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Upper Pleistocene Stratigraphy, Paleoecology, and Archaeology of the Northern Yukon Interior, Eastern Beringia
1. Bonnet Plume Basin

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ABSTRACT. New stratigraphic and chronometric data show that Bonnet Plume Basin, in northeastern Yukon Territory, was glaciated in late Wisconsinan time rather than during an earlier advance of Laurentide ice. This conclusion has important ramifications not only for the interpretation of all-time glacial limits farther north along the Richardson Mountains but also for non-glaciated basins in the Porcupine drainage to the northwest. The late Wisconsinan glacial episode in Bonnet Plume Basin is here named the Hungry Creek advance after the principal Quaternary section in the basin. Sediments beneath the till at Hungry Creek have produced well-preserved pollen, plant macrofossils, insects, and a few vertebrate remains. The plant and invertebrate fossils provide a detailed, if temporally restricted, record of a portion of the mid-Wisconsinan interstadial, while the vertebrate fossils include the oldest Yukon specimen of the Yukon wild ass. Some of the mid-Wisconsinan sediments have also yielded distinctive chert flakes that represent either a previously unreported product of natural fracturing or a by-product of stone tool manufacture by human residents of Bonnet Plume Basin.

In addition to presenting new data on these diverse but interrelated topics, this paper serves as an introduction to a series of reports that will treat in turn the Upper Pleistocene record of Bluefish, Old Crow, and Bell basins, respectively.

RÉSUMÉ. De nouvelles données stratigraphiques et chronométriques indiquent que le bassin de Bonnet Plume situé au nord-est du Yukon était glaciaire au Wisconsin supérieur plutôt que lors de la crue antérieur de glace laurentienne. Les conséquences entraîne la révision des interprétations des limites glaciaires maximales en bordure des montagnes Richardson plus au nord et en bassin non glaciaire au reseau hydrographique de la Porcupine au nord-ouest. La phase supérieure du Wisconsin dans le bassin de Bonnet Plume est connue ici comme la crue de Hungry Creek, d'après la section quaternaire principale du bassin. Les dépôts sous l'alluvion glaciaire à Hungry Creek ont produit des spécimens fossiles bien préservés de grains de pollen, de plantes, d'insectes et de quelques restes de vertébrés. Les fossiles de plantes et d'invertébrés indiquent, de façon très détaillée mais peu étendu dans le temps, de l'interstade mi-Wisconsin, tandis que les fossiles de vertébrés comprennent le plus vieux spécimen connu au Yukon de l'âne sauvage du Yukon. Certains des sédiments de la phase mi-Wisconsin ont aussi fourni des éclats particuliers de chert qui indiquent soit une formation de fissures non décrites jusqu'ici, soit un sous-produit de la fabrication d'outils de pierre par des résidents humains du bassin de Bonnet Plume. En plus de présenter de nouvelles données sur ces thèmes diversifiés mais connexes, ce texte sert d'introduction à une série de rapports qui traiteront respectivement du Pléistocène supérieur dans les bassins de la Bluefish, de la Old Crow et de la Bell.

Резюме. Новые стратиграфические и хронометрические данные показывают, что бассейн Боннет Плам Бейзин в северо-восточной части территории Юкон подвергся действию ледников скорее во время позднего висконсина,а не во время более раннего наступления лаврентийского ледника. Это заключение имеет важные последствия не только для интерпретации конечных границ наступления ледника далее на севере вдоль гор Ричардсона, но также для не подвергшихся воздействию ледника бассейнов на стоках Поркупайн на северо-западе. Наступление ледника во время позднего висконсина в бассейне Боннет Плам Бейзин названо здесь наступлением на Хангри Крик по названию главной части четвертичного периода в этом бассейне. Отложения под валунной глиной в районе Хангри Крик содержат хорошо сохранившиеся цветочную пыльцу, макроископаемые растения, насекомых и некоторые останки беспозвоночных. Ископаемые растения и останки беспозвоночных обеспечивают подробный, хотя и временно ограниченный материал средне-висконсинского интерстадиала в то время, как ископаемые позвоночных включают наиболее старый образец, найденный на Юконе, юконского дикого осла. В некоторых отложениях средне-висконсинского интерстадиала были обнаружены отчетливые кусочки кремнистого сланца, которые представляют собой или результаты естественного откола, о котором раньше не сообщалось, или

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отходы при изготовлении каменных орудий людьми-жителями бассейна Боннет Плам Бейзин.

В дополнение к представлению новых данных на эти различные, но взаимосвязанные темы, эта работа служит в качестве вступления к серии докладов, в которых будет сообщаться в свою очередь о материалах верхнего плейстоцена, обнаруженных последовательно в бассейнах Блуфиш, Олд Крау и Белл.

INTRODUCTION

This is the first of a projected series of reports arising from research conducted under the multidisciplinary Yukon Refugium Project initiated in 1974. This and following background material (Previous Work, Methods, Physical Setting) apply generally to the entire report series.

The principal focus of the project has been the non-glaciated lowlands of northern Yukon which afford an unusual wealth of Pleistocene exposures and a great number and variety of well preserved fossils. However, it was known (Hughes, 1972) that Laurentide glaciation of adjacent areas lying to the south and east had influenced profoundly the late Quaternary history of the non-glaciated area, and hence that history of the respective areas was inextricably linked. Accordingly, considerable effort has been devoted to study of Bonnet Plume Basin, where geomorphic and stratigraphic evidence of late Quaternary glaciation is well displayed. Discussion of Bonnet Plume Basin in the first paper of the projected series is intended to provide the background knowledge of glacial events necessary for an understanding of the history of the non-glaciated area.

New data have forced major reinterpretation of the glacial history of Bonnet Plume Basin and the glaciated area northward along the flanks of Richardson Mountains, as interpreted by Hughes (1972). The reinterpretation affects equally the history of the non-glaciated area as previously understood. Some of the ramifications of the reinterpretation are introduced herein, with the intent that they will be more fully treated in subsequent reports of the series.

Efforts to understand the long-term evolution of landscapes and ecosystems in Canada are significantly hampered in most areas by the erosional and depositional phenomena attributed to Pleistocene glaciation. Repeated advances of glaciers have either erased or obscured the paleoenvironmental record of most areas of the country. Several important areas lie outside the maximum former extent of ice cover, however, and these invite our attention for the opportunity to examine long and potentially continuous biostratigraphic records which may represent hundreds of thousands or even millions of years.

The largest of the non-glaciated areas in Canada is in Yukon Territory, of which nearly half was not covered by glaciers during the Pleistocene (Fig. 1). Together with non-glaciated areas of Alaska and eastern Siberia and intervening shelf areas, this ice-free region of Yukon comprises the central portion of Beringia (Hopkins, 1967; Yurtsev, 1974) and has been viewed as a glacial refugium for plants and animals. Such refugia are important for several reasons. Not only do they offer the possibility for long and relatively continuous records of environmental change, but also they are believed to have been centres for the dispersal of life forms following deglaciation (Hultén, 1937, 1968; Yurtsev, 1974; Bodaly and Lindsey, 1977; Youngman, 1975; Murray, 1981).

