LATE-WISCONSINAN CHRONOLOGY AND HISTORY OF VEGETATION IN THE OGILVIE MOUNTAINS, YUKON TERRITORY, CANADA

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ABSTRACT

Studies of Pleistocene geology and history in the western Ogilvie Mountains, bordering on the east of the unglaciated region in Yukon, were made by Hughes who has recognized three major glacial episodes characterized by successive advances and retreats of valley glaciers originating in cirques along the axis of the southern Ogilvie Ranges. Palynological studies and radiocarbon dating have been used to support and confirm the chronology of complex moraine sequence. The youngest of these glacial episodes is believed to have culminated prior to 10,000-12,900 years ago.

The history of late Wisconsinan vegetation in this area, as inferred from palynological and paleobotanical studies, holds special interest because of the postulated survival of plants in the adjacent unglaciated area which provided a potential late-glacial dispersal centre in addition to migrations reaching the area later from the southeast and south. It seems that birch, alder, willow and spruce were among the early pioneers from the western source. A mixing of the western and eastern floral elements after deglaciation is an interesting problem. The magnitude of the postglacial climatic changes appears to have been smaller than in the more southerly regions. At several sites studied, the onset of the permafrost regime has been an important factor in the development of vegetation, because of its influence on both the groundwater conditions and soil development.

