow, Alaska; note the prominent "zero curtain" in the fall of each year.

The Arctic Brown soil is first to thaw, thawed to the greater depth and froze earlier in the fall. Late season snow cover retards the initiation of thawing in the Tundra and Bog soils to late June. In these soils, seasonal thaw is less than 50% that of the Arctic Brown and freeze-back was considerably slower. The Tundra and Bog soils pass through a narrower diurnal and seasonal range of soil temperatures than does the Arctic Brown. The modifying effect is caused by the insulating peat layer and the high moisture content in the Tundra and Bog soils. Variations in soil temperatures result from differences in texture, soil moisture, snow cover, vegetation, microrelief and exposure.

Water Bodies: Masses of impounded water and flowing water influence the temperatures of the underlying ground (Brewer, 1958; Lachenbruch et al., 1962). In general, water bodies that do not freeze to the bottom in the winter are underlain by a zone of about 60 meters of unfrozen sediment. The volume and shape of this unfrozen zone is dependent upon the configuration and size of the water body. In northern Alaska, lakes less than 2 meters deep usually freeze to the bottom and consequently are underlain by perennially frozen ground with temperatures up to 3C warmer than under adjacent tundra. Shallow streams that freeze to the bottom modify the temperature of the underlying perennially frozen ground. Brewer (1958) has shown that one such stream introduced a 3C warming to a depth of 40 meters. The effects of the proximity of the ocean upon ground temperatures at the 30-meter depth was reported by Brewer (1958). At approximately 100 meters inland, the temperatures was -7.33C; at the edge of the ocean, -4.91C; and approximately 100 meters offshore, -0.96C. Lachenbruch (1957) has stated that it is unlikely that perennially frozen ground would exist to depths greater than about 30 meters beneath the ocean for distances of more than roughly 500 meters offshore.

Geomorphology

The Barrow area is an emergent coastal plain. A sequence of weakly defined uplifted beach ridges are observed on the present

tundra surface. Radiocarbon age determination from the reworked deposit of the first inland beach ridge yielded a date of 25,000 years B.P. (Brown, 1965). This may represent a transgression that took place prior to the Wisconsin maximum (Woronzofian Transgression, see Hopkins, 1967; Brown, 1965; Sellmann and Brown, 1965). The present-day, hooked-shaped gravel spit is currently building to the southeast and is believed to be at least 1,100 years old (Rex, 1964; Pewe and Church, 1962; Hume, 1965; Brown and Sellmann, 1966; and Hume and Schalk, 1967). Based on a number of radiocarbon dates, Brown (1965) concluded that the majority of the soils and surficial features in the present Barrow land surface are not older than 8,300 years and are perhaps considerably younger.

As mentioned previously, the physical aspect of the Coastal Plain and the Barrow area is dominated by polygonal ground, oriented lakes and rapidly eroding lagoonal shorelines. These active geomorphic features are intricate reflections of the perennially frozen ground and will be briefly reviewed under two broad headings: 1) polygonal ground and ice wedges; and 2) lakes and shoreline processes.

Polygonal Ground and Ice Wedges: Ice wedge polygons are interconnecting ground patterns, generally orthogonal with diameters ranging from a few meters to more than 100 meters. The troughs form the outlines of the polygons and are underlain by ice wedges. These wedges are vertically foliated, vein-like intermeshing masses of ice that generally taper downward through the upper 10 meters of perennially frozen ground. Northern Alaska is an area of active, ice-wedge growth (Pewe, 1966). The thermal contraction theory is commonly accepted as the mechanism responsible for the formation of ice wedges and the resulting polygons (Lachenbruch, 1962). Briefly stated, the ground contracts and cracks in winter as it cools. The cracks are partially filled with hoarfrost or spring melt-water and a vertical, vein-like mass of ice forms. The ground expands during the summer closing unfilled cracks and forcing perennially frozen ground

upward to form ridges or flows in the seasonally thawed zone adjacent to the growing wedge. The contraction cracks originate at the top of the wedge and propagate upward and downward thus assuring repeated cracking in the wedge in a zone of weakness. This repeated cracking and filling of the ground with ice over many hundreds of years produces the large, V-shaped masses of ice that may eventually occupy 90% of the near-surface ground volume. Black (1963 and unpubl.) has measured the distribution and frequency of ground cracking for several types of polygonal ground in the Barrow area and found that more than 50% of the wedges crack each winter.

The geomorphic and pedologic implications of ice wedges are numerous, and only a few are briefly mentioned. Lachenbruch (1962) has indicated that the wedges or their casts serve as excellent stratigraphic markers. Ice-wedge growth is a function of climate and can be a valuable indicator of climatic variations. Their casts and truncated remains can indicate periods of thaw or thermal erosion (Brown, 1965, 1967). The pushing up of ridges adjacent to wedges forms basins which impound water and can lead to thermokarst or melt-out ponds. Water flowing over ice-wedge troughs may melt the wedges and cause drainage or accentuate erosional processes. The accumulation of ice-wedge ice in the ground is responsible for increasing the volume of the ground which may result in areas of topographic highs (Hussey and Michelson, 1966). Conversely, areas of low ice form depressions. Depositional events are also detected by the locations and activity of wedges. Finally, the stirring of the soil by the pressures resulting from ice-wedge growth and seasonal expansion of the ground result in the complex soil morphology uncommon to areas lacking perennially frozen ground. Polygons are commonly thought to proceed through a cycle from initially flat surface with cracks to networks with slightly raised edges and finally to polygons with high centers and deep troughs (Black, unpubl.; Drew and Tedrow, 1965). Subdivision of the polygons into smaller units occur with time and changing thermal regimes of the ground. This provides clues to changing climates and the relative ages of the land surfaces.

Lakes and Shoreline Processes: The presence of elliptically shaped, shallow lakes and drained lake basins have an average orientation of 10-15° west of north has lead to a multiple-working hypothesis for the explanation of their occurrence. A hypothesis based upon the existence of a former prevailing wind that was parallel to the long axis of the lakes has been abandoned, principally because elongation is still active today (Black and Barksdale, 1949; Black, 1964). Present-day prevailing winds are approximately perpendicular to the long axis of the lakes. The second and more plausible wind theory (Livingstone, Bryan and Leahy, 1954; Carson, 1962) is that orientation is in part the result of longshore currents that erode at the ends of the lakes faster than along the downwind shorelines. Carson (1962) has refined and quantified this approach. He maintains that the sublittoral shelves which are formed along the elongated east and west shorelines inhibit erosion by wind-driven currents, wave action and thermal erosion, while these agents are active at the north and south ends of the lakes. Lewellen (1965) has documented this differential rate by measurements on a sequence of aerial photography (1948-1964). He domonstrated that the north end of East Twin Lake had eroded at a rate of 1.3 m/yr. Figure illustrates the total amount of erosion along this lake shore and the adjacent lagoonal shoreline for the period of measurement.

The erosive character of the lakes as an active geomorphic agent has been described by Britton (1957, 1958) as the thaw-lake cycle. In the process of eroding the surrounding tundra, the lakes enlarge their basins. As the eroding lakes remove the interlake divides, they merge to form large lakes such as Footprint Lake in the Barrow area. Eventually a drainage divide is breached and all or part of the lake basin is drained leaving the shelves or lake bottom exposed. On this new land surface, ice wedge polygons form from either the partial thaw of the underlying truncated mesh of ice wedges or by the growth of new wedges. Small ponds remain in the old drained basins or develop in centers of raised-edge polygons. These ponds slowly erode their borders, merge with other ponds, and, in turn, form new lakes.

The effect of the thaw-lake cycle on the near-surface sediment and soil parent material is considerable. Much of the near-surface sediment in the Barrow area has been reworked by the lake erosion cycle; thereby destroying the primary sedimentary structure. The presence of very old lake basins are often difficult to detect where highly developed polygonal ground has formed. For their detection, geochemical studies are useful indicators of pre-existing fresh water environments (O'Sullivan, 1966; Brown, 1966, in press). These combinations of geomorphic agents impose serious limitations on an interpretation of soil forming processes since second and third cycle sediments and peats may be present at any given location (Brown, 1967). Britton (1957) has accurately stated that today's lake is tomorrow's land surface and that the present land surface is the site of future lakes.

In addition to erosion by lakes, the ocean and lagoonal shorelines are similarly susceptible to rapid erosion as was demonstrated by MacCarthy (1953). Erosion along the lagoon is greatly expedited by the differential thaw of the ice wedges which then permit large blocks of frozen ground to calve or slump onto the beach where they are quickly retransported into the ocean or lagoon. Rates of erosion as great as 10 meters per year have been reported from a study of some 75 kilometers of lagoonal shoreline in the Barrow area (Lewellen, 1965; Lewellen and Brown, 1965). Rates between 0.2 and 2 m/yr are more common with differential erosion or retreat a function of cliff exposure and composition and currents and depth of offshore waters (see Figure 3.10for total amount of erosion between 1948 and 1964).