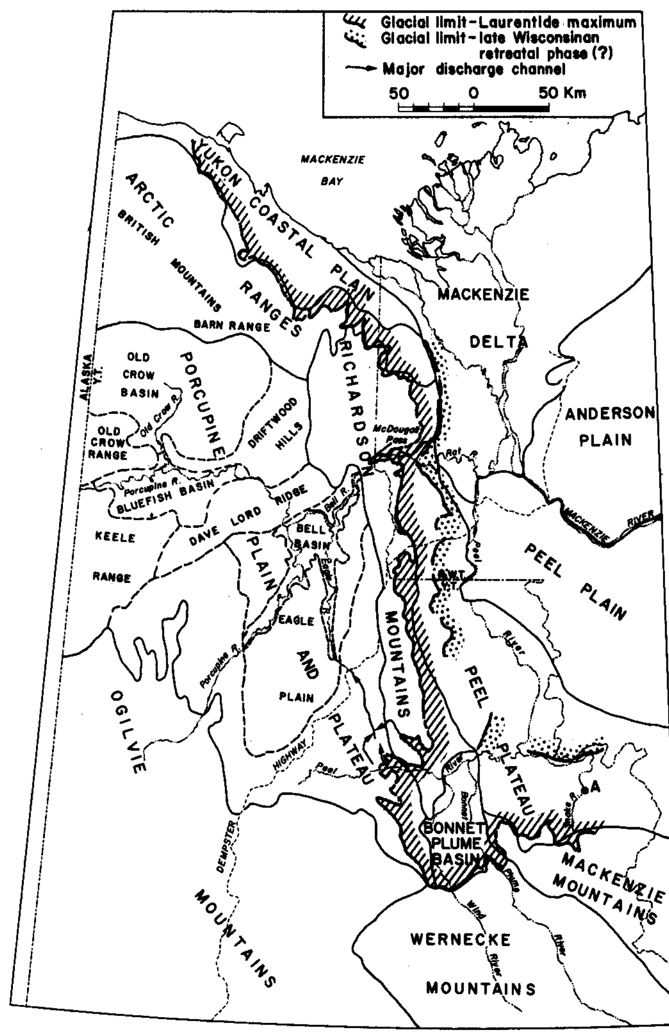

FIG. 1. Physiography and glacial limits, northern Yukon and western District of Mackenzie, N.W.T. Physiographic divisions modified from Bostock (1948, 1967); glacial limits based on Hughes (1972), Hughes *et al.* (1972), Hughes and Pilon (1973), and Rampton (in press). A = Snake River locality mentioned in text.

The Beringian refugium has been studied from several perspectives in recent years, including culture history (Vasil'evsky, 1979), paleoecology and biogeography (e.g., Gressitt, 1963), and several syntheses have appeared (Hopkins 1967; Kontrimavichus, 1976; Hopkins *et al.*, in press). This refugium is of particular interest because of its critical role in the interchange of Palearctic and Nearctic biota. During periods of maximum glaciation the continental shelf between Alaska and Siberia was exposed as a broad land mass commonly known as the Bering Land Bridge. Alternate exposure and inundation of this land bridge significantly influenced the biogeography of both terrestrial and marine organisms (Hopkins, 1967, 1973; Sher, 1974; Péwé, 1975; Harington, 1978). Ice-free areas in the Yukon Territory comprise the easternmost region of non-glaciated Beringia and offer, in Canada, unique opportunities to understand the long-term evolution of the landscape and its inhabitants. Among the latter, one of the most interesting is the human lineage which is believed to have reached the New World by way of the Beringian area (Bryan, 1978; Laughlin and Harper, 1979; Morlan and Cinq-Mars, in press).

In addition to proposing major revisions to Quaternary geological history in northern Yukon, this paper presents new data in four allied areas of investigation: (1) a pioneer study of amino acid racemization emphasizing the analysis of wood samples; (2) a series of macrofossil samples that contain bryophytes, vascular plants, and insects in states of preservation unprecedented in mid-Wisconsinan contexts; (3) the oldest known Yukon specimen of the Yukon wild ass; and (4) mid-Wisconsinan microflakes that may be by-products of stone tool manufacture.

PREVIOUS WORK

Geological reconnaissance in the Porcupine drainage began with the explorations of Ogilvie (1890) and McConnell (1891), and Camsell (1906) provided early reports on the Peel River system. General descriptions of the western border of northern Yukon, as well as more detailed geological and topographic data, were published as a result of the international boundary surveys (International Boundary Commission, 1918). Of particular note is Bostock's (1948) excellent description of the physiography of northwestern Canada in which the limit of glaciation was accurately defined for the first time. Vertebrate fossils were first collected in the 1870s in the Old Crow area (Harington, 1977:29-35), and sporadic collecting during the first half of the twentieth century culminated in two northern Yukon collecting trips by Geist (1952-53, 1955).

Previous work leading directly to this project began in association with Operation Porcupine (Norris, 1963) in 1962, when O. Hughes, assisted by V. Rampton, made an extensive reconnaissance of Quaternary geomorphology and stratigraphy. Rampton first described sections along Old Crow river in that year and made the first northern Yukon collection of vertebrate fossils to find their way to the National Museum of Natural Sciences in Ottawa. Rampton's (in press) subsequent work on the Yukon Arctic Coastal Plain has been relevant to research in the northern Yukon interior.

During field work in 1962, 1968, and 1969, Hughes developed an outline of Quaternary geology for northern Yukon involving two glaciolacustrine episodes and an intervening period of fluvial and lacustrine sedimentation (Hughes, 1963, 1969, 1970, 1972). Hughes also collected samples for analysis by various paleoenvironmental specialists (Delorme, 1968; Lichti-Federovich, 1973, 1974; Matthews, 1975).

When C.R. Harington joined the staff of the National Museum of Natural Sciences in 1965, Rampton's collection from Old Crow River came to his attention. Of special significance among these specimens were remains of an extinct muskox, *Boötherium* (probably a female of the helmeted muskox, *Symbos cavifrons*), and giant moose (*Alces latifrons*, previously known only from Eurasian Pleistocene deposits). These finds encouraged Harington to undertake field work which began in 1966 and continues to the present time in both the Old Crow and Dawson areas (Harington, 1977, 1978; Harington and Clulow, 1973).

During Harington's first northern Yukon field season he discovered a bone tool evidently made by early man among the paleontological specimens along the banks of Old Crow River, and he brought this find to the attention of W.N. Irving who at the time was engaged in an archaeological excavation of the Klo-kut site near the village of Old Crow. Irving devoted his 1967 field season to a search for more fossil artifacts as well as more general surveys along the Old Crow and Porcupine Rivers. Archaeological reconnaissance and excavation during subsequent years produced an outline of prehistory involving a poorly defined Upper Pleistocene (probably mid-Wisconsinan) record and a series of cultural complexes dated to the Holocene (Irving, 1971; Irving and Harington, 1973; Harington, 1975; Morlan, 1973; Irving and Cinq-Mars, 1974). T. Hamilton and T. Ager made significant (but unpublished) geological contributions to Irving's work. Laboratory analysis by R. Bonnichsen in 1973 led to the first significant statement concerning the fossil artifacts (Bonnichsen, 1978), and his observations have since been published in detail (Bonnichsen, 1979).

As of 1974, the ongoing field work of all these investigators had provided a large but somewhat unwieldy body of data from more than 150 study sections and collecting localities. These data included abundant evidence of the late Upper Pleistocene vertebrate, invertebrate, and plant populations of eastern Beringia, and they indicated that people were probably present in the region by at least 30 000 years ago. The need to gather more evidence on early man and his environment provided the impulse for two multi-disciplinary projects: the Northern Yukon Research Programme and the Yukon Refugium Project. This