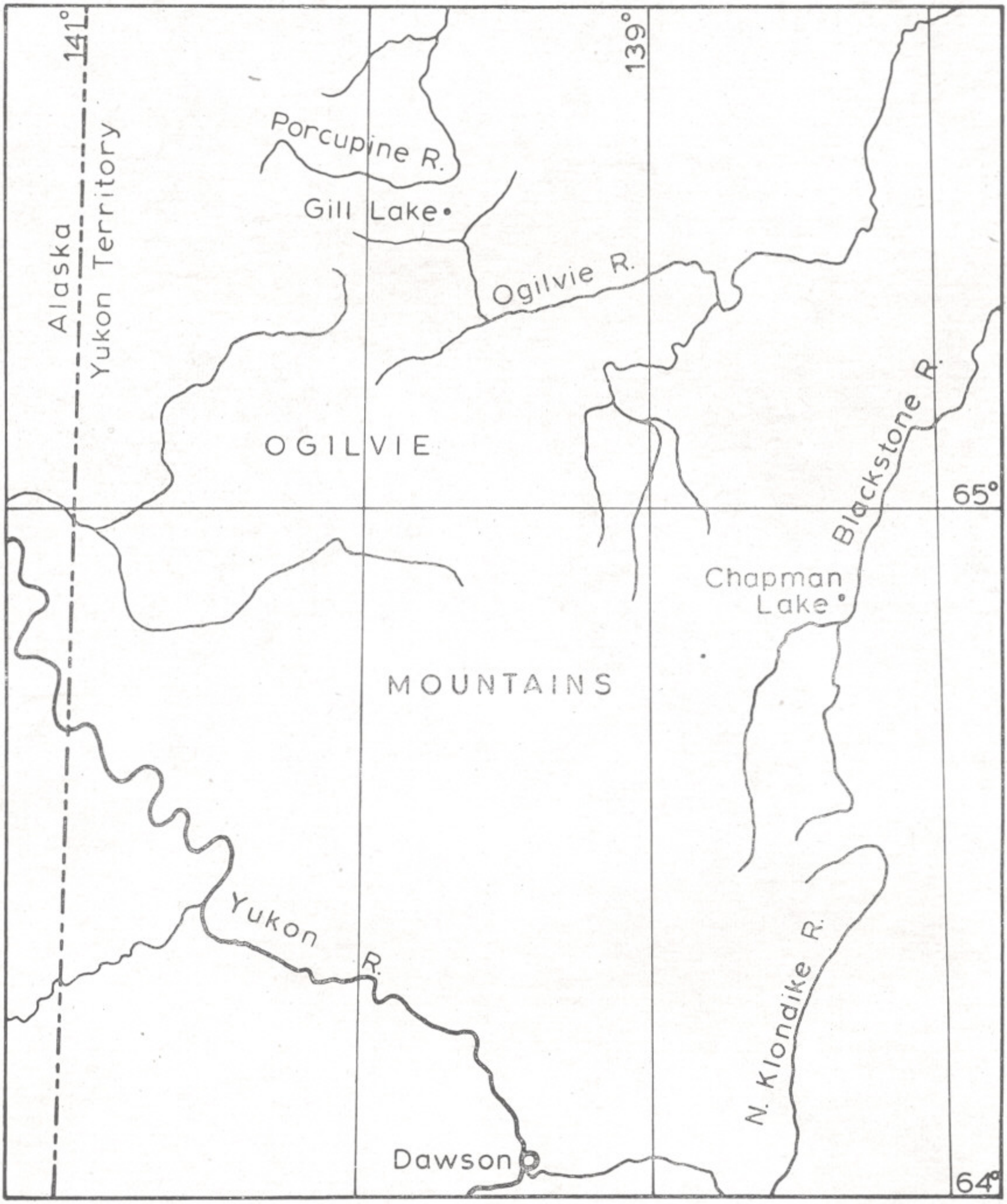
INTRODUCTION

THIS brief account on Late-Quaternary history of a selected area in the Ogilvie Mountains is a progress report, compiled within the cope of a more extensive, long-term investigation in the Yukon Territory by the authors. The geological part of this report is based on reconnaissance by Hughes, made in conjunction with aircraft supported operations Ogilvie and Porcupine of the Geological Survey of Canada (VERNON & HUGHES, in Press). The area studied in some detail by Hughes lies north of Dawson and is shown in Fig. 1. It includes the North Klondike River valley; extends northward to Chapman Lake and along Blackstone River, and thence northwestward to the Gill Lake area. The area lies in the peripheral zone of the unglaciated region in Yukon and Alaska, and it supported mountain glaciation only at the maximum of the last glaciation, whereas farther to the southward the mountain ranges closer to the Gulf of Alaska were extensively ice-covered (KARLSTROM, 1964). The area was selected because of its relatively easier access from Dawson by road and aircraft, and because aerial photo-reconnaissance had indicated the presence of glacial features, such as cross-valley moraine systems, and exposures of surficial deposits necessary for a stratigraphic and chronological investigation.

PHYSIOGRAPHY AND GLACIAL HISTORY