Subsurface Geology

The Arctic Coastal Plain is composed of the Gubik formation of Pleistocene age which unconformably overlies rocks of Cretaceous and Tertiary age (Black, 1964; O'Sullivan, 1961). The Gubik sediments are shallow, near-shore marine deposits composed of admixtures of silts, fine sands, and gravels. Fluvial,

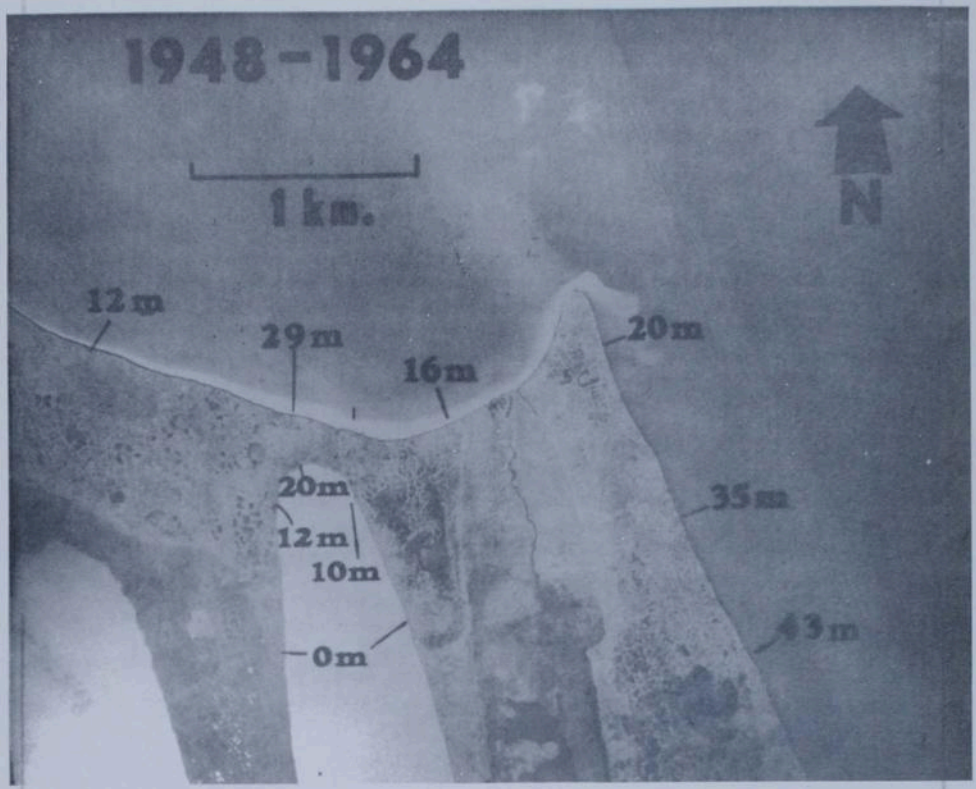

Figure 3.10. Aerial photograph of Twin Lakes and Elson Lagoon shorelines indicating differential rates of erosion between 1948 and 1964.

lacustrine and eolian deposition and frost processes have modified the upper sediments. Black (1964) distinguished three main lithologic units: The Skull Cliff (oldest), the Meade River and the Barrow unit (youngest). The stratigraphic portion of the present research program further delineated the two near-surface units found in the Barrow areas: The Barrow unit (upper) overlies unconformably the Skull Cliff unit (lower) (Sellmann, Brown, Schmidt, 1965). The upper unit varies between 7 and 10 meters in thickness and overlies the lower unit between 2 and 7 meters below sea level. Grain size analyses from 6 holes spaced along two traverses (Sellmann and Brown, 1965) 3 and 6 kilometers in length, yield the following average values:

	Upper Unit	Lower Unit
Less than 0.002 mm(%)	6	22
0.002 to 0.05 mm (%)	8	42
Greater than 0.05 mm (%)	86	36
Mediam diameter (mm)	0.11	0.04
Skewness	0.89	0.46

The upper unit was deposited in a high energy, near-shore environment and the lower unit either in an alternately open and closed lagoonal environment or low energy, near-shore environment. Differences in the microfossil assemblages between the units were observed. A radiocarbon date of greater than 36,000 years was obtained from the lower unit. A stratigraphic study of the Barrow village estuary indicates an accumulation of perhaps 10 meters of sediment during the past 6,500 years within that basin (Faas, 1966).

Summary

The Barrow environment can be characterized as follows:

1) Situated at the northern extremity of the Arctic Coastal Plain, it has a climate consisting of long, dry, cold winters and short, moist, cool summers. The latter is moderated by the influence of the Arctic Ocean.

2) Vegetation is meadow-like with an abundance of sedges, grasses, herbs and a few dwarf shrub species.

3) Soils are predominantly wet, with an average seasonal thaw of approximately 40 cm.

4) Perennially frozen ground underlies the entire land surface to depths in excess of 300 meters.

5) The near-surface coastal plain sediments are marine in origin and mid- to late-Pleistocene in age.

6) The tundra landscape is characterized by active geomorphic processes such as lake erosion, polygonal ground formation and frost stirring of the soil.

Specific references for Section 3

Benson, C. S., 1962. Reconnaissance snow studies on the Arctic slope. Proc. 13th Alaskan Science Conf., p. 164-166.

Black, R. F., Ice wedges and permafrost of the Arctic Coastal Plain of Alaska, 788 p., unpubl. ms.

Black, R. F., 1954. Precipitation at Barrow, Alaska, greater than recorded. Am. Geophys. Union Trans. 35:203-206.

Black, R. F., 1963. Les coins de glace et le gel permanent dans le Nord de l'Alaska. Annales de Geographie No. 391, p. 257-271.

Black, R. F., 1964. Gubik formation of Quaternary age in northern Alaska. U.S. Geol. Survey Prof. Paper 302-C.

Black, R. F. and W. L. Barksdale, 1949. Oriented lakes of Northern Alaska. Jour. Geology 57:105-118.

Boyd, W. L., 1958. Microbiological studies of Arctic soils. Ecology 39:332-336.

Boyd, W. L. and J. W. Boyd, 1964. The presence of bacteria in permafrost of the Alaskan Arctic. Canadian Jour. Microbiology 10:917-918.

Brewer, M. C., 1958. Some results of geothermal investigations of permafrost in Northern Alaska. Am. Geophys. Union Trans. 39:19-26.

Britton, M. E., 1957. Vegetation of the Arctic tundra.in Arctic Biology, 18th Ann. Biol. Colloquium, Oregon State College, p. 26-61.

Britton, M. E., 1958. A tundra landscape. Research Rev., ONR, p. 4-13.

Britton, M. E., 1964. ONR Arctic Research Laboratory, Bioscience, p. 44-48.

Brown, J., 1965. Radiocarbon dating, Barrow, Alaska. Arctic 18:36-48.

Brown, J., 1966. Ice-wedge chemistry and related frozen ground processes, Barrow, Alaska. Proc. Intern. Permafrost Conf., NAS-NRC Publ. 1287, p. 94-98.

Brown, J., 1967. Tundra soils formed over ice wedges, northern Alaska. Soil Sci. Soc. Amer. Proc. 31:686-691.

Brown, J., (in press). Soil properties developed on the complex tundra relief of northern Alaska. Buiietyn Peryglacjalny.

Brown, J. and P. L. Johnson, 1965. Pedo-ecological investigations, Barrow, Alaska. U.S. Army CRREL Tech. Rept. 159.

Brown, J. and P. L. Johnson, 1966. U.S. Army CRREL Topographic Map, (1:25,000). U.S. Army CRREL Spec. Rept. 101.

Brown, J. and P. V. Sellmann, 1966. Radiocarbon dating of coastal peat, Barrow, Alaska. Science 153:299-300.

Brown, J., S. L. Dingman, and R. I. Lewellen, 1968. Hydrology of a small drainage basin on the coastal plain of northern Alaska. U.S. Army CRREL Res. Rept. 240.

Cantlon, J. E., 1961. Vegetation along environmental gradients in Arctic Alaska. Ecol. Soc. America Bull. 42:162-163, abst.

Cantlon, J. F., 1961. Plant cover in relation to macro-, meso-, and micro-relief. Final Report, AINA-ONR grants, ONR 208-212 and Vegetation along environmental gradients in Arctic Alaska, Ecol. Soc. Amer. Bull. 42:162-163.

Carson, C. E. and K. M. Hussey, 1962. The oriented lakes of Arctic Alaska. Jour. Geology 70:417-439.

Clebsch, E. E. C., 1957. The summer season climatic and vegetational gradient between Point Barrow and Meade River, Alaska, M.S. thesis, Univ. Tenn., 60 p.

Colinvaux, P. A., 1964. Origin of ice ages: Pollen evidence from Arctic Alaskan Science 145:707-708 and Science 147:633.

Dostovalov, B. N. and V. A. Kudriavtsev, 1967. General geocryology. Publishing House, Moscow University.