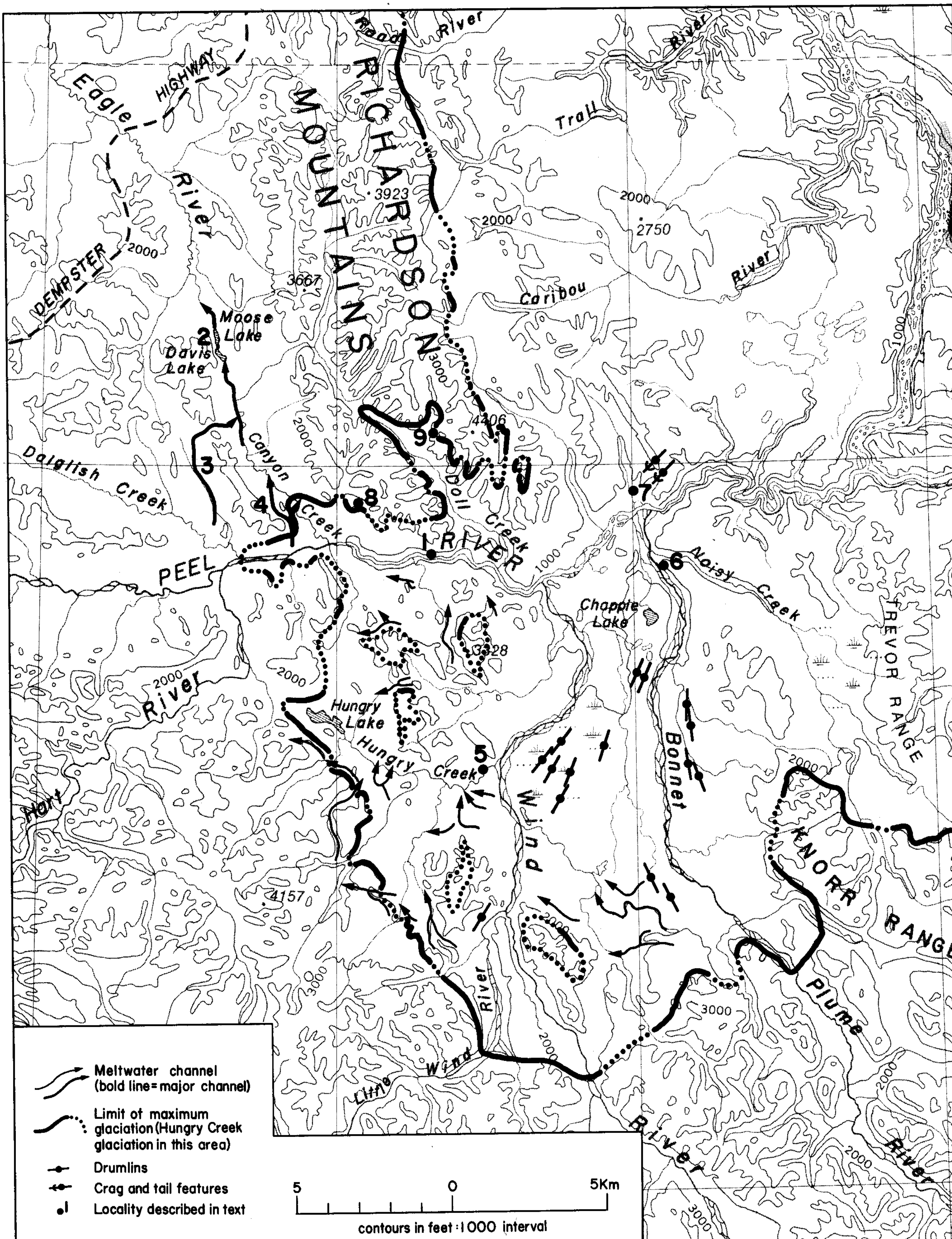

FIG. 2. Bonnet Plume Basin and vicinity, showing the limit of maximum Laurentide glaciation (= Hungry Creek Glaciation in Bonnet Plume Basin), meltwater channels that allowed water to flow into the Porcupine drainage, and sites mentioned in the text. Hungry Creek section is loc. 5.

series of papers represents the research of the Yukon Refugium Project.

METHODS

Narratives describing our field work have appeared elsewhere (Morlan *in* MacDonald, 1975, 1977, and Marois, 1980; Morlan, 1976; Morlan, 1980:x-xi). The research reported in this paper was conducted during several visits to Bonnet Plume Basin (Fig. 2). On each of two occasions, Hughes devoted several hours to the Hungry Creek section in 1972, and he and Harington recovered the first rodent remains by wet-sieving organic silt from the basal unit at the section in that year. Hughes stopped briefly at Hungry Creek with Rutter in 1974. Most of the samples reported here were collected during four days of intensive work by Hughes, Morlan, and Schweger in 1976, and a final one-day examination of the bluff in 1978 was devoted primarily to the sediments overlying the till.

The length of the Hungry Creek section made it useful to subdivide it into a series of six numbered stations (Fig. 3). Geological field descriptions and interpretations of stratigraphic units were made on cleaned near-vertical faces where the probability of encountering slumped sediments or modern rootlets was minimal. Considerable time was expended tracing the lateral continuity of certain marker horizons, a procedure essential to understanding the history of such sections, since they exhibit rapid facies changes.

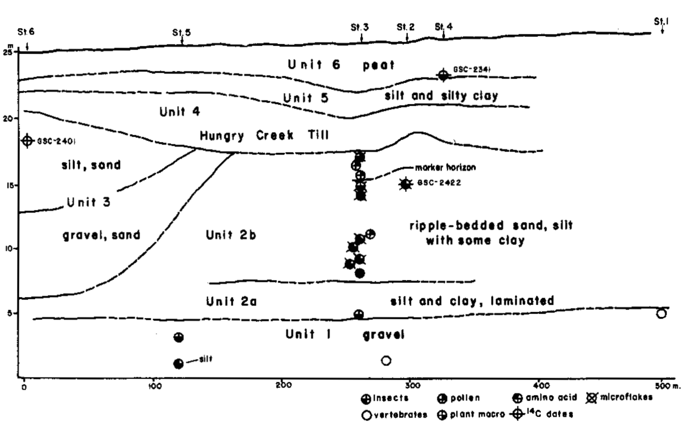

FIG. 3. Generalized diagram of the Hungry Creek section (HH 72-54) as of 1976, showing stations, and the positions of samples mentioned in text. Dashed line indicates unit boundary is assumed. For details on the stratigraphy at each station see Table 1 (below).

A marker horizon comprising distinctively bedded silt and clay has been used to correlate several Hungry Creek stations.

Radiocarbon Dating

Radiocarbon dates provide some of the best data for correlation of stations and sections. Virtually all of the sections under study are partly alluvial in origin, raising the specter of rebedded organics. It was suspected at the start of these investigations that some of the radiocarbon samples analysed in earlier years were allochthonous, and some of the more recently dated samples confirm this suspicion. Consequently, a number of criteria have been adopted to ensure that dated samples would accurately reflect the age of associated organics and sediments.

For example, if the prospective radiocarbon sample is wood, every attempt is made to collect enough that a single piece can be dated. At the time of collection, the wood is examined *in situ* to determine whether it is in growth position or exhibits bark, branches, or other delicate structures that would be unlikely to survive redeposition. The texture and character of the host sediments may provide clues as to the suitability of wood for dating. However, even wood found in detrital organic or alluvial contexts may be judged acceptable for dating if it exhibits structures that indicate penecontemporaneous growth, death, and final deposition. Wood samples are routinely identified, if possible, before being sent to the radiocarbon laboratory at the Geological Survey of Canada (GSC). If adequate quantities are available, a sample of the dated piece is saved for amino acid racemization analysis. Finally, the organic component, if any, from the host sediments is examined for pollen, plant macrofossils, bryophytes, insects and vertebrates. Hence many of the northern Yukon radiocarbon dates stand by themselves as paleoenvironmental data points. Several radiocarbon dates come from the Hungry Creek section. In addition, dates from other sections and from intervals within a lake core sequence provide information valuable for regional correlation of events.

Amino Acid Dating

An important aspect of the Yukon Refugium Project is to explore other dating techniques of which amino acid racemization (the conversion of the L configuration to D configuration of amino acids) has been emphasized. Amino acid D/L ratios (indicating degree of racemization with a ratio of 1 meaning completely racemized) had not previously been tested for correlation of beds and relative age dating in continuous permafrost regions of Yukon Territory. Furthermore, certain types of material, specifically freshwater mulluscs and wood, had never been used before in any such study in Canada. It was our objective to evaluate the usefulness of the method in this region while also exploring the feasibility and reliability of various types of sample material. Bone, teeth, molluscs, and wood were collected from many horizons from most sections investigated in northern Yukon.

Preliminary results from amino acid analysis have been described elsewhere (Rutter *et al.*, 1980). An important discovery is that the racemization ratios of fragmented, unidentified bone samples did not reveal a consistent relationship with stratigraphic data. It appears that success depends upon comparing ratios of the same types of bone from the same species, a criterion rarely met. On the other hand, molluscs produced useful and interpretable ratios if the samples of mulluscs were first sorted to the generic level. Ratios based upon single mollusc genera are useful for correlation and relative dating, whereas admixtures of different genera give spurious results due to each genus having its own racemization rate. Wood samples are abundant in many horizons of most sections in the northern Yukon, making it worthwhile to evaluate wood ratios for correlation and relative age dating. Results thus far are encouraging, and wood is now our most important amino acid correlation tool. In addition it has not been necessary to identify wood to the generic level for our purposes, but the effects of generic differences on racemization rates are being evaluated at the present time. In the Hungry Creek section only wood was analysed, and the results are discussed in a later section (see Stratigraphy).