Physiography of the region has been summarized by Bostock (1948 & 1961). Ogilvie Mountains comprise the western extension of a high rim which borders the central Yukon plateau on the south side. Some peaks in the Southern Ogilvie Ranges are more than 7,000 feet high, and the lower passes are 3,000 to 4,000 feet in elevation. The North Klondike River flows south from the North Fork Pass in the Southern Ogilvie Ranges. The Chapman Lake area lies in the Taiga Valley physiographic subdivision (BOSTOCK, 1961), and the Gill Lake is near Mt. Klotz (summit altitude 5,900 feet) in the Northern Ogilvie Ranges.

Glaciation in the area studied was characterized by successive advances of mountain glaciers which at their maximum extent reached only a few miles beyond the mountain front. At least three distinct glacial advances have been recognized by Hughes: (1) a younger advance represented by terminal moraines with relatively fresh, sharp morainic topography, such as is found in the North Fork Pass area; (2) an advance of intermediate age, represented by subdued but readily recognizable end-moraines near Chapman Lake, downvalley and outside of the younger moraines and (3) an older



TEXT-FIG. 1 — Index map. The area studied extends from the North Frk Pass, at the headwaters of the North Klondike River, to Chapman Lake and to Gill Lake.

advance, represented by erratics and patches of glacial till along the Blackstone River outside the moraines of the intermediate advance. These erratics and till of the older advance may prove with detailed study to be the product of more than one older advance.