Douglas, L. A., 1961. A pedologic study of tundra soils from Northern Alaska. Ph.D. thesis, Rutgers Univ., 147 p.

Douglas, L. A. and J. C. F. Tedrow, 1959. Organic matter decomposition rates in Arctic soils. Soil Sci. 88:305-312.

Douglas, L. A. and J. C. F. Tedrow, 1961. Tundra soils of Arctic Alaska. 7th Intern. Cong. Soil Sci. Proc., Comm. V., Vol. IV:291-304.

Drew, J. V., 1957. A pedologis study of Arctic Coastal Plain soils near Point Barrow, Alaska. Ph.D. thesis, Rutgers Univ., 117 p.

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

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

Drew, J. V. and J. C. F. Tedrow, 1962. Arctic soil classification and patterned ground. Arctic 15:109-116.

Faas, R. W., 1966. Paleoecology of an arctic estuary. Arctic 19:343-348.

Grigor'ev, N. F., 1966. Perennially frozen rocks in the near shore zone of Yakutia. Akad. Nauk SSSR, Sibirskve Otd, Inst. Merzlotovsndiia, Izd-vo "Nauka", Moskva, 180 p.

Hopkins, D. M., 1967. Quaternary marine transgressions in Alaska in The Bering Land Bridge, Stanford Univ. Press, Stanford, Calif., p. 47-90.

Hulten, E., 1961. List of plants growing around the base at Barrow (Mimeographed Arctic Research Laboratory Note).

Hume, J. D., 1965. Sea level changes during the last 2,000 years at Point Barrow, Alaska. Science 150:1165-1166.

Hume, J. D. and M. Schalk, 1967. Shoreline processes near Barrow, Alaska: A comparison of the normal and the catastrophic. Arctic 20:86-103.

Hussey, K. M. and R. W. Michelson, 1966. Tundra relief features near Point Barrow, Alaska. Arctic 19:162-184.

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

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

Lachenbruch, A. H., 1962. Mechanics of thermal contraction cracks and ice-wedge polygons in permafrost. Spec. Geol. Soc. America Paper 70, 69 p.

Lachenbruch, A. H. and M. C. Brewer, 1961. Geothermal evidence for recent climatic change near Barrow, Alaska. Geol. Soc. Amer. Spec. Paper 68, p. 117.

Lachenbruch, A. H., M. C. Brewer, G. W. Greene, and B. V. Marshall, 1962. Temperatures in permafrost, in Temperature, its Measurement and Control in Science and Industry, Vol. 3, Part I, p. 791-803.

Lewellen, R. I., 1965. Characteristics and rates of thermal erosion, Barrow, Alaska. M.S. dissertation, Univ. of Denver.

Lewellen, R. I. and J. Brown, 1965. A retrograding lagoonal shoreline, Barrow, Alaska. Abst. VII Intern. Congr. INQUA, p. 291.

Livingstone, D. A., K. Bryan, Jr. and R. G. Leahy, 1958. Effects of an Arctic environment on the origin and development of fresh-water lakes, Limn. and Ocean 3:192-214.

MacCarthy, G. R., 1953. Recent changes in the shoreline near Point Barrow, Alaska. Arctic 6:44-51.

Materials of the VIII All-Union Conference on Geocryology, Vol. 2-8, Yakutsk, 1966.

Mather, J. R. and C. W. Thornthwaite, 1956. Microclimatic investigation at Point Barrow, Alaska, 1956. Drexel Inst. Tech. Lab. Climatology, Publ. Climatology V. 9, 51 p.

Mather, J. R. and C. W. Thornthwaite, 1958. Microclimatic investigations at Point Barrow, Alaska, 1957-1958. Drexel Inst. Tech., Lab. Climatology, Publ. Climatology, V. 11, No. 2, 239 p.

Nuttonson, M. Y., 1950. Agricultural climatology of Siberia, natural belts and agro-climatic analogues in North America. American Inst. of Crop Ecology.

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

O'Sullivan, J. B., 1966. Geochemistry of permafrost, Barrow, Alaska. Permafrost Intern. Conf., NAS-NRC Publ. No. 1287, p. 30-37.

Péwé, T. L., 1966. Ice wedges in Alaska - classification, distribution, and climatic significance. Permafrost Intern. Conf., NAS-NRC Publ. No. 1287, p. 76-81.

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

Rex, R. W., 1964. Arctic beaches, Barrow, Alaska. In Papers in Marine Geology, MacMillan, N. Y., p. 384-400.

Sellmann, P. V. and J. Brown, 1965. Coring of frozen ground, Barrow, Alaska. U.S. Army CRREL Spec. Rept. 81.

Sellmann, P. V., J. Brown and R. A. M. Schmidt, 1965. Late-Pleistocene stratigraphy, Barrow, Alaska. Abst. VII Intern. Congr. INQUA, p. 419-420.

Spetzman, L. A., 1959. Vegetation of the Arctic Slope of Alaska. U.S. Geol. Survey Prof. Paper 302-B, p. 19-58.

Tedrow, J. C. F. and J. E. Cantlon, 1958. Concepts of soil formation and classification in Arctic Regions. Arctic 11:166-179.

Tedrow, J. C. F., J. V. Drew, D. E. Hill and L. A. Douglas, 1958. Major genetic soils of the Arctic slope of Alaska. Jour. Soil Sci. 9:33-45.

U.S. Department of Commerce, Local Climatological Data, Annual Summary 1966, Barrow, Alaska.

Van Cleve, K., 1967. Nutrient loss from organic matter placed in soil in different climatic regions. Ph.D. dissertation, Univ. Calif. 290 pp.

Wiggins, I. L., 1951. The distribution of vascular plants on polygonal ground near Point Barrow, Alaska, Contr. Dudley Herbarium 4:41-56, Stanford Univ.

Wiggins, I. L. and J. H. Thomas, 1962. A Flora of the Alaskan Arctic Slope, Univ. Toronto Press, 425 p.

Section 4

Bibliography of the Barrow, Alaska, IBP Ecosystem Model*

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Bibliography of the Barrow, Alaska, IBP Ecosystem Model*

Bernard, H. W. and J. J. Kelley Jr. 1964. Some observations of soil temperature at Barrow, Alaska. Dept. Atmospheric Sciences, Univ. Wash.

Black, R. F. 1954. Precipitation at Barrow, Alaska, greater than recorded. Am. Geophys. Union Trans., 35:203-206.

Bohnsack, K. K. 1968. Distribution and abundance of the tundra arthropods in the vicinity of Pt. Barrow, Alaska. Final Report, AINA.

Boyd, W. L. 1958. Microbiological studies of arctic soils. Ecol., 39: 332-336.

Boyd, W. L. 1959. Limnology of selected arctic lakes in relation to water supply problems. Ecol., 40:49-54.

Boyd, W. L., and J. W. Boyd. 1962. Viability of thermophiles and coliform bacteria in arctic soils and water. Can. Jour. Microbiol., 8:189-192.

Boyd, W. L., and J. W. Boyd. 1963b. A bacteriological study of an arctic coastal lake. Ecol., 44:702-710.

Boyd, W. L., and J. W. Boyd. 1964. The presence of bacteria in permafrost of the Alaskan arctic. Can. Jour. Microbiol., 10:917-918.

Brewer, M. C. 1958. The thermal regime of an arctic lake. Amer. Geophys. Union Trans., 39:278-284.

Brown, J. 1965. Radiocarbon dating, Barrow, Alaska. Arctic, 18:36-48.

Brown, J. 1966. Ice-wedge chemistry and related frozen ground processes, Barrow, Alaska. Proc. Intern. Permafrost Conf., NAS-NRC Publ. 1287, pp. 94-98.

Brown, J. 1967. Tundra soils formed over ice wedges, northern Alaska. Soil Sci. Soc. Amer. Proc., 31:686-691.

Brown, J. (In press) Soil properties developed in the complex tundra relief of northern Alaska. Builetyn Peryglacjalny.

Brown, J., S. L. Dingman, R. I. Lewellen. (In press) Hydrology of a small drainage basin on the coastal plain of northern Alaska. U. S. Army CRREL Res. Report 240.

Brown, J., C. L. Grant, F. C. Ugolini, and J. C. F. Tedrow. 1962. Mineral composition of some drainage waters from Arctic Alaska. Jour. Geophys. Research, 67:2447-2453.

Brown, J., and P. L. Johnson. 1965. Pedo-ecological investigations, Barrow, Alaska. U. S. Army CRREL Tech. Rept. 159.

Brown, J., and P. V. Sellman, 1966. Radiocarbon dating of coastal peat, Barrow, Alaska. Science, 153:299-300.

Clebsch, E. E. C. 1957. The summer season climatic and vegetational gradient between Point Barrow and Meade River, Alaska. M. S. thesis, Univ. Tennessee, 60 pp.

Cohen, D. M. 1954. Age and growth studies on two species of whitefish from Point Barrow, Alaska. Stanford Ichthyological Bull., 4:168-187.