D/L ratios of alanine, valine, leucine, phenylalanine, proline and aspartic acid are routinely determined. Aspartic acid has proved to be the most useful because of the relatively fast rate of racemization and reliability (Kvenvolden, 1980). Therefore, only D/L ratios of aspartic acid are reported here. On the other hand, species composition, climatic history, and diagenetic alterations can affect the racemization rate and must be considered among the variables in amino acid analysis. For example, during what percentage of time since deposition of a specimen has it been subjected to permafrost conditions and, therefore, a slower racemization rate?

The method used in our analysis is presented in Appendix A, and that description will serve to introduce amino acid results provided in subsequent papers in this series.

Plant and Insect Fossils

One objective of this and later papers is to show the importance of paleoenvironmental data for interpreting the stratigraphy and regional relationships of alluvial sections. Such goals require that numerous samples be examined with the inevitable consequence that many samples collected at Hungry Creek have thus far received only preliminary attention. Hence, in the lists of insect and plant macrofossils, many taxa are entered at the generic level, and only one of the samples yielded enough fossils to justify quantitative analysis.

Suites of pollen samples were collected from several of the stations at the Hungry Creek exposure. To date, only a few samples have been processed and some of these are barren. Pollen samples were processed using heavy liquid techniques (Schweger, 1976; Schweger and Janssens, 1980).

Samples collected for plant macrofossils and insects ranged in size from 7 to 50 kg. Most were recovered from levels sampled for pollen, and all were keyed to the stratigraphic units shown in Table 1. The majority of the samples are from Station 3. The term 'seed' is used loosely to include achenes, capsules, fruits, endocarps, samaras and other such propagules, but not leaves or buds. Leaves, except for those of conifers, are relatively rare, and no attempt has been made thus far to identify other tissues. Although flotation techniques are often valuable for concentrating organic remains (Struever, 1968), significant biases may be introduced by such techniques (Keeley, 1978). The single plant macrofossil assemblage analyzed quantitatively is composed of fossils hand-picked under a microscope from residue that had received no more than sieve treatment (0.180 mm sieve openings in the lab, or 0.425 mm if sieved initially in the field). Most of the plants from other samples were picked prior to any flotation procedures used to concentrate other types of fossils. Similarly, the samples submitted for bryophyte analysis were only sieved (1 mm sieve openings; no flotation techniques) before the fossils were picked.

In order to obtain sufficient concentrations of insect fossils, sieved sample residues were processed by kerosene ("paraffin") flotation (Kenward, 1974). This procedure does not appear to bias insect assemblages to the same degree that flotation techniques bias plant macrofossil recovery. Where the amount of sieved residue was small, kerosene flotation was not used. Sample 76-31 was not processed with the kerosene method.

Pollen identification was aided by the pollen reference collection in the Department of Anthropology, University of Alberta. Identification of plant macrofossils was made by reference to standard keys and illustrations and the Geological Survey of Canada (GSC) collection of seeds and fruits. Mosses were identified in the herbarium of the University of Alberta (ALTA). Likewise the synoptic insect collection housed at the GSC aided in identification of the insect fossils, with supplementary assistance from the Coleoptera collections at the Biosystematics Research Institute and the National Museum of Man.

Quantitative data on macrofossils are expressed as percentages. In the case of the insects, the sum used for calculation of percents is the minimum number of individuals. This figure represents the most abundant identifiable fragment of a taxon. For Coleoptera, these are usually either pronota, heads, or elytra. For plants the sum is the maximum number of seeds or other identifiable propagules. In the case of *Picea,* the percentage value is based on the sum of whole needles plus the more abundant of either needle tips or bases.

Ideally, one should compare fossil assemblages with one another and with "modern" assemblages on a taxon to taxon basis, but in many samples this is impossible due to differing levels of preservation and fossil identification. Since many plant and insect macrofossils can be identified to species level, it may seem a retrogressive step to group such fossils into the broad groupings described in Appendix B, but by this means samples consisting of poorly preserved fossils or ones which have received little study can be compared with others treated in more detail.

The informal groupings used in this and subsequent papers in this series (Appendix B) are those which experience has shown to be best suited to the type of insect and plant fossils usually found at northern Yukon localities.

TABLE 1. Stratigraphic Units, Hungry Creek Section

STATION 6

UNIT 4 — Hungry Creek Till

UNIT 3b

20.5-19.50m: Silt, coarse; sand; gravel; disturbed.

19.50-19.07m: Gravel, dark grey, silty, compact; pebbles up to 5cm.

19.07-18.55m: Silt, brownish grey.

18.55-18.40m: Three clay layers with interlayered fine to medium sand; fine detrital organics.

18.40-17.48m: Sand, fine to medium, grey; scattered wood; detrital coal; GSC-2401 from 18.30m level (see Table 2).

17.48-17.27m: Clay, dark grey.

17.27-17.05m: Sand, fine, ripple cross-laminated; wood; detrital coal.

17.05-16.35m: Silty clay, clayey silt, dark grey; ped faces oxidized to brown.

16.35-13.1m: Sand, fine to medium, grey brown, ripple cross-laminated; sparse fine organic detritus; occasional wood-rich lenses 2-5cm thick; detrital coal fragments 0.5-2cm common near top.

UNIT 3a

13.10-6.15m: Sandy gravel and coarse sand; occasional cobbles to 10cm; pebbles and cobbles mainly grey and brown qtzite, black chert, pink and maroon qtzite, grey limestone; spare granite.

UNIT 2

6.15-4.60m: Silt, tan brown with dark grey layers; oxidized on joint faces in lower 0.5m.

UNIT 1

4.60-3.50m: Gravel, dark grey.

3.50-0m (water level): Concealed.

STATION 5

UNIT 4 — Hungry Creek Till

UNIT 3

18.0-17.45m: Sand, very fine to coarse; 10cm of silt at top.

17.45-17.40m: Diamicton with clayey silt matrix, very stony, pebbles up to 6cm.

17.40-17.00m: Sand, fine to medium, grey, massive.

17.00-12.40m: Gravel, mostly fine and sandy; layers with detrital coal and wood at 16.76m, 16.83m, 16.96-17.0m.

UNIT 2

12.40-6.05m: Silt with clay bands at base; very fine to fine sand with organic detritus at top; partly slumped and not studied in detail.

6.05-4.85m: Sand, coarse, black; plus silt and very fine sand; fine detrital organics.

4.85-4.60m: Silt, mottled, very dark grey to reddish brown; oxidized on ped faces.

UNIT 1

4.60-4.50: Gravel, silty, grey-brown.

4.50-3.25m: Gravel, very dark grey, well sorted, pebbles mostly flat-lying.

3.25-3.15m: Sand, black, lithic, medium to coarse; sparse detrital organics. SAMP. 76-53 from organics.

3.15-0.80m: Gravel, dark grey; pebble lithology as for Unit 1, Station 1; horizons of dark grey to mottled silt; cryoturbated zone near middle of unit. SAMP. 76-52 and AMINO ACID SAMP. UA-689 from silt lens at 1.1-1.3m.

0.80-0m (water level): Concealed.

STATION 3

UNIT 4 — Hungry Creek Till

UNIT 2b

17.40-17.34m: Clay, dark grey brown, deformed; thickens locally to 25cm.

17.34-16.00m: Sand, very fine to fine, grey brown, ripple cross-laminated, with detrital organics; grades upward to grey-brown, clayey silt; bedding deformed by drag-folds overturned to SW. SAMP. 76-46 (17.04-16.8m). POLLEN AT 17.10 and 16.50m.

16.00-15.32m: Silt and very fine sand, grey brown; massive to faintly bedded; bedding contorted. POLLEN AT 15.70m.