CLIMATE AND VEGETATION

The Yukon Territory is a rugged land of mountain ranges and intervening plateaux, cut off from the influence of the Pacific Ocean by the Coast and St. Elias Mountains (Bostock, 1948; Boughner & Thomas, 1960) which provide a strong barrier to the maritime climate from the west. Interior Yukon has less protection against the winter cold waves from the Northwest Territories in the east. The Yukon Territory is subject to wide variations in temperature during the winter depending on whether the dominant influence is modified air from the North Pacific or intensely cold air from the Beaufort Sea (Boughner & Thomas, 1960, p. 12). Topography favours extremely low minimum temperatures during Arctic cold waves, which fortunately are usually of short duration. January mean temperature at Dawson has ranged from -43°F in 1909, to 7°F in 1926.

Spring and fall seasons are remarkably short, for example, at Dawson mean temperature rises from 28°F to 57°F between mid-April and mid-June. The short summers are commonly warm with mean temperatures above 50°F during June, July and August. The highest recorded temperature at Dawson is 95°F. However, freezing temperatures can occur every month of the year.

Mean annual precipitation in most of Yukon is rather uniform ranging from 9 to 17 inches at the valley stations where records are available. There is no pronounced dry or wet season, although spring has the least precipitation and July and August are the rainiest months. Winter snowfall averages from 40 to 80 inches with the heaviest falls in the St. Elias Mountains where ice fields exist at present.

Botanical studies in Yukon extend back more than 50 years. In 1906, Macoun reported on the climate and flora or Yukon. From 1941 to 1950 Hultén published his comprehensive work on the flora of Alaska and Yukon. In 1951 Porsild reported on the botany of southeastern Yukon. Notes on botany are included in the papers by Campbell (1952), Hansen (1953) and Heusser (1960). In recent years, extensive botanical studies have been made in Yukon by J. A. Calder (Plant Research Institute, Ottawa). The interior Yukon, including the study area for this report, is still rather poorly known botanically.

Dawson lies in the northwestern extension of the Boreal Forest Region of Canada (Rowe, 1959). On the southern slopes, and south of the Ogilvie Mountains the chief forest habitat, the valley slope, bears stands of white spruce (*Picea glauca*), either pure or mixed with Alaska white birch (*Betula papyrifera* var. *humilis*) or with aspen (*Populus tremuloides*). Commonly the most favourable spruce site is on lower slopes high enough to be above the valley floors where cold air collects. However, the best stands of timber along rivers in this region, such as Stewart, McQuesten, North Klondike and lower Blackstone are in floodplain situations immediately adjacent to the stream, where permafrost is locally absent. It seems that poor drainage coupled with a thicker cover of organic deposits and the accompanying permafrost are more important factors in excluding white spruce from valley floors than the low air temperatures. Along the valley bottoms, on exposed uplands and boggy areas, stunted white spruce and black spruce (*Picea mariana*) are commonly found. On upland slopes alpine fir (*Abies lasiocarpa*) is associated with spruce. Alpine fir is an important species in the tree cover near timberline south of Dawson, for example, on Keno Hill and as close to Dawson as Barlow Dome (Lat. 63°50′ N, Long. 137° 30′ W). However, Hughes did not note it along North Klondike or East Blackstone rivers in southern Ogilvie Mountains, or in the northern part of Klondike Plateau. Instead, along North Klondike valley it is white spruce that forms the upper tree limit. Tamarack (*Larix laricina*) is absent from this forest section and lodgepole pine (*Pinus contorta* var. *latifolia*) is found infrequently in the southern parts of the section.

Bostock (1961, p. 113) gives the altitude of timberline in Southern Ogilvie Ranges at about 4,000 feet on the south of the divide, but it is at least 1,000 feet lower on the northern side. In describing the Taiga Valley physiographic subdivision, which includes the Chapman Lake area, Bostock (*l.c.*, p. 114) states that the northward draining slopes and hills are covered by tundra and niggerheads (a fen with abundant small cyperaceous hummocks), with willow (*Salix*) brush, small spruce and birch scattered and in groups on better drained sites. Hedge-like stands of larger spruce and poplar grow on the more deeply thawed ground along the larger streams.