Colinvaux, P. A. 1964. Origin of ice ages: Pollen evidence from Arctic Alaska. Science, 145:707-708, and Science, 147:633.

*With corrections and minor changes by F. A. Pitelka.

Comita, G. W., and W. T. Edmondson, 1953. Some aspects of the limnology of an arctic lake, Stanford Univ. Publ., Biol. Sci., 11:7-13.

Comita, G. W. 1956. A study of a calanoid copepod population in an arctic lake. Ecol., 37;336-591.

Douglas, L. A. 1961. A pedologic study of tundra soils from northern Alaska. Ph.D. thesis, Rutgers Univ., 147 pp.

Douglas, L. A., and J. C. F. Tedrow. 1959. Organic matter decomposition rates in arctic soils. Soil Sci., 88:305-312.

Douglas, L. A., and J. C. F. Tedrow. 1961. Tundra soils of Arctic Alaska. 7th Intern. Cong. Soil Sci. Proc., Comm. V, Vol. IV:291-304.

Drew, J. V. 1957. A pedologic study of Arctic Coastal Plain soils near Point Barrow, Alaska. Ph.D. thesis, Rutgers Univ., 117 pp.

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

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

Edmondson, W. T. 1955. The seasonal life history of Daphnia in an arctic lake. Ecol., 36:439-455.

Hock, R. J., H. Erickson, W. Flagg, P. F. Scholander, and L. Irving. 1952. Composition of the ground-level atmosphere at Point Barrow, Alaska. Jour. Meteor., 9:441-442.

Holmes, R. T. 1966a. Breeding ecology and annual cycle adaptations of the red-backed sandpiper (Calidris alpina) in northern Alaska. Condor, 68:3-46.

Holmes, R. T. 1966b. Feeding ecology of the red-backed sandpiper (Calidris alpina) in Arctic Alaska. Ecol., 47:32-45.

Holmes, R. T. 1966c. Molt cycle of the red-backed sandpiper (Calidris alpina) in western North America. Auk, 83:514-533.

Holmes, R. T., and F. A. Pitelka. 1964. Breeding behavior and taxonomic relationships of the curlew sandpiper. Auk, 81:362-379.

Holmes, R. T., and F. A. Pitelka. 1968. Food overlap among co-existing sandpipers on northern Alaskan tundra. Syst. Zool., 17:305-318.

Holmquist, C. 1963. Some notes on Mysis relicta and its relatives in northern Alaska. Arctic, 16:109-128.

Hulten, E. 1961. List of plans growing around the base at Barrow. (Mimeographed note, Arctic Research Laboratory).

Hurd, P. D. 1958. Analysis of soil invertebrate samples from Barrow, Alaska. Final Report, Arctic Inst. North America. Mimeo., 24 pp.

Kalff, J. 1965. Primary production rates and the effects of some environmental factors on algal photosynthesis in small arctic tundra ponds. Ph. D. thesis, Indiana Univ., 122 pp.

Kelley, J. J., Jr. 1964. An analysis of carbon dioxide in the arctic atmosphere at Point Barrow, Alaska. 1961-1962-1963. Univ. Wash., Dept. Atmospheric Sci. Tech. Rept.

Kelley, J. J., Jr., D. T. Barley, and B. J. Lieske. 1964. Radiative energy exchange over arctic land and sea. Univ. Wash., Dept. Atmospheric Sci. Scientific Report.

Kelley, J. J., Jr., and D. F. Weaver. 1965. Carbon dioxide and ozone in the arctic atmosphere. Proc. 15th Alaskan Sci. Conf., pp. 151-167.

Kelley, J. J., Jr., and D. F. Weaver. 1968. Measurement of the thermal regime of the soil and atmosphere near an arctic tundra surface. Dept. Atmospheric Science, Univ. Wash., Scientific Report.

Kelley, J. J., Jr., D. F. Weaver, and B. P. Smith. 1968. The variation of carbon dioxide under the snow in the arctic. Ecol., 49:358-361.

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

Lewellen, R. I. 1965. Characteristics and rates of thermal erosion, Barrow, Alaska. M. S. thesis, Univ. Denver.

Lieske, B. J., and L. A. Stroschein. 1967. Measurement of radiative flux divergence in the arctic. Archiv für Meteor., Geophy., und Bioklim. Band 15, Heft 1-2, pp. 67-81.

Lieske, B. J., and L. A. Stroschein. 1968. Radiative regime over arctic tundra. Univ. Washington, Dept. Atmospheric Science, ONR report.

Livingstone, D. A., K. Bryan, Jr., and R. G. Leahy. 1958. Effects of an arctic environment on the origin and development of freshwater lakes. Limn. and Ocean., 3:192-214.

Maher, W. J. 1961. Population ecology of three species of jaegers in northern Alaska. Ph.D. thesis, Univ. California (Berkeley), 385 pp.

Maher, W. J. 1964. Growth rate and development of endothermy in the snow bunting (Plectrophenax nivalis) and Lapland longspur (Calcarius lapponicus) at Barrow, Alaska. Ecol., 45:520-528.

Mather, J. R., and C. W. Thornthwaite. 1956. Microclimatic investigation at Point Barrow, Alaska, 1956. Drexel Inst. Tech., Lab. Climatology, Publ. Climatology vol. 9, 51 pp.

Mather, J. R., and C. W. Thornthwaite. 1958. Microclimatic investigations at Point Barrow, Alaska, 1957-1958. Drexel Inst. Tech., Lab. Climatology, Publ. Climatology, vol. 11, no. 2, 239 pp.

Mayer, W. V. 1953a. A preliminary study of the Barrow ground squirrel, Citellus parryi barrowensis. Jour. Mamm., 34:334-345.

Mayer, W. V., 1953b. Some aspects of the ecology of the Barrow ground squirrel, Citellus parryi barrowensis. Stanford Univ. Publ., Biol. Sci., 11:48-55.

Mayer, W. V., and E. T. Roche. 1954. Developmental patterns in the Barrow ground squirrel, Spermophilus undulatus barrowensis. Growth, 18:53-69.

McBee, R. H., and L. P. Gaugler. 1956. Identity of thermophilic bacteria isolated from arctic soils and waters. Jour. Bact., 71:186-187.

McBee, R. H., and V. H. McBee. 1956. The incidence of thermophilic bacteria in arctic soils and waters. Jour. Bact., 71:182-185.

Menzies, R. J., and J. L. Mohr. 1962. Benthic Tanaidacea and Isopoda from the Alaskan Arctic and the Polar Basin. Crustaceana, 3:192-202.

Mohr, J. L., D. J. Reish, J. L. Barnard, R. W. Lewis, and S. R. Geiger. 1961. The marine nature of Nuunh Lake and small ponds of the peninsula of Point Barrow, Alaska. Arctic, 14:211-223.

Mullen, D. A. 1965. Physiologic correlations with population density and other environmental factors in the brown lemming, Lemmus trimucronatus. Ph. D. thesis, Univ. California (Berkeley), 177 pp.

Mullen, D. A. 1968. Reproduction in brown lemmings (Lemmus trimucronatus) and its relevance to their cycle of abundance. Univ. Calif. Publ. Zool., 85:1-24.

O'Sullivan, J. B. 1966. Geochemistry of permafrost: Barrow, Alaska. Proc. Permafrost Int. Conf. NAS-NRC Publ. 1287, pp. 30-37.

Pieper, R. D. 1963. Production and chemical composition of arctic tundra vegetation and their relation to the lemming cycle. Ph.D. thesis, Univ. California, 95 pp.

Pitelka, F. A. 1957a. Some aspects of population structure in the short term cycle of the brown lemming in northern Alaska. Cold Spring Harbor Symp. Quant. Biol., 32:237-251.

Pitelka, F. A. 1957b. Some characteristics of microtine cycles in the arctic. In Arctic Biology, 18th Annual Biol. Coll., Oregon State Univ., pp. 73-88.

Pitelka, F. A. 1959. Numbers, Breeding schedule, and territoriality in pectoral sandpipers of northern Alaska. Condor, 61:233-264.

Pitelka, F. A. 1964. The nutrient recovery hypothesis for arctic microtine cycles. I. Introduction. Pp. 55-56, in Grazing in Terrestrial and Marine Environments, Blackwell Scientific Publications, Oxford.

Pitelka, F. A., P. Q. Tomich, and G. W. Treichel. 1955a. Breeding behavior of jaegers and owls near Barrow, Alaska. Condor, 57:3-18.

Pitelka, F. A., P. Q. Tomich, and G. W. Treichel. 1955b. Ecological relations of jaegers and owls as lemming predators near Barrow, Alaska. Ecol. Mono., 25:85-117.

Prescott, G. W. 1953. Preliminary notes on the ecology of freshwater algae on the Arctic Slope, Alaska, with description of some new species. Amer. Midl. Nat., 50:464-473.