15.32-15.27m: Silt, dark brownish grey.

15.27-15.10m: Silt, pale grey, coarse nut structure. MARKER HORIZON from 15.32-15.08m.

15.10-15.08m: Silt, clayey, dark grey brown.

15.08-14.75m: Sand, very fine to fine; ripple cross-laminated. SAMP. 76-44 (14.80-15.08m).

14.75-14.27m: Silt, brownish grey; capped by layer of silty clay 1-2cm thick.

14.27-13.10m: Sand, very fine to fine; ripple cross-laminated; with organic detritus including small pieces of wood. SAMP. 76-35 (14.10-14.27m). POLLEN SAMP. at 14.00m. AMINO ACID SAMPLES. UA-693a, UA-693b, UA-693c from 14.10-14.27m.

13.10-12.93m: Silt with three clay layers 1.5-3cm thick.

12.93-12.03m: Silt, grey to grey-brown; compact.

12.03-12.00m: Clay 2cm; silt 1cm; clay 2cm.

12.00-11.29m: Silt, grey-brown. POLLEN AT 11.30m.

11.29-10.88m: Sand, very fine to fine; ripple cross-laminated; with detrital organics. SAMP. 76-33 and AMINO ACID SAMP. UA-698 from 10.88-11.29m.

10.88-10.33m: silt, grey-brown; and clay, very dark grey; stratified; clay and silt interbedded.

10.33-10.07m: Sand, very fine to fine; ripple cross-laminated. SAMP. 76-31 and AMINO ACID SAMP. UA-690, 10.07-10.33

10.07-9.24m: Silt; with five clay layers 2-8cm thick; microbanding in silt layers.

9-24-9.00m: Silt, very fine sand; ripple cross-laminated; detrital organics SAMP. 76-29 and AMINO ACID SAMP. UA-697 from 9.12-9.24m.

9.00-8.78m: Silt, pale grey-brown; massive. SAMP. 76-28 and AMINO ACID SAMP. UA-688 from 2-5cm sand layer at 9.00m.

8.78-8.73m: Clay, dark grey, with microbanding.

8.73-8.33m: Silt, pale grey-brown; massive.

8.33-7.95m: Clay, silty, very dark grey. Thin zones of very fine sand with organics at 8 and 8.18m (sampled for SAMP. 76-27 and AMINO ACID SAMP. UA-696). POLLEN AT 8.00m.

UNIT 2a

7.95-7.50m: Silt with microbanding.

7.50-7.02m: Clay, very dark grey; appears massive when moist, but reveals micro-laminae 1-2mm thick when dry. Vivianite flecks. Upper 4cm is silt and very fine sand in laminated couplets.

7.02-6.53m: Silt, pale grey-brown; silty clay at 6.80-6.89m and 6.53-6.71m (latter very dark to black, with vivianite flecks and visible laminae or varves when dry).

6.53-6.25m: Silt and silty clay; laminated; bedding contorted; granite dropstones.

6.25-5.60m: Silt, pale brownish grey; four layers 7-20 cm thick, bounded by five dark grey clay layers, 1-6 cm thick.

5.60-5.35m: Silt, clayey, dark grey; four sharply defined layers 2-3cm thick, interbedded with light brownish grey silt.

5.35-5.05m: Silt and clayey silt; gradational bedding; vivianite on ped faces.

5.05-4.75m: Silt and very fine sand, brownish grey; compact; vertical joints; discontinuous organic layers 1-2mm thick. SAMP. 76-26 (4.75-5.05m).

UNIT 1

4.75m: Gravel, very dark grey; apparently continues to water level (0m).

STATION 4

Top of Exposure

UNIT 6

26.40-23.20m: Peat, mainly brown unhumified with very dark brown to black humified zones; woody from 23.60m to surface. GSC-2341 (Table 2) from base of peat near St. 4; SAMP. HH7 from 23.20-23.25m.

UNIT 5

23.20-20.70m: Silt, brownish grey with irregular lenses and pods of stony silt, very ice-rich, flows when thawed.

UNIT 4

20.78-18.4m: Hungry Creek Till.

UNIT 2

18.40-12.00m: Silt, clay, and fine sand; not studied in detail.

12.0-0m (water level): Concealed.

STATION 1

Top of Exposure — not studied

UNIT 2 (base)

10.00-5.45m: Silt, clay and fine sand with organic detritus; not studied in detail.

UNIT 1

5.45-1.50m: Gravel, dark grey; pebbles of dark grey and brown quartzite and sandstone, black chert, black argillite, grey limestone and sparse dark green diabase; sand fraction mainly lithic (black argillite); thin lenses of black lithic sand. Silt lenses, dark grey to black with allochthonous organics at approx. 2.5m level.

1.50-0m (water level): Concealed.

STATION 2

UNIT 4 — Hungry Creek Till

UNIT 2b

19.20-16.35m: Silt and fine sand.

16.35-16.18m: MARKER HORIZON (as at Station 3)

16.18-15.85m: Silt, dark brownish grey at base; grading upward to ripple cross-laminated very fine sand with organic detritus.

15.85-15.40m: Silt, pale grey-brown; varve-like couplets consist of 5cm silt, 3mm clayey silt at base, 1cm silt, 3mm clayey silt at top.

15.40-14.80m: Sand, fine to medium; abundant organic detritus, including large pieces of wood at 14.9m. GSC-2422 (Table 2) SAMP. 76-49 and AMINO ACID SAMPLES. UA-695a, UA-695e, UA-695g from 14.9m level.

14.80-12.50m: Silt and very fine sand.

12.50-0m (water level): Concealed.

Undoubtedly modifications will be required in the future, but for the time being the groups defined below (see Paleoecology) are adequate for comparison of Hungry Creek sample 76-31 with others from Alaska and the Yukon.

Vertebrate Fossils

Most vertebrate fossils obtained by excavation of the bluffs have been recovered by trowelling. However, it has been possible to obtain significant concentrations of small mammal, bird, and fish bones and scales by sieving large quantities of sediment, usually with 1.6 mm sieve openings. Harington (1977:89-98) provided details on collecting methods used by National Museum of Natural Sciences field parties in Yukon. Identifications of vertebrate remains have depended upon comparisons with reference collections in the Paleobiology and Vertebrate Zoology Divisions, National Museum of Natural Sciences, and the Archaeological Survey of Canada, National Musuem of Man.

Archaeological Specimens

Most of the artifacts from the Pleistocene of northern Yukon have been collected during paleontological investigations and consist of bones, tusks, and antlers that were artificially fractured, flaked, polished or cut prior to fossilization. Interestingly, no such specimens have been recovered from Bonnet Plume Basin. A new kind of possible archaeological evidence emerged from ongoing paleoenvironmental analysis in the autumn of 1980 when tiny chert flakes were noticed among the sediments of samples being examined for their seed and insect contents. The attributes of the microflakes and their quantitative significance in the sediment are still under study, but their appearance and stratigraphic occurrence will be described in this report.

PHYSICAL SETTING

Physiography

Although this paper is concerned mainly with one small basin, understanding of the regional implications of the evidence presented here requires an appreciation of the physical setting of the entire northern Yukon. Bonnet Plume Basin lies just within the limit of Laurentide glaciation of the southern end of the Richardson Mountains (Fig. 1). The basin is underlain by moderately deformed Upper Cretaceous and Lower Tertiary sandstone, conglomerate, coal and shale that is for the most part concealed beneath thick glaciolacustrine and glacial deposits.

The Richardson Mountains and to a lesser degree the Arctic Ranges constituted a barrier to advances of the Laurentide ice-sheet, and they separate the glaciated Peel Plateau and Yukon Coastal Plain from the unglaciated Porcupine Plain and Plateau area. The Richardson Mountains comprise folded and faulted sedimentary rocks of Cambrian to Cretaceous ages. In the south, ridges are rounded, with elevations between 3000 and 4000 ft (914 to 1219 m). The northern part is locally more rugged with elevations to 5500 ft (1676 m). Only a few peaks were high enough to support small glaciers, so that the familiar cirque, arrete and horn forms of higher parts of the Cordillera are mostly lacking.