The region north of the study area, along the Porcupine and Peel Rivers, lies in the Alpine Forest-Tundra Section (ROWE, 1959). Open, park-like stands of stunted white spurce, alternating with fens, bogs and alpine meadows, or with rock barrens, are characteristic of the mountain slopes. On northern and eastern aspects the alpine fir commonly occurs at transition to alpine tundra, and at lower altitudes the black spruce is most frequent, either in pure stands or mixed with white spruce. On more favourable sites occur stands of white spruce and white birch (*Betula papyrifera* vars.). Tamarack and poplar species are infrequent components of the forest vegetation.

PALYNOLOGICAL STUDY

Cores for this phase of the investigation were obtained with a SIPRE ice-corer (HUGHES & TERASMÄE, 1963). Hand augering was employed at the Gill Lake site, whereas a motor-powered SIPRE corer with a modified, and more efficient cutting teeth was used at Chapman Lake by Hughes. A nearly continuous 3-inch core of frozen peat and sediments was collected in segments, which were carefully cleaned and put into plastic bags. It is necessary to emphasize that coring of sediments in this area is complicated by deep permafrost conditions. Probing in bogs is impossible and coring sites must be carefully selected to provide the maximum amount of information. At the time no equipment was available for coring lake bottom sediments which are commonly unfrozen (JOHNSTON & BROWN, 1963).

Small samples were taken from the core segments in the laboratory, and the core was logged in detail for reference in stratigraphic studies. The inorganic sediments and silty peat samples were treated with hydrofluoric acid, and all samples were prepared using the acetolysis method. Good concentration of pollen and spores was obtained from most samples, except from those of the bottom part of the Chapman Lake core where barren sediments were encountered.

Results of the study have been compiled in two pollen diagrams (TEXT-FIGS. 2, 3). After an examination of the diagram it became evident that the bottom of pollen-bearing sediments had not been reached at Gill Lake. However, it had been impossible at that site to core deeper with the hand-operated equipment and the standard cutting head of the SIPRE corer.

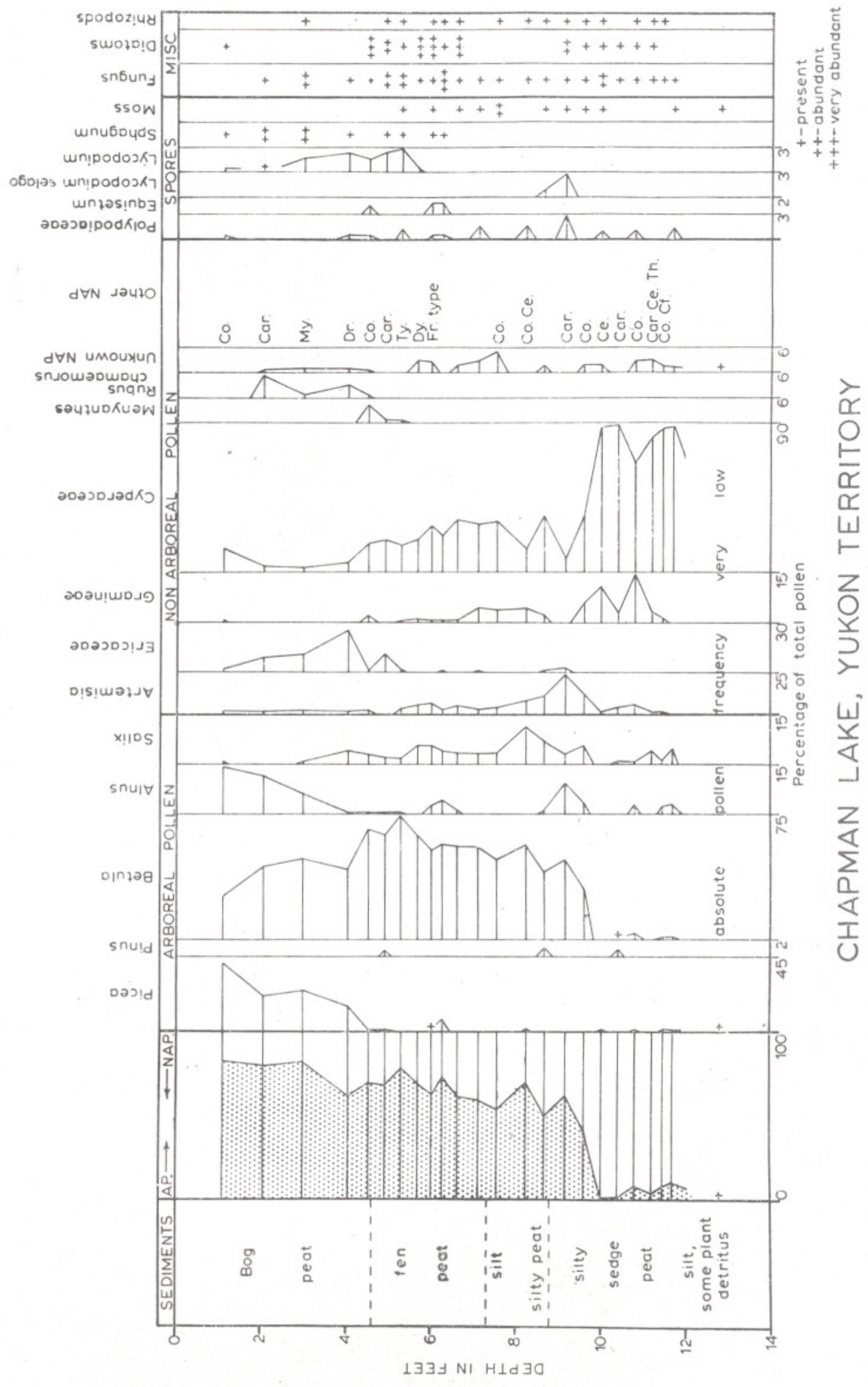
Both diagrams show evidence of vegetational changes and the bottom of the Gill Lake diagram, dated at 12,550 ± 190 years (GSC-128), is tentatively correlated with the 9-foot depth of the Chapman Lake diagram. A sample from the bottom of organic deposit in the Chapman Lake core yielded an age of 13,870 ± 180 years B.P. (GSC-296).