Prescott, G. W. 1963a. Ecology of Alaskan freshwater algae. II. Introduction: General considerations. Trans. Amer. Micro. Soc., 82:83-93.

Prescott, G. W. 1963b. Ecology of Alaskan freshwater algae. III-IV. Introduction: General features (additional notes). Trans. Amer. Micro. Soc., 82:137-143.

Prescott, G. W. 1965. Ecology of Alaskan freshwater algae. V. Limnology and flora of Malikpuk Lake. Trans. Amer. Micros. Soc., 84:427-478.

Rausch, R. 1950. Observations on a cyclic decline of lemmings (Lemmus) on the Arctic Coast of Alaska during the spring 1949. Arctic, 3:166-177.

Scholander, P. F., W. Flagg, R. J. Hock, and L. Irving. 1953. Studies on the physiology of frozen plants and animals in the arctic. Jour. Cellular Comp. Physiol., vol. 42, suppl. 1, 56 pp.

Scholander, P. F., W. Flagg, V. Walter, and L. Irving. 1952. Respiration in some arctic and tropical lichens in relation to temperature. Amer. Jour. Botany, 39:707-713.

Scholander, P. F., W. Flagg, V. Walter, and L. Irving. 1953. Climatic adaptation in arctic and tropical poikilotherms. Phys. Zool., 26:67-92.

Schultz, A. M. 1961, 1962. Productivity and nutrient cycles in the soil-vegetation-animal system of arctic tundra. Annual Progress Report, NSF G-12963 and NR 307-264.

Schultz, A. M. 1965a. The nutrient recovery hypothesis for arctic microtine cycles. II. Ecosystem variables in relation to arctic microtine cycles. In Grazing in Terrestrial and Marine Environments, pp. 57-68.

Schultz, A. M. 1965b. The tundra as a homeostatic system. Paper presented at AAAS symposium, "Polar Lore Since 1954," Dec. 29, 1965, Berkeley, Calif.

Shoemaker, C. R. 1955. Amphipoda collected at the Arctic Laboratory ONR, Pt. Barrow, Alaska, by G. E. MacGinitie. Smithson. Inst. Misc. Coll., 128:61-78

Sullivan, Rev. W. D. 1957. Identification of protozoa from the region of Point Barrow, Alaska. Trans. Amer. Micro. Soc., 76:189-196.

Thompson, D. Q. 1955a. The ecology and population dynamics of brown lemming, Lemmus trimucronatus, at Point Barrow, Alaska. Ph.D. thesis, Univ. Missouri, 138 pp.

Thompson, D. Q. 1955b. The 1953 lemming emigration at Point Barrow, Alaska. Arctic, 8:37-45.

Thompson, D. Q. 1955c. The role of food and cover in population fluctuations of the brown lemming at Point Barrow, Alaska. 20th North American Wildlife Conf. Trans., pp. 166-176.

Thompson, D. Q. 1955d. Ecology of the lemmings. Final Report, Arctic Inst. North America, Proj. ONR-133, 64 pp.

Thompson, D. Q., and R. A. Person. 1963. The eider pass at Point Barrow, Alaska. Jour. Wildl. Mgt., 27:348-356.

Van Cleve, K. 1967. Nutrient loss from organic matter placed in soil in different regions. Ph.D. thesis, Univ. California, 290 pp.

Voth, P. D. 1952. Biology of Marchantia polymorpha and associated plants in the Alaskan Arctic. Proj. Report NONR 338 (00).

Weber, N. A. 1949. Late summer invertebrates, mostly insects, of the Alaskan Arctic slope. Ent. News, 60:118-128.

Weber, N. A. 1950a. The role of lemmings at Point Barrow, Alaska. Science, 111:552-553.

Weber, N. A. 1950b. A survey of the insects and related arthropods of Arctic Alaska. Amer. Ent. Soc. Trans., Part I, 76:147-206.

Wiggins, I. L. 1951. The distribution of vascular plants on polygonal ground near Point Barrow, Alaska. Contr. Dudley Herbarium, Stanford Univ., 4:41-56.

Wiggins, I. L., and J. H. Thomas. 1962. A flora of the Arctic Alaskan Slope. Univ. Toronto Press, x + 425 pp.

Wohlschlag, D. E. 1953. Some characteristics of the fish populations in an Arctic Alaskan lake. Stanford Univ. Publ., Biol. Sci., 9:19-29.

Wohlschlag, D. E., 1954a. Growth peculiarities of the cisco, Coregonus sardinella (Valenciennes) in the vicinity of Point Barrow, Alaska. Stanford Ichthy. Bull., 4:189-209.

Wohlschlag, D. E. 1954b. Mortality rates of whitefish in an arctic lake. Ecol., 35:388-396.

Wohlschlag, D. E. 1956. Information from studies of marked fishes in the Alaskan Arctic. Copeia, 1956:237-242.

Wohlschlag, D. E. 1957. Differences in metabolic rates of migratory and resident freshwater forms of an arctic whitefish. Ecol., 38:502-510.

GENERAL BACKGROUND

Arnborg, L., H. J. Walker, and J. Peippo. 1966. Water discharge in the Colville River, Alaska, 1962. Geografiska Annaler, 48:195-210.

Arnborg, L., H. J. Walker, and J. Peippo. 1967. Suspended load in the Colville River, Alaska, 1962. Geografiska Annaler, 49:131-144.

Bee, J. W., and E. R. Hall. 1956. Mammals of northern Alaska. Univ. Kansas Mus. Nat. Hist. Misc. Publ. 8, 309 pp.

Black, R. F. 1963. Les coins de glace et le gel permanent dans le nord de l'Alaska. Anales de Geographie No. 398, pp. 257-271.

Black, R. F. 1964. Gubik formation of Quaternary age in northern Alaska. U. S. Geol. Survey Prof. Paper 302-C.

Bliss, L. C. 1956. A comparison of plant development in microenvironments of arctic and alpine tundra. Ecol. Mono., 26:303-337.

Bliss, L. C. 1962. Net primary production of tundra ecosystems. Pp. 35-48, in "Die Stoffproduktion der Pflanzendecke" (H. Lieth, ed.), G. Fischer Verlag, Stuttgart.

Britton, M. E. 1957. Vegetation of the arctic tundra. In Arctic Biology, 18th Ann. Biol. Colloquium, Oregon State University, pp. 26-61.

Brown, J., and P. L. Johnson. 1966. U. S. Army CRREL topographic map: Barrow area (1:25,000). U. S. Army CRREL Spec. Rept. 101.

Cade, T. J. 1960. Ecology of the peregrine and gyrfalcon populations in Alaska. Univ. Calif. Publ. Zool., 63:151-290.

Cantlon, J. F. 1961. Plant cover in relation to macro-, meso-, and micro-relief. Final Report, AINA-ONR grants, ONR 208-212.

Carson, C. E., and K. M. Hussey. 1962. The oriented lakes of Arctic Alaska. Jour. Geol., 70:417-439.

Carson, C. E. 1968. Radiocarbon dating of lacustrine strands in Arctic Alaska. Arctic, 21:12-26.

Drew, J. V., and J. C. F. Tedrow. 1962. Arctic soil classification and patterned ground. Arctic, 15:109-116.

Ford, J. A. 1959. Eskimo prehistory in the vicinity of Point Barrow, Alaska. Amer. Mus. Nat. Hist., Anthro. Papers vol. 47, 272 pp.

Hume, J. D., and M. Schalk. 1967. Shoreline processes near Barrow Alaska: a comparison of the normal and the catastrophic. Arctic, 20:86-103.

Hussey, K. M., and R. W. Michelson. 1966. Tundra relief features near Point Barrow, Alaska. Arctic, 19:162-184.

Irving, L. 1950. Measurement of some physiological reactions of arctic conditions. Annals N. Y. Acad. Sci., 51:1045-1050.

Irving, L., G. C. West, L. J. Peyton, and S. Pompek. 1967. Migration of willow ptarmigan in arctic Alaska. Arctic, 20:77-85.

Irving, L., G. C. West, and L. J. Peyton. 1967. Winter feeding program of Alaska willow ptarmigan shown by crop contents. Condor, 69:69-77.

Kunai, M. 1965. The properties of marine air and marine fog at Barrow, Alaska. Proc. Int. Conf. Cloud Physics (Tokyo and Sapporo).

Lachenbruch, A. J. 1962. Mechanics of thermal contraction cracks and ice-wedges polygons in permafrost. Geol. Soc. Amer., Spec. Paper 70: 69 pp.

Lachenbruch, A. H., M. C. Brewer, G. W. Greene, and B. V. Marshall. 1962. Temperatures in permafrost. In "Temperature, its measurement and control in science and industry," vol. 3, pt. 1, pp. 791-803.

Leffingwell, E. de K. 1919. The Canning River region, northern Alaska. U. S. Geol. Survey Prof. Paper 109, 251 pp.