The Arctic Ranges (Fig. 1) are comprised of folded and faulted sedimentary rocks, ranging from Proterozoic to Cretaceous in age, with isolated small granitic intrusions. Only isolated peaks rise above 5000 ft (1524 m), and none of these supported glaciers. However, as with the Richardson Mountains, the mountainous aspect is enhanced by lack of trees and the presence of landforms such as solifluction lobes and cryoplanation terraces that occur only at higher elevations farther south.

The Porcupine Plain and Plateau area embraces terrain as diverse as the virtually flat Old Crow, Bluefish and Bell basins and the mountains of Keele Range. Except for Old Crow Range, which is composed mainly of granite of Old Crow Batholith, the region is underlain by folded and faulted sedimentary rocks of Proterozoic to Lower Cretaceous age. Elevations range from about 1000 ft (305 m) to slightly over 4000 ft (1219 m). The basins are structural depressions produced by faulting and downwarping that began in Cretaceous time and continued into the Pleistocene.

On the northeast side of Old Crow Basin, Lower Cretaceous rocks form a southwest-dipping homocline that disappears beneath Pleistocene sediments and possibly terminates against a northwest-trending fault concealed beneath the sediments at the southwest margin of the basin. Carboniferous strata dip southward along the north side of the basin, and presumably are overlain by Cretaceous and younger strata in the subsurface, but structural complication is indicated by northwest-trending Timber Ridge, a ridge of Mississippian rocks with gentle northeastern dip that stands above the Pleistocene sediments in the north-central part of the basin.

Bluefish Basin is bounded by Yukon fault on the southeast and at least in part by Kaltag-Porcupine fault zone on the northwest (Norris *et al.*, in press). The ridge that divides Bluefish and Old Crow basins is probably also fault-bounded.

Bluefish and Bell basins are separated by Dave Lord Ridge, a block of folded and faulted sedimentary rocks of Ordovician to Jurassic age, part of the Aklavik Arch Complex. Bell Basin lies at the north end of Eagle Plain, a broad synclinorium underlain by Cretaceous sandstone and shale, with Upper Devonian and Permo-Carboniferous rocks outcropping along the eastern, southern and western margins.

Peel Plateau to the east of the Richardson Mountains is underlain by gently dipping, locally faulted Cretaceous rocks. The northwestern part of the plateau, which forms the transition between Peel Plain and the mountains, has been deeply dissected post-glacially by tributaries to Peel River. Rather than flowing along the lowest part of Peel

Plain as might be expected, Peel River below Snake River is incised into the sloping plateau surface, a position indicating its origin as an ice-marginal channel.

Climate and Permafrost

Northern Yukon is influenced by weather patterns from the Arctic Ocean. Winter temperatures are cold, summers are cool, and annual precipitation is low (190-375 mm). Records from the village of Old Crow (elevation 825 ft; 251 m) indicate a mean annual temperature of -5°C, a January mean of -29°C and a July mean of 16°C. The recorded annual precipitation is 192 mm, nearly half (92 mm) of which falls during the summer months (Burns, 1973; Oswald and Senyk, 1977).

The northern part of Yukon falls within the zone of continuous permafrost (Brown, 1960). Except under lakes and the channels of larger streams, frozen ground is inevitably encountered in the soil, generally within a few decimeters of the surface, even in late summer. Permafrost gives rise to a number of characteristic surface features, such as orthogonal and polygonal patterned ground which is most noticeable in Old Crow, Bluefish, and Bell basins.

Flora and Fauna

Hultén (1968) described the flora of the Old Crow-Porcupine region as being poorly known. This is still true, but the situation has improved with recent collecting (Welch and Rigby, 1971; Wein *et al.*, 1974; Cwynar, 1980; Cwynar and Ritchie, pers. comm., 1980). Bonnet Plume Basin and the surrounding areas on the west side of Richardson Mountains remain poorly known with respect to botany.

Northern Yukon has been divided into a number of eco-regions (Oswald and Senyk, 1977) or eco-districts (Ritchie, 1980). Along the Yukon coastal plain, sedge tussock tundra dominates. Farther south, in British and Richardson Mountains, the vegetation is made up of tundras of varying composition depending upon bedrock, exposure, and drainage. Scattered spruce is found only in valley bottoms.

The large interior basins or lowlands are generally characterized by sedge-moss fens and bogs, with shrub tundra on drier peat surfaces. Open spruce-lichen vegetation is located on older peats or near bodies of water. The valley bottom alluvium of Old Crow, Porcupine, and Peel Rivers and their tributaries is vegetated with successional stands of *Salix, Populus, Alnus* and *Picea* with fens and ox-bow lakes. Treeline is formed by spruce at altitudes of approximately 1000-1500 ft (305-457 m). *Larix laricina* occurs as far north as Bell Basin, but the nearest pines are south of the Ogilvie Mountains, some 150 km south of Bonnet Plume Basin.

The insect fauna of northern Yukon is still poorly known, but this situation is slowly being remedied by the collecting programmes associated with the Biological Survey of Canada — Terrestrial Arthropods project (Bull. Ent. Soc. Can. 11(2):37). Fortunately the systematics and distribution of ground-beetles (Carabidae), the group most critical for fossil studies, is better known than for the other groups commonly represented in fossil assemblages (Lindroth, 1961-1968; Ball, 1966). According to Lindroth's monograph, approximately 201 species of Carabids are either known or suspected to occur in northern Yukon. Of these, 105 species are obligate or facultative tundra inhabitants.

Many of the samples collected from northern Yukon Pleistocene sections are alluvial in origin. Presently, the weevil, *Lepidophorus lineaticollis* Kby., is one of the most common beetles in alluvial sites both within and beyond treeline, and *Lepidophorus* fossils are also common in the northern Yukon samples. Two other taxa that are also usually present as fossils, the weevil *Vitavitus thulius* Kiss. and the pill beetle *Morychus,* are currently very rare members of the northern Yukon fauna, the former having been collected for only the first time in Yukon during the 1981 field season.

Vertebrates in northern Yukon Territory include fishes, birds, mammals, and one species of frog (*Rana sylvatica,* F.R. Cook, pers. comm. 1981); reptiles are not known from the region. Recent summaries are available elsewhere for fishes (Cumbaa *et al.*, 1981), birds (Irving, 1960) and mammals (Youngman, 1975).

Human History and Prehistory

The archaeological record of northern Yukon is a discontinuous but very lengthy and complex one. Early to mid-Wisconsinan evidence derived primarily from redeposited bone, antler and ivory fossils (Irving and Harington, 1973; Bonnichsen, 1979; Morlan, 1980; Harington, 1980a) has been supplemented more recently by the discovery of tiny chert flakes that may represent mid-Wisconsinan flintknapping (see below), but both of these lines of evidence are hypothetical while neither can be integrated in cultural-historical terms, nor can they be linked with later prehistoric manifestations. The oldest primary archaeological site in the area is known as the Bluefish Caves (Cinq-Mars, 1979; Morlan and Cinq-Mars, in press), and it is as important for its paleoenvironmental implications as for its archaeological content.