Pollen zones as proposed by Livingstone (1955) for northern Alaska have been adopted for this study. Zone I comprises the bottom part of the Chapman Lake diagram and is characterized by the abundance of cyperaceous pollen; Zone II begins at the sudden increase of birch pollen, and the lower boundary of Zone III is placed at the beginning of the significant increase of spruce and alder pollen. Further subdivision of these zones may be possible but seems unwarranted because of the limited data available for this study.

In the Gill Lake diagram the increase in ericaceous and *Rubus chamaemorus* pollen near the top is interpreted as a change in local environment from a lacustrine phase (characterized by the presence of *Nuphar* pollen) to a bog phase. The significance of certain other changes is less clear from this limited information. The presence of the silt layer at the 8 to 9-foot depth in the Chapman Lake diagram is assumed to have regional environmental significance. This layer is correlated with the bottom of the Gill Lake core, and it is possible that deeper coring there would have revealed the presence of more organic sediments beneath the silt layer. The date of 12,550 ± 190 years may indicate the approximate age of the lower boundary of pollen Zone II.

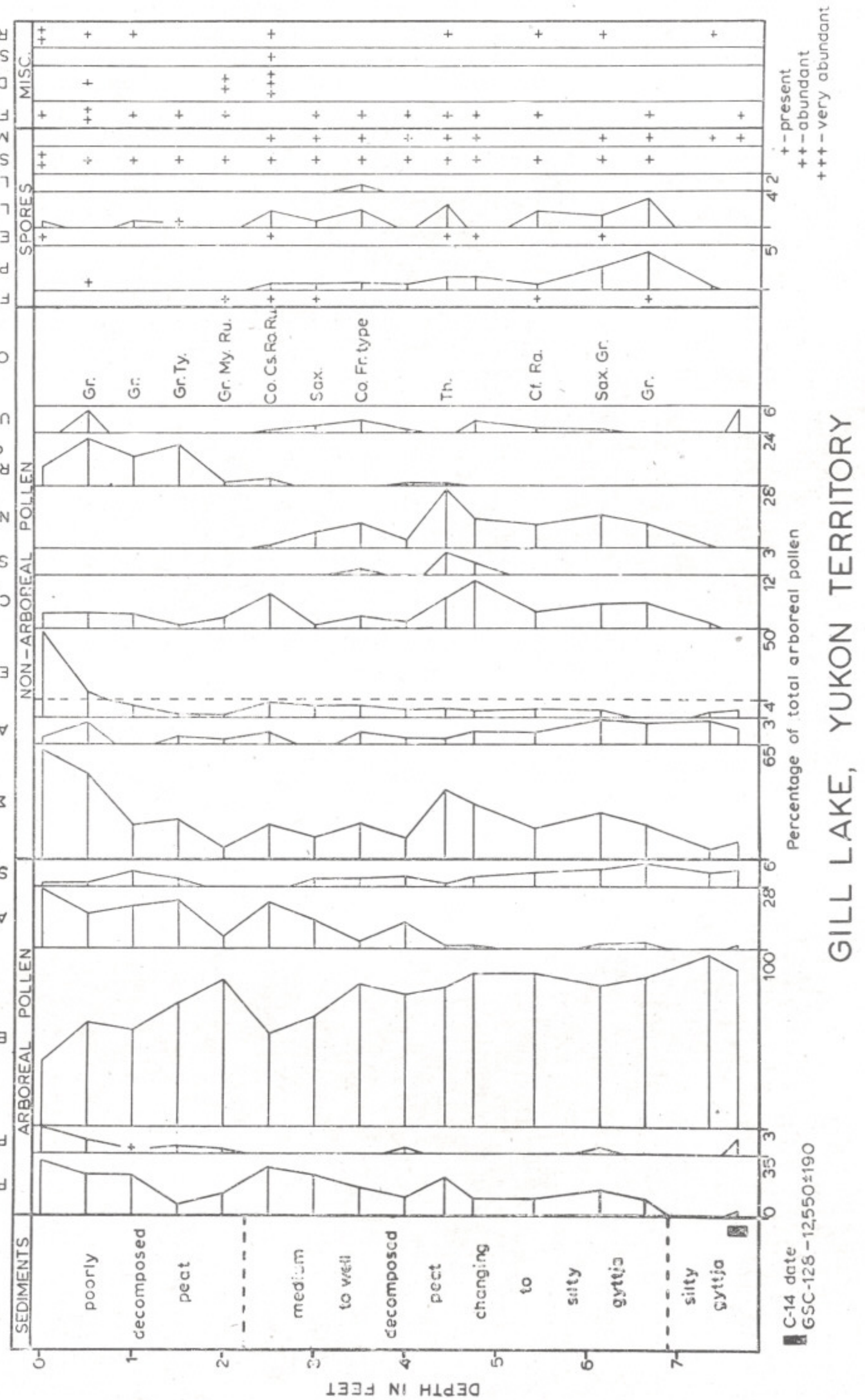
DISCUSSION

The following chronology for the late-Wisconsinan, and earlier events is indicated



C-14 dates: Fen peat (5′ depth): 9620 ± 150 (GSC-310).
Silty peat (8′ depth): 10,900 ± 150 (GSC-311).
Silt, some plant detritus (13′ depth): 13,870 ± 180 (GSC-296)

TEXT-FIG. 2 — Pollen diagram of the Chapman Lake core.



TEXT-FIG. 3 — Pollen diagram of the Gill Lake core.

by this study. One or more older glaciations, as indicated by the occurrence of erratics and scattered drift deposits beyond the outer limit of Chapman Lake moraine, and by similar deposits elsewhere in Ogilvie Mountains, remain undated. These older glaciations are assumed to be of pre-Wisconsinan age.

The Chapman Lake moraine is older than 13,870 ± 160 years, as indicated by the date GSC-296 on the oldest datable material from the Chapman Lake core. Considerable dissection took place between the intermediate glaciation represented by Chapman Lake and Gill Lake moraines, and the last glaciation represented by moraines in North Fork Pass and Miner River; these moraines themselves were considerably modified (Vernon & Hughes, *in press*). The intermediate glaciation is assumed to be of early-Wisconsinan age.