Livingstone, D. A. 1955. Some pollen profiles from Arctic Alaska. U. S. Geol. Survey Prof. Paper

Livingstone, D. A. 1957. Pollen analysis of a valley fill near Umiat, Ecology, 36:587-600

MacCarthy, G. R. 1953. Recent changes in the shoreline near Point Barrow, Alaska. Arctic, 6:44-51.

Reed, R. W. 1964. Arctic beaches, Barrow, Alaska. In "Papers in marine geology," Macmillan, N. Y., pp. 384-400.

Spetzman, L. A. 1959. Vegetation of the arctic slope of Alaska. U. S. Geol. Survey Prof. Paper 302-B, pp. 19-58.

Steere, W. C. 1953. On the geographical distribution of arctic bryophytes. Stanford Univ. Publ., Biol. Sci., 11:30-47.

Stroschein, L. A. 1964. An automated radiation climatology station at Pt. Barrow, Alaska. Proc. 15th Alaskan Sci. Conf., pp. 61-72.

Tedrow, J. C. F. 1957-1961. A study of the pedologic processes operating in the arctic areas of Alaska. Progress reports.

Tedrow, J. C. F., and J. E. Cantlon. 1958. Concepts of soil formation and classification in arctic regions. Arctic, 11:166-179.

Tedrow, J. C. F., J. V. Drew, D. E. Hill, and L. A. Douglas. 1958. Major genetic soils of the arctic slope of Alaska. Jour. Soil Sci., 9:33-45.

Weber, F. R., R. M. Chapman, and E. P. Hagy. 1966. Bibliography of geology and related subjects northern Brooks Range and North Slope, Alaska. (Mimeographed compilation.)

West, G. C. 1968. Bioenergetics of captive willow ptarmigan under natural conditions. Ecology, in press.

West, G. C., and M. S. Meng. 1966. Nutrition of willow ptarmigan in northern Alaska. Auk, 83:303-315.

West, G. C., and M. S. Meng. 1968. Seasonal changes in body weight and fat and relation of fatty acid composition to diet in the willow ptarmigan. Wilson Bulletin, in press.

Wiggins, I. L., and J. H. Thomas. 1962. A flora of the Alaskan Arctic Slope. Univ. Toronto Press, 425 pp.

Recent Additions to Barrow Bibliography

Clebsch, E.E.C. and R.E. Shanks 1968, Summer climatic gradients and vegetation near Barrow, Alaska. Arctic 21: 161-171.

Dennis, J.G. 1968. Growth of tundra vegetation in relation to arctic microenvironments at Barrow, Alaska. Ph.D. dissertation, Duke University.

Hodgson, H.J. 1966. Floral initiation in Alaskan Gramcneae. Bot. Gaz. 127(1) 64-70.

Johnson, P.L. and Kelley, J.J. Jr. 1969. Dynamics of carbon dioxide in an arctic biosphere. Ecology (in press).

Kalff, J. 1967, Phytoplankton dynamics in an Arctic lake. Jour. Fish. Res. Board Canada 24: 1861-1871.

Kalff, J. 1967, Phytoplankton abundance and primary production rates in two arctic ponds. Ecology 48:558-565.

Kalff, J. 1968 Some physical and chemical characteristics of Arctic fresh waters in Alaska and northwestern Canada. Jour. Fish. Res. Board Canada 25:2575-2587.

Kelley, J.J. Jr. 1968 An analysis of carbon dioxide in the arctic atmosphere near Barrow, Alaska, 1961-1967. Final Report, Dept. Atmos. Sciences, Univ. of Wash.

Kelley, J.J. and D.F. Weaver (in press) The temperature regime and energy balance near the Arctic tundra surface, Arctic.

MacLean, S.F. Jr. and N.A.M. Verbeck, 1968, Nestrong of the black grullemot at Point Barrow, Alaska. Auk, 85:139-140.

Tieszen, L.L. and P.L. Johnson 1968, Pigment structure of some arctic tundra communities, Ecology 49:370-373.

Kelley, J.J., D.F. Weaver, B.P. Smith, 1968. The variation of carbon dioxide under the snow in Arctic. Ecology 49:358-361.

INTERNATIONAL BIOLOGICAL PROGRAM

TUNDRA BIOME

Analysis of Ecosystems
United States International Biological Program

Alpine Tundra Intensive Site Study

This notice is being sent to scientists interested in the Tundra Environment. In particular, we are soliciting for research participants in a proposed intensive study of Alpine Tundra. The site for this study would be Green Lakes Valley and Niwot Ridge which is close to the University of Colorado, Mountain Research Station.

Enclosed you will find: Tundra Biome Newsletter No. 1; U.S./I.B.P. mailing list; an account of the Institute of Arctic and Alpine Research, University of Colorado; a resume of the Alpine Tundra Intensive Study proposal; and two questionnaires for potential participants. We have also taken the liberty of enclosing a brochure on the new journal, Arctic and Alpine Research.

If you are interested in participating in the proposed Intensive Site Study of the Alpine Tundra Ecosystem, please fill in the enclosed forms and/or write to us.

J. D. Ives and P. J. Webber
Institute of Arctic and Alpine Research (INSTAAR)
University of Colorado
Boulder, Colorado 80302

I B P

TUNDRA BIOME

ANALYSIS OF ECOSYSTEMS

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

Tundra Biome Newsletter No. 1 July 1969

"Successfully manipulating the environment for the long-term benefit of man depends on the degree to which the whole environment is considered in formulating the strategy."

This statement from a paper by Eugene P. Odum contains the underlying principle of the Tundra Biome Program - to direct its basic scientific investigations towards a better understanding of the entire cold-dominated ecosystem. Three broad objectives are paramount to the development and implementation of the Biome's multidisciplinary, integrated research design:

1. To investigate the abiotic factors unique to arctic, subarctic and alpine environments, such as extremes of temperature, day-length and permafrost, and to determine their influence on the dynamics of biotic and abiotic components of tundra and taiga ecosystems; and to bring this basic knowledge to bear on problems of primary and secondary productivity and of degradation, maintenance and restoration of the natural level of environmental quality.

2. To obtain an understanding of the structure and function of the wet tundra ecosystem as exemplified in the Barrow, Alaska, area, and in so doing, evaluate the causes for the periodic fluctuations in the microtine populations.

3. To obtain the necessary data for circumpolar tundra synthesis with Finland, Norway, Sweden, Great Britain, Canada, Ireland, U.S.S.R., and others involved in tundra/taiga I.B.P. research, and to develop stochastic models for predicting behaviour of tundra/taiga ecosystems.

This program is one of six organized within the U.S. I.B.P. Analysis of Ecosystems Program. The other five biomes are Grassland, Deciduous Forest, Coniferous Forest, Desert, and Tropical. Reports on this program and other I.B.P. projects are available; see the list at the end of this newsletter. The central approach of these integrated programs is to utilize systems analysis to predict the consequences of natural or man-induced environmental changes or stresses in a particular ecosystem. Mathematical models are developed from the results of process-oriented experimental research (intensive site studies). Predictions from model simulation are validated by a series of monitoring or observational studies distributed across a wide range of biome environments (comprehensive site studies).

The Tundra Biome Program, after a period of organizational meetings and working sessions, is about to initiate its first research program. This will be a synthesis and modeling project of the Barrow, Alaska, data base. This project will formulate a tundra model, synthesize and interpret a selective portion of the Barrow ecological data, and provide data input into a cooperative modeling effort. The results of the

synthesis and modeling will identify gaps in our basic understanding of this and other cold-dominated ecosystems and contribute to the design of the integrated biome research plan. The overall research design and accompanying integrated research proposal will be formulated early in the synthesis and modeling program. Both terrestrial and aquatic aspects of the ecosystem are included. At least one intensive site and numerous comprehensive sites are planned. The above activities should be well underway by 1 October 1969, the requested initiation date for the NSF-sponsored Barrow synthesis project. Potential U.S. participants in the Tundra Biome Program are requested to complete and return the attached questionnaire so that their interests in the Biome Program can be included.

Organizationally, the Biome Program is fortunate to have involved several Arctic/Alpine-oriented universities to provide leadership roles in the central program. The University of Alaska, through the Institute of Arctic Biology (Dr. George West, Program Coordinator), has contributed immensely in the original biome planning. Its specific interests are in the arctic/taiga ecosystems with their current efforts partly directed toward ecological questions raised by recent oil-oriented activities on the permafrost landscape. The University of Colorado, through the Institute of Arctic and Alpine Research (Dr. Jack Ives, Program Coordinator), is assuming the leadership role in developing an integrated alpine research program. San Diego State College will undertake the Barrow synthesis project (Harry Couloumbe, Analysis Coordinator). The initial development of the Tundra Biome Program was under the directorship of Frank Pitelka, who recently resigned. Jerry Brown is currently acting as Biome Director and Program Coordinator for the synthesis project.

Forthcoming events of interest to the Tundra Biome are:

20th Alaska Science Conference, University of Alaska, August 24-27, 1969. Theme: Change in the North: People, Resources, and Environment. For further information contact: Victor Fischer, University of Alaska, College, Alaska 99701.