Abundant, scattered and diverse artifact concentrations have been found in the uplands bordering Old Crow Basin and along the western flanks of the Richardson Mountains, but few of these finds are buried in interpretable stratigraphic contexts so that dating and interpretation depend heavily on typological comparisons (Irving and Cinq-Mars, 1974; Cinq-Mars, 1978; Morlan and Cinq-Mars, in press). Later prehistoric and historic periods are relatively well documented with the final phases of prehistory firmly identified with the historic Vunta Kutchin and Tukkuth Kutchin Indians in the Porcupine River drainage and the Tatlit Kutchin Indians in the Peel River drainage, including Bonnet Plume Basin (Morlan, 1973). Nonetheless, despite one wide-ranging reconnaissance in Bonnet

TABLE 2. Radiocarbon dates: Bonnet Plume Basin and vicinity

Lab. No.	Date	Material	Locality	Collector	Comments
GSC-2422	36 900+/−300	Wood(*Picea*)	HH 72-54(65°34.5′N;135°30′W)	OLH(1976)	Below Hungry Creek till. Associated with microflakes, macrofossils, and amino acid analyses. Wood ident. by L. D. Farley-Gill (GSC Wood Ident. Rpt. 76-58). Counted in 5L counter at 4 atm; Loc. 5, Fig. 2.
GSC-2401	>40,000	Wood(*Picea*)	HH 72-54(65°34.5′N;135°30′W)	OLH(1976)	Below Hungry Creek till. Wood is rounded; identified by R. J. Mott (GSC Wood Ident. Rpt. 76-59). Sample mixed with dead gas for count in 5L counter; Loc. 5, Fig. 2.
GSC-2341	8980+/−90	Peat	HH72-54(65°34.5′N;135°30.5′W)	OLH(1976)	Unit 6, near St. 4. Plant and insect fossils of HH-7 from same level (no *Picea* seen). Sample mixed with dead gas for count in 2L counter; Loc. 5, Fig. 2.
GSC-2971	8700+/−80	Wood(*Salix*)	HH 79-1(65°34′N;135°30′W)	OLH(1979)	0.5 km upstream from HH 72-54; Organic silt with abundant macrofossils of *Picea*. Sample counted in 5L counter.
GSC-2758	15 200+/−230	Organic Mud	Lateral Pond(65°57′N;135°56′W)	R&C(1978)	Pond bordered by moraine of Hungry Creek (?) Glaciation. Sample from 230-235 cm level of core; mixed with dead gas for count in 2L counter (J. C. Ritchie, pers. comm., 1981); Loc. 8, Fig. 2.
GSC-2690	16 000+/−420	Organic mud	Cw-1(66°03′N;135°42′W)	R&C(1978)	Pond bordered by moraine of Hungry Creek (?) Glaciation. Sample from 398-408 cm level of core; mixed with dead gas for count in 2L counter (J. C. Ritchie, pers. comm., 1981); Loc. 9, Fig. 2.

OLH = O.L. Hughes; R = J.C. Ritchie; C = L. Cwynar

Plume Basin, the archaeology of the area discussed in this paper is poorly known (Morlan *in* MacDonald, 1977).

GEOMORPHOLOGY

Bonnet Plume Basin

As defined by Bostock (1948, Map 922A), Bonnet Plume Basin comprises a restricted area between and immediately adjacent to the lower reaches of Wind and Bonnet Plume Rivers. The term is used more generally here to include an area to the west bounded by the all-time limit of Laurentide glaciation. This limit (Fig. 2) is defined by meltwater channels, moraines, and other ice-marginal features, plus scattered observations of the limit of erratics of Canadian Shield origin. Drumlins and crag-and-tail features indicate that a lobe of Laurentide ice moved southwesterly into the basin, splayed southward toward Mackenzie Mountains, and extended tongues westerly into Hungry Lake depression and along the present course of Peel River, and northwesterly along Doll Creek valley. Very large ice-marginal channels occur at or near the northern and western periphery of the former ice lobe (Fig. 2; Hughes, 1972: Map 1319A). These channels evidently carried not only meltwater but also the flow of such major streams as Snake, Bonnet Plume and Wind rivers that were diverted westward by the ice lobe. Moraines are best developed along the northeast side of Doll Creek valley. There and elsewhere they impound small lakes, such as Lateral Pond (informal name applied by Cwynar and Ritchie, 1980) and an unnamed pond near Doll Creek where dates from cores provide important limiting ages for the glaciation responsible for the moraines (Fig. 2, Table 2; Cwynar and Ritchie, 1980; Ritchie, pers. comm. 1981). The southern part of Bonnet Plume Basin proper comprises a till plain with extensive patches of glaciofluvial gravel. In the northern part of the basin, the till plain is blanketed by thick ice-rich glaciolacustrine silt and clay. The glaciolacustrine surface is pocked by thermokarst lakes and ponds, and spectacular retrogressive-thaw flow slides occur where the Wind, Bonnet Plume and Peel rivers are incised through the sediments.

At Aberdeen Falls (Fig. 2, loc. 1), about 19 km above the mouth of Wind River, Peel River plunges into a steep-sided canyon incised into limestone and shale of Cambrian age. The canyon widens between Wind and Bonnet Plume rivers, where it is incised into thick Pleistocene sediments overlying Tertiary sediments, and constricts again as it traverses rocks of Cambrian age. The present course of the river is clearly youthful, suggesting the possibility that an antecedent course may have followed the broad depression now occupied by Hungry Lake and Hungry Creek, continuing thence northeasterly across Bonnet Plume Basin. The suggestion of a buried depression is given some substance by recent borings in the middle of the basin that demonstrate drift thicknesses in excess of 65 m (O. Cullingham, pers. comm. 1980).

Eagle River Discharge Channel

The Eagle River discharge channel (Fig. 2, loc. 2) is a canyon-like feature more than 1 km wide incised into siltstone and mudstone of Mississippian age between Canyon Creek and a headwater tributary of Eagle River. The channel has been partially infilled with alluvial fan deposits that divide the channel into segments occupied by Moose Lake, Davis Lake and an unnamed lake to the south.

The all-time limit of Laurentide glaciation is marked by ice-marginal channels and kame terraces that slope northwestward toward the south end of the discharge channel. At a point about 9.5 km northwest from the confluence of Canyon Creek with Peel River, the former ice surface, as defined by ice-marginal features, merges with a terrace remnant lying slightly above 1250 ft (380 m). This represents the level of the southern end of the discharge channel at the maximum of the glacial advance. Another terrace remnant 6 km northwest may be part of the same surface (which in that case sloped northwestward at 3-4 m/km) or a lower surface developed during further downcutting. The bottom of Davis Lake is at about 1175 ft (358 m), but there may be several metres of sediment above the bedrock floor of the channel.

During its maximum stand, Laurentide ice occupied the Hungry Lake depression and extended up Peel River at least 10 km west of Canyon Creek. All northward drainage from the Mackenzie and Wernecke mountains was diverted westward in major ice-marginal channels until, with Peel River flow, it was discharged northward through a channel (Fig. 2, loc. 3) that begins near the mouth of Dalglish Creek and trends northward then eastward to join Canyon Creek valley 13 km south of Davis Lake. The Dalglish Creek channel, comparable in size to the Eagle River channel, has been considerably modified by construction of alluvial fans where tributary streams enter the channel, and by capture of the southern part of the channel by Dalglish Creek. The threshold level of the channel cannot therefore be determined readily. However, remnant areas of thick glaciolacustrine silt, on either side of Hart River near its mouth, have nearly flat surfaces between about 1250 and 1350 ft (380 and 410 m), indicating that a restricted glacial lake persisted for some time at a level above 1350 ft. Slight retreat of the Laurentide ice from its maximum stand opened a channel that lies about 2.5 km west of the lower reaches of Canyon Creek (Fig. 2, loc. 4), and further retreat opened the whole lower reach of Canyon Creek for northwestward discharge. Discharge through Eagle River channel must have been maintained until the Bonnet Plume lobe of the Laurentide ice sheet had withdrawn eastward out of the basin, permitting establishment of northward drainage along the present course of Peel River.

STRATIGRAPHY OF BONNET PLUME BASIN

By far the most instructive section in Bonnet Plume Basin is that at Hungry Creek (Fig. 2, loc. 5; Figs. 3, 4). There, a Laurentide till of late Wisconsinan age overlies organic-bearing sediments of probable early and mid-Wisconsinan age and is overlain by a substantial thickness of Holocene peat. The section has been chosen as the type locality for the single till, here called the Hungry Creek Till, that occurs throughout Bonnet Plume Basin. There are numerous exposures of the till in the northern part of the basin, where it is underlain by gravel and minor glaciolacustrine sediments and overlain by thick glaciolacustrine sediments. The exposures have been examined only briefly. A representative section from near the confluence of Bonnet Plume River and Noisy Creek (Fig. 2, loc. 2) is described below.