The moraine in the North Fork Pass is tentatively correlated with the silt layer of the Chapman Lake core. Dates immediately below this silt layer, and two feet above it, place the event between 10,900 ± 150 years and 9620 ± 150 years B.P. The latter date is supported by a bog bottom date from a depression in the North Fork Pass moraine which indicated that this moraine is older than 7510 ± 100 years B.P. (GSC-50).

It is interesting to note the considerable similarity between the glacial succession in the Ogilvie Mountains and that of north-central Brooks Range, Alaska, some 400 miles to the northwest of the Chapman Lake area. Two advances assumed to be of pre-Wisconsinan age have been recognized in the Brooks Range (Detterman, Bowsher & Dutro, 1958), and at least one pre-Wisconsinan glaciation is inferred from scattered moraine segments, drift deposits and erratics in the Ogilvie Mountains. The oldest well presented moraine (Banded Mountain) of Anatuvuk valley, Brooks Range, is radiocarbon dated (Porter, 1964) as older than 13,270 ± 160 years (Y-1084); the Chapman Lake moraine of the Ogilvie Mountains (older than 13,870 ± 160 years) and the Gill Lake moraine (older than 12,550 ± 190 years) can be tentatively correlated with it. Only one re-advance later than 13,870 years B.P. is inferred from the North Fork Pass moraine and other similar moraines in the Ogilvie Mountains. However, in the Anatuvuk valley Porter (1964) recognizes three re-advances younger than 13,270 years B.P. The first of these (Anayaknaurak) probably represents only a minor fluctuation of the glacier and the third (Anivik) is closely associated with the intermediate one (Antler Valley). The single late re-advance in the Ogilvie Mountains therefore may be correlated collectively with the three late re-advances in the Brooks Range, and more specifically with the Antler Valley re-advance.

A correlation of similar vegetational successions between the Ogilvie Mountains and the Brooks Range is made possible by comparing the available pollen diagrams from both regions. Livingstone (1955 & 1957) has made pollen-chronological studies in northern Brooks Range near Umiat, and it is interesting to note the excellent correlation between his Chandler Lake pollen diagram and that from Chapman Lake in the Ogilvie Mountains. However, in his later study Livingstone (1957) attempted to date the pollen zone boundaries, and obtained an age of 5900 ± 200 years for the top of Zone II. Two dates, 7500 ± 250 years and 8125 ± 250 years, are shown to bracket the Zone I/II boundary. A rather older age seems to be indicated for the Zone I/II boundary at Chapman Lake, probably in the range of 11,000 to 12,000 years. It is hoped that further palynological studies in the Chapman Lake area, supported by radiocarbon, dates will clarify this interesting and important problem.

A rather puzzling feature of the pollen diagrams is the apparent lack of evidence to indicate the ice re-advance which formed

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Text fig. 3 — List of abbreviations:

Car	Caryophyllaceae
Ce	Chenopodiaceae
Cf	Cruciferae
Co	Compositae
Cs	Cornus
Dr	Drosera
Dy	Dryas
Fr-type	Franseria-type
Gr	Gramineae
My	Myrica
Ra	Ranunculaceae
Ro	Rosaceae
Ru	Rumex
Sax	Saxifragaceae
Th	Thalictrum
Ty	Typha

the North Fork Pass moraine. Although firn line in the Ogilvie Mountains must have been lowered to cause this re-advance, there does not seem to be any obvious evidence for it in a significant displacement of vegetation zones at Chapman Lake or Gill Lake, both of which are between the 3000 and 3500 foot altitude. Perhaps an improved paleoecological interpretation based on more detailed paleobotanical studies can be made in the future.