Conference on productivity and conservation in Northern Circumpolar lands, Edmonton, Alberta, October 15-17, 1969. For further information contact: Dr. W.A. Fuller, P.O. Box 500, University of Alberta, Edmonton, Alberta, Canada.

Future issues of this newsletter will appear as sufficient items of interest accumulate. Your interest and inquiries concerning future biome activities, both nationally and internationally, are actively encouraged and welcomed.

Due to the press of August field commitments, answers to summer correspondence may be delayed until early September. Direct inquiries to: J. Brown, Box 345, Hanover, N.H. 03755.

Selected I.B.P. Reports

These reports are available directly from the I.B.P. Office, Division of Biology and Agriculture, National Academy of Sciences, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

1. Man's survival in a changing world.

2. Progress Report, Analysis of Ecosystems, March 1969.

3. I.B.P. Inter-American Newsletter.

4. Research Studies Constituting the U.S. Contribution to the International Biological Program, Part 2.

Institute of Arctic and Alpine Research

JACK D. IVES*

Late in 1967 the University of Colorado went ahead with the first phase of expansion and development of its Institute of Arctic and Alpine Research (INSTAAR). The Institute was founded in 1951 by Dr. John W. Marr who served as its Director until 1967.

The major objective of INSTAAR is the evaluation and appreciation of arctic and alpine environments through research and teaching. The term "environment" is intended to stress the need for an inter-disciplinary philosophy and approach to research, and to teaching through research, at various levels. The underlying principle is the conviction that an adequate understanding of any environment requires a "total" approach, an appreciation of the whole through an integrated study of the parts and of the interrelations between those parts. INSTAAR's particular role is the study of some of the earth's more extreme environments that are found at high altitudes and high latitudes or that existed during glacial phases of the Quaternary Era. As the Institute is going through a phase of major expansion, current emphasis is being placed on the so-called field sciences (earth, biological and atmospheric); the study of man's present and past use of and appreciation of these extreme environments will be added to the program in the near future.

Besides laboratory and office facilities in Boulder, INSTAAR possesses a well-equipped Mountain Research Station at 9,600 feet elevation in the Front Range of the Colorado Rocky Mountains. This provides year-round accommodation and logistical support to altitudes over 12,000 feet within 90 minutes' travel time of the Boulder campus headquarters.

INSTAAR, therefore, is an inter-disciplinary research and teaching organization within the Graduate School. The faculty, while salaried directly through the Institute, hold their professional appointments in the relevant academic department, usually in the College of Arts and Sciences. Their research activities are related to the Graduate School while their teaching responsibilities are coordinated with the relevant department, although special inter-disciplinary courses are developed by the Institute and cross-listed for academic credit currently in Biology, Geography and Geology. In addition to the full-time faculty, INSTAAR staff includes field and laboratory technicians, editorial, secretarial and administrative personnel. Faculty of other departments interested in the Institute's program cooperate as INSTAAR Research Associates.

Graduate students interested in the work of the Institute apply for graduate status within the academic department most closely associated with their proposed

*Director of INSTAAR, University of Colorado, Boulder, U.S.A.

INTENSIVE SITE STUDY PROPOSAL

Analysis of the Alpine Tundra Ecosystem

The project is to be a contribution to the United States participation in the International Biological Program (IBP) and forms part of the Tundra Biome section of the U.S./I.B.P. Analysis of Ecosystems program; it will correspond to and be coordinated with the Arctic Tundra study being developed for Alaska. Intensive study will be made in Green Lakes Valley and on Niwot Ridge in the Front Range of the Colorado Rocky Mountains. This will allow the construction of a model for an alpine tundra ecosystem which would then be modified after comparative studies of other U.S. alpine areas so that it has a wider application. The headquarters proposed for this operation is the Institute of Arctic and Alpine Research (INSTAAR), University of Colorado.

The ecosystem model should supply answers to some of the following questions and corollary objectives.

a) What is the existing and potential primary and secondary production of this ecosystem?

b) What are the major pathways of energy flow and material cycling in the ecosystem?

c) What are the controlling environmental parameters of the ecosystem and what factors produce tundra?

d) What temporal changes occur in the ecosystem?

e) How similar are alpine and arctic ecosystems?

f) Can the relatively simple tundra ecosystem provide a clearer understanding of some basic ecological principles than the ecosystems of other Biomes?

g) What are the effects of man on the alpine ecosystem?

h) What management programs are necessary to protect the natural resources of the alpine ecosystem?

The watershed approach of Bormann and Likens (1967) will be used to delimit the ecosystem. This approach facilitates the study of energy and material budgets. The compartment model method will ensure comparability between tundra sites and between Biomes. A minimal program will be to follow the major pathways shown in Figure 1. This diagram was constructed at the Norway workshop for tundra ecosystems (Heal, 1968) and it is anticipated that it will become beter defined and more sophisticated. The analysis of the complex organization of the ecosystem necessitates the systems approach. It is axiomatic that systems analysis requires interdisciplinary team effort as no one individual could contain the entire study. This proposal will follow the four National Science Foundation Criteria for Integrated Research

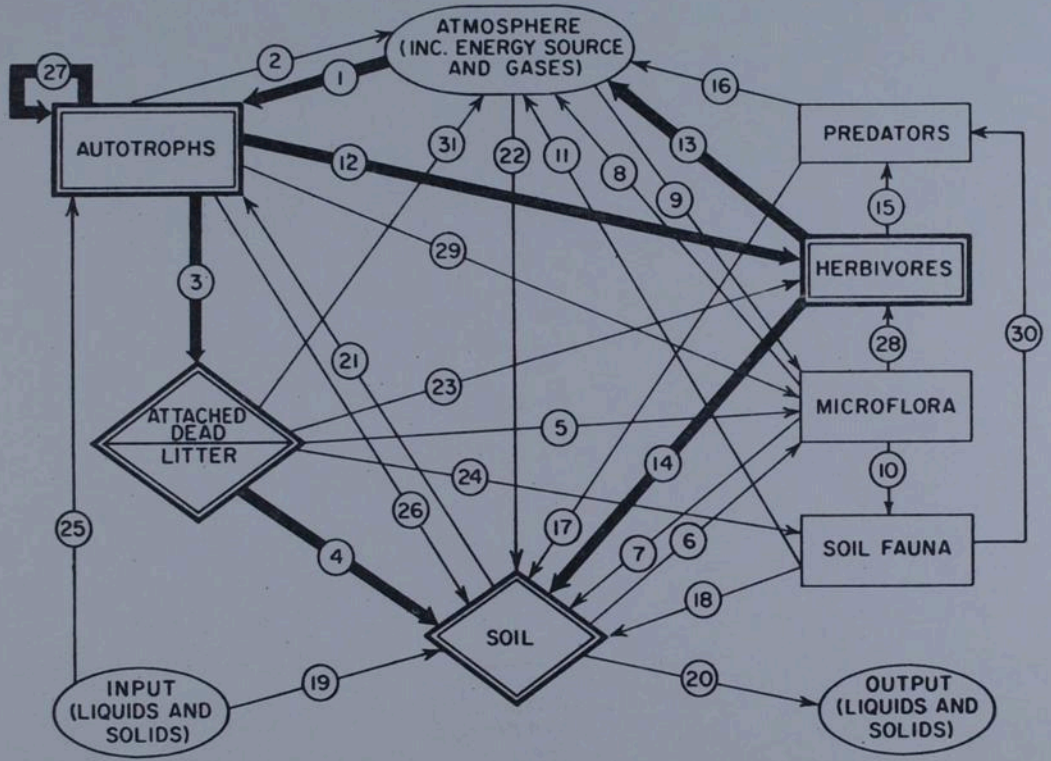

Figure 1. Flow diagram for energy and materials in tundra ecosystems. Compartments which are double framed and the heavy flow lines are the items which require study in a basic program (from the Norway Workshop, 1968).

Programs. INSTAAR will be the central clearing house through which program development, data exchange and synthesis will take place.

The Green Lakes Valley watershed has an areal extent of about 10 km^2, of which 80 per cent is above treeline. The watershed drains into Silver Lake at 3,115 m (10,221 feet). It has a sharply defined boundary, part of which is the Continental Divide and is part of the City of Boulder watershed. The watershed, although small, provides a rich variety of substrates, perennial snowbanks, talus slopes, solifluction terraces, stone nets, exposed bedrock, glacial till and a series of lakes. Although only 10 per cent of the area is vegetated, all the major tundra types of the Central Rockies occur here. Insects, alpine birds, small mammals, predatory mammals and hawks are abundant and will provide information on the herbivors and predators of the ecosystem. At the lower end of the watershed krummholz makes the boundary or ecotone with the sub-alpine forest.