FIG. 4. Photograph of the Hungry Creek section as it appeared in summer of 1976. Note the large overhanging peat sequence beneath which ice-rich clayey sediments of Unit 5 have melted back nearly 5 m. The columnar erosional remnants beneath the overhang are comprised of Hungry Creek till (Unit 4) which is underlain by sediments of Unit 2b. Units 2a and 1 are out of the photograph at the base of the section.

HH72-54: Hungry Creek

Stratigraphy of the southwestern extremity of Bonnet Plume Basin is known from a single section on Hungry Creek near its confluence with Wind River (Fig. 2, loc. 5; Figs. 3, 4; Table 1). The gravel at the base of the section, Unit 1, comprises dark grey to dark brown sandstone, black argillite, grey limestone, black chert, and sparse green diabase, all of which occur in Wernecke Mountains to the south. The gravel contains scattered rounded balls of peat, irregular lenses of woody silt, and thin bands of silt and sand with wood fragments, plant detritus, insects and bones. At the downstream end of the section (Station 1) the unit has yielded the remains of several rodents, and it is the possible source of a woolly mammoth molar and limb bones of sheep and possibly bison that were found on a gravel bar downstream from the section. In addition, a horse mandible was collected from the Unit 1 gravel between Stations 2 and 3 in 1979 and is described below (see Paleoecology). Near the upstream end of the section, a silt lens within Unit 1 gravel at Station 5 produced samples containing insects and plants indicative of open, treeless conditions (see Paleoecology).

The lower part of the next higher unit consists of laminated silt and clay approximately 3 m thick. These appear to be typical varved glaciolacustrine sediments, and they contain numerous dropstones, one of which was observed to be a granite pebble from the Canadian Shield. These characteristics indicate that the sediments were deposited in a glacial lake impounded in front an advancing lobe of the Laurentide ice sheet. We will refer to these sediments as Unit 2a, but it is difficult to decide where to place the contact with overlying Unit 2b. In general, there is a loss of varved appearance upward through the sequence, and the sediments gradually become coarser, but they do so intermittently in that thin laminae of sand become more frequent and thicker as layers of clay become thinner and less common. The highest well-laminated couplets of contrasting texture are seen at the 7.5 m level, and these are overlain by 45 cm of microbanded silty clay which we have defined as the top of Unit 2a. (Levels as cited are carried continuously upward through the section, measured from water level of Hungry Creek as of 6 July 1976.) Current-bedded sand containing detrital organics at 8.0 m is therefore assigned to Unit 2b. Fossils which might indicate the environment during deposition of Unit 2a come from only one small sample. Both the insects and the plants suggest tundra conditions.

Unit 2b is 9.4 m thick and is comprised of alternating layers of sand and silt of variable individual thicknesses. Some of the silt layers exhibit microbanding and occasionally contain thin layers of clay, but the sand layers are ripple cross-laminated with the bedding planes marked by concentrations of mostly fine detrital organics. Among the organics are wood (spruce, willow), mosses, seeds, insects, and molluscs; vertebrate remains have not been seen. Near the top of Unit 2b, at the 15.08-15.32 m level, is a distinctive triplet of silt beds that can be used as a marker horizon for refined correlations among several of the Hungry Creek stations. Above this marker band, the bedding planes are increasingly deformed, and the top of Unit 2b exhibits drag folds overturned toward the southwest to indicate the direction of ice movement that overrode the locality and deposited the till of Unit 4 (see below). Unit 2b is fluvial but possibly part of a delta complex. It contains no autochthonous peats, incipient soils, or other features such as dessication cracks, frost cracks, and other normal indications of exposure to subaerial weathering. Pollen spectra, plus plant and insect fossils from Unit 2b, show that it was deposited at a time when climate was warm enough for spruce forests to exist in Bonnet Plume basin.

At the 14.90 m level of Unit 2b at Station 2 a beaver-chewed spruce stick has produced a date of 36 900 ± 300 B.P. (GSC-2422; Table 2). This date is important not only for the chronology of Unit 2b, but also for the dating of all areas of Richardson Mountains affected by Laurentide glaciation in classical Wisconsinan time. Samples from this level provided our first indications of the richness of the Hungry Creek fossil record and the existence of chert microflakes in these deposits. The macrofossils are discussed below (see Paleoecology), and in a section on Archaeology we present reasons for suggesting that the microflakes are by-products of artificial flint-knapping. One reason for the selection of the 14.90 m level for radiocarbon dating is that it produced more wood than most other levels of Unit 2b. Indeed the general scarcity of wood in this unit is peculiar in view of other macrofossil evidence for the occurrence of spruce in the vicinity.

Additional evidence on the chronology of Unit 2b has been obtained from amino acid racemization analysis. D/L ratios of aspartic acid were determined for 12 wood samples from several horizons of Unit 2b. Six samples were analyzed from Station 3, and one each from Stations 2 and 5 (Fig. 3, Table 1, Appendix A). Table 3 presents the results. UA sample numbers 693a, b, c and 695b, e, g represent samples of three different wood pieces analyzed from the same horizon at Stations 2 and 3 whereas the rest are single wood pieces from different horizons. As indicated in Table 3, some of the samples were analyzed twice in order to determine the precision of the results.

TABLE 3. D/L ratios of aspartic acid in wood from Hungry Creek

UA Samp.	Stn. No.	Level (m)	No. of Runs	Aspartic Acid D/L ratio	Stnd. Dev.
UA-693a	3	14.10-14.27	2	0.15	0.018
UA-693b	3		1	0.19	—
UA-693c	3		1	0.17	—
UA-695b	4	14.90	2	0.12	0.014
UA-695e	4		1	0.17	—
UA-695g	4		2	0.18	0.008
UA-698	3	10.88-11.29	1	0.20	—
UA-690	3	10.07-10.33	1	0.21	—
UA-697	3	9.12- 9.24	2	0.16	0.006
UA-688	3	9.00	1	0.13	—
UA-696	3	8.00- 8.18	1	0.18	—
UA-689	5	1.10- 1.30	1	0.14	—

Analyses by N. Rutter
For stratigraphic context of samples, see Fig. 3 and Table 1.
UA = University of Alberta

The D/L ratios of aspartic acid vary between 0.12 and 0.21. From our experience in northern Yukon, these ratios are typical for wood that has been subjected to long periods of permafrost conditions during the Late Pleistocene. It is hazardous to place absolute dates on these ratios, but with the data presently at hand from this location and others in northern Yukon, an age of between 10 000 and 50 000 years is probably reasonable. These age estimates support the radiocarbon date of 36 900 ± 300 years B.P. (GSC-2422) derived from wood in the upper part of Unit 2b.

Unit 3 consists of sand, gravel and minor silt that fills a major channel cut into Unit 2. Lenses containing wood, organic detritus and detrital coal occur in the upper 7 m of the fill. Rounded spruce wood from the 18.3 m level in Unit 3 yielded a radiocarbon date of > 40 000 (GSC-2401,

Table 2). Bedding of both Units 2b and 3 is highly disturbed near the contact with the overlying till (Unit 4).

The till of Unit 4 consists of pebbles and cobbles of quartzite, chert and limestone, plus minor dolomite and diabase and rare granite of Canadian Shield origin in a calcareous clayey silt matrix. The till and advance are here named the Hungry Creek Till and Hungry Creek Advance, respectively.

The sediments (Unit 5) that overlie the till are typically ice-rich. They recede by retrogressive thaw beneath dangerously overhanging peat of Unit 6 (Fig. 4) which eventually collapses, wholly or partially concealing Unit 5. The few accessible partial exposures of the unit show the sediments to be primarily silt and silty clay, typically with a few percent of coarse sand and pebbles but in places stony and till-like. Structure in Unit 5 ranges from rather distinctly bedded to highly involuted. The sediments themselves suggest deposition in shallow water immediately adjacent to the ice front. The more till-like facies may represent mudflows from an ablating glacier surface. The involutions suggest post-depositional cryoturbation. It is probable that the Eagle River discharge channel was cut to below the level of the Hungry Creek locality prior to deglaciation of the area, so the site was not covered by an extensive glacial lake during retreat of the ice margin.

As much as 3 m of peat comprise Unit 6 at the top of the section, and a sample from the base of this Unit has been dated to 8980 ± 