In his recent study Porsild (1964) has pointed out the important differences between the eastern and western North American Arctic. He notes that, based on available botanical data, any plant refugia which may have existed in the eastern Arctic during the Quaternary, must have been near sea-level rather than on the frigid and windblown summits of mountains protruding above the ice fields. However, the unglaciated mountain plateaux of Yukon and Alaska have for some time been known to harbour floras richer and more varied than those of the intervening valleys. Porsild (1964, p. 93) states that in Yukon the upper limit of valley glaciation roughly coincided with the present timberline at 4500 to 5600 feet above sea level (*see* also Porsild, 1951). He further states that, " the climate at this time must have been sufficiently favourable for the plateaux above the ice to have served as refugia for numerous arctic and alpine species for, otherwise, it would be very difficult to explain how the endemic or widely disjunct species, for which these plateaux are renowned, could have arrived in post-Pleistocene time." The palynological studies made lend support to this assumption, and indicate, furthermore, that species of *Alnus, Betula, Salix,* and *Picea* also must have survived in these refugia in order to appear in the bottom samples (as indicated by the presence of their pollen) of cores taken in areas covered by glaciers of the last glaciation (*see* also Hansen, 1953, & Heusser, 1960). Further palynological and ecological studies are required for a satisfactory interpretation of postglacial climatic changes, such as were attempted for the Mackenzie delta area farther north by Mackay and Terasmae (1963).

REFERENCES

Bostock, H. S. (1948). Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel. *Geol. Surv. Brch. Can., Mem.* 247:

Idem (1961). Physiography and resources of the Northern Yukon. *Can. geogr. J.*, **43** (4): 112-119.

Boughner, C. C. & Thomas, M. K. (1960). The Climate of Canada. *Can. Brch. Dept. Trans., meteorol.* Toronto.

Campbell, J. D. (1952). The paleobotany and stratigraphic sequence of the Pleistocene Klondike " muck deposits ". *Unpubl. Ph.D. Thesis, McGill Univ.* Montreal.

Detterman, R. L., Bowsher, A. L. & Dutro, J. J. (1958). Glaciation of the Arctic slope of the Brooks Range, northern Alaska. *Arctic*, **11**: 43-61·

Hansen, H. P. (1953). Postglacial forests in the Yukon Territory and Alaska. *Amer. J. Sci.* **251**: 505-542.

Heusser, C. J. (1960). Late-Pleistocene Environments of North Pacific North America. *Amer. geogr. Soc. Spec. Publ.*, No. **35**.

Hughes, O. L. & Terasmae, J. (1963). SIPRE ice-corer for obtaining samples from permanently frozen bogs. *Arctic*, **16** (4): 271-272.

Hultén, E. (1941-1950). Flora of Alaska and Yukon. *Gleerup*, Lund.

Johnston, G. H. & Brown, R. J. E. (1963). Effect of a lake on distribution of permafrost in the Mackenzie River Delta. *Nat. Res. Council Can., Proc. 1st Can. Conf. Permafrost, Techn.* Memorandum no. **76**: 218-225.

Karlstrom, T. N. V. (1964). Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska. *Prof. Pap. U. S. geol. Surv.*, 443:

Livingstone, D. A. (1955). Some pollen profiles from arctic Alaska. *Ecology*, **36** (4): 587-600.

Idem (1957). Pollen analysis of a valley fill near Umiat, Alaska. *Amer. J. Sci.*, **255**: 254-260.

Mackay, J. R. & Terasmae, J. (1963). Pollen diagrams in the Mackenzie Delta area, N.W.T. *Arctic*, **16** (4): 228-238.

Macoun, J. (1906). Climate and flora of Yukon District. *Rep., geol. Surv. Can.*, 15 (1902-03), Pt. A,: 38-54.

Porsild, A. E. (1951). Botany of southeastern Yukon adjacent to the Canol Road. *Bull. nat. Mus. Can.*, 121:

Idem (1964). *Potentilla stipularis* L. and *Draba sibirica* (Pall.) Thell new to North America. *Can. Fld Nat.*, **78**: 92-97.

Porter, S. C. (1964). Late Pleistocene glacial chronology of north-central Brooks Range, Alaska. *Amer. J. Sci.*, **262**: 446-460.

Rowe, J. S. (1959). Forest Regions of Canada. *Bull. Dep. north. Affs., natur. Resources*, 123.

Vernon P. & Hughes, O. L. (in *press*). Surficial geology of the Dawson, Larsen Creek and Nesh Creek map-areas, Yukon Territory· *Bull. geol, Sur. Can.* 136.