Although many alpine sites are available both in the conterminous United States and Alaska, the best use of manpower and funds should result from making an intensive study of one area and then by comparing it with other areas. This site has many desirable features. It is close to the Mountain Research Station which has excellent staff and facilities. There are small field laboratories and living quarters on the site which are accessible year round. The location and nearness to a university campus and International Airport keep transportation costs to a minimum. travel to most tundra sites is burdensome. With Headquarters for the alpine tundra section in Boulder, the advantages of proximity to the Grasslands Ecosystem Project are obvious. It might be argued that an intensive alpine site should be chosen close to the arctic Alaskan site, but the Central Rockies provide a better contrast for comparing arctic and alpine conditions. The present site is clearly delimited and yet is part of a tundra system which is almost 100 km in length. The site is the property of the City of Boulder so that it is undisturbed as the public has been excluded for many years. INSTAAR benefits from a close association with the City of Boulder and has full research opportunities within the watershed, thus ensuring the safe installation of instrumentation. The effects of man can be studied by comparison with the neighboring disturbed sites (Scott-Williams, 1967). The area is well known to many alpine specialists who have been visitors and students. There is an 18-year meteorological record for the site and the flora, fauna, vegetation, geology, hydrology and limnology are reasonably well documented (Benedict, 1965, 1966, 1967, 1968, 1969; Caldwell, 1968; Clark and Peterson, 1968; Ives, 1953; Marr, 1961; Marr, et al., 1968a, 1968b; Madole, 1970; Osburn, 1958, 1966, Pennak, 1963; Quick, 1966; Stein and Amundsen, 1968). INSTAAR has several new research programs underway in the watershed, for example, mass wasting and hydrological processes, permafrost and climatological studies, and an alpine transplant garden program. These studies will have a direct relevance to the ecosystem analysis and will provide it with a strong earth and atmospheric sciences base. Continuity of endeavor is assured through many of the key scientists being recruited as permanent faculty of INSTAAR. Relationships between INSTAAR and the relevant academic departments of the University of Colorado ensure the attraction of a continuing stream of high caliber graduate students.

REFERENCES

Benedict, J.B.

1966: Radiocarbon dates from a stone-banked terrace in the Colorado Rocky Mountains, U.S.A. Geografiska Annaler, 48A(1): 24-31.

1967: Recent glacial history of an alpine area in the Colorado Front Range, U.S.A., I. Establishing a lichen-growth curve. Journal of Glaciology, 6(48): 817-832.

1968: Recent glacial history of an alpine area in the Colorado Front Range, U.S.A., II. Dating the glacial deposits. Journal of Glaciology, 7(49): 77-87.

1969: Microfabric of patterned ground. Arctic and Alpine Research, 1(1): 45-48.

Benedict, J.B. and Outcalt, S.I.

1965: Photo-interpretation of two types of rock glacier in the Colorado Front Range, U.S.A. Journal of Glaciology, 5(42): 849-856.

Bormann, F.H. and Likens, G.E.

1967: Nutrient cycling. Science, 155: 424-429.

Caldwell, M.M.

1968: Solar ultraviolet radiation as an ecological factor for plants. Ecological Monographs, 38: 243-268.

Clark, J.M. and Peterson, E.B.

1968: Insolation in relation to cloud characteristics in the Colorado Front Range. In Osburn, W.S. and Wright, H.E., Jr. (eds.), Arctic and Alpine Environments, Indiana, Indiana University Press, 3-11.

Heal, O.W.

1968: The International Biological Programme Project at Moor House. Nature Conservancy, Merlewood Research and Development Paper No. 2, 27 p.

Ives, R.L.

1953: Later Pleistocene glaciation in the Silver Lake Valley, Colorado. Geographical Review, 63: 229-253.

Marr, J.W.

1961: Ecosystems of the east slope of the Front Range of Colorado. University of Colorado Studies, Series in Biology, No. 8, 134 p.

1967: Data on mountain environments. I. Front Range, Colorado, sixteen sites, 1952-1953. University of Colorado Studies, Series in Biology, No. 27, 110 p.

Marr, J.W., Johnson, A.W., Osburn, W.S. and Knorr, O.A.

1968a: Data on mountain environments. II. Front Range, Colorado, four climax regions, 1953-1958. University of Colorado Studies, Series in Biology, No. 52, 169 p.

Marr, J.W., Clark, J.M., Osburn, W.S. and Paddock, M.W.

1968b: Data on mountain environments. III. Colorado Front Range, four climax regions, 1959-1964. University of Colorado Studies, Series in Biology, No. 53, 181 p.

Madole, R.F.

1970: Pinedale and Bull Lake Glaciation in the Upper St. Vrain drainage basin, Boulder County, Colorado. Arctic and Alpine Research, 2(1): in press.

Osburn, W.S.

1958: Ecology of winter snow-free areas of alpine tundra of Mivot Ridge, Boulder County, Colorado. Ph.D. thesis, University of Colorado.

1966: Ecological concentration of nuclear fallout in a Colorado mountain watershed. In Adberg, B. and Hungate, F.P. (eds.), Radioecological Concentration Processes, New York, Pergamon Press, 675-709.

Pennak, R.W.

1963: Ecological and radiocarbon correlations in some Colorado mountain lake and bog deposits. Ecology, 44: 1-15.

Quick, H.F.

1966: Population of small mammals in the Boulder City watershed and a preliminary estimate of biomass cycle in 1964. Attachment No. 11 to U.S.A.E.C. Contract No. AT(11-1)-1191. Radio-ecology of the Colorado Front Range,- W.S. Osburn, Principal Investigator; mimeographed.

Scott-Williams, Beatrice E. Willard

1967. Effects of visitors on alpine tundra. Associations in Rocky Mountain National Park, Colorado, U.S.A. IUCN Publications, New Series No. 7: 214-216.

Stein, Janet R. and Amundsen, C.C.

1967: Studies on snow algae and fungi from the Front Range of Colorado. Canadian Journal of Botany, 45: 2034-2046.

Tundra Biome Questionnaire July 1969

TO: Potential U.S. I.B.P. Tundra Biome Participants

FROM: Jerry Brown, Box 345, Hanover, N.H. 03755

SUBJECT: Questionnaire on recent and future tundra-oriented research.

The results of this brief questionnaire will be incorporated into a biome-wide planning document which will include a FY 71 budget. Your answers will serve to realistically estimate the program's capabilities within the existing pool of trained and experienced arctic-alpine-taiga scientists. Some of you may have already been contacted personally. However, I would appreciate this information once again. Your prompt reply will be in the interest of research on cold-dominated environments. This information will be closely coordinated with the organizational elements of the Tundra Biome and other agencies and institutions concerned with northern and high altitude research.

1. Interests (Check one or number priorities)
   ___ Arctic Tundra
   ___ Alpine Tundra
   ___ Taiga
   Discipline(s)_____
   Specific location(s) of recent or current research:_____

2. Project Title(s) of current or recent tundra/taiga research and number of graduate students and assistants involved:_____

3. Title of tundra/taiga projects already under consideration within the next two years and approximate number of personnel involved in each (graduate students, assistants, etc.):_____

Tundra Biome Questionnaire (Contd.)

4. I do not have a current or proposed research program in tundra/taiga, but continue to send me information on the Tundra Biome. (Simply return this form with your name and address: Item No. 6).

5. Send additional copies of the Tundra Biome Newsletter to the following individuals or organizations:

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

6. From (Name and Address)

_____

_____

_____

Zip_____

Remarks

pjw/jep

QUESTIONNAIRE

If you are interested in participating in the Alpine Tundra Intensive Site Study, please complete and submit this form.

Name(s) and address(es) of possible participant or group of participants:

_____

_____

_____

_____

_____

Research interests and skills:

_____ Producers
_____ Consumers
_____ Decomposers

_____ Abiotic
_____ Aquatic
_____ Terrestrial

Specialty:

Discipline

_____ Taxonomy
_____ Quantitative ecology
_____ Physiological ecology
_____ Radiation ecology
_____ Pollution ecology
_____ Palaeoecology
_____ Pathology
_____ Wildlife management
_____ Conservation
_____ Climatology
_____ Hydrology
_____ Geology and Geomorphology
_____ Soil science
_____ Biogeochemistry
_____ Other (specify)

_____

_____

Taxon and/or Factor

_____ Tracheophytes
_____ Bryophytes
_____ Lichens
_____ Algae
_____ Fungi
_____ Bacteria
_____ Pollen
_____ Man
_____ Mammals
_____ Birds
_____ Amphibians and Reptiles
_____ Fish
_____ Insects
_____ Crustaceans
_____ Time

Taxon and/or Factor (continued)

_____ Radiation
_____ Temperature
_____ Atmosphere
_____ Water
_____ Geologic substratum
_____ Soil
_____ Sediments
_____ Other (specify)

_____
_____

Additional information and/or suggestions:

_____
_____
_____
_____
_____

Names and addresses of interested tundra and ecosystem specialists who are not included on our mailing list:

_____
_____
_____
_____
_____

IBP TUNDRA BIOME

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(July 4, 1969)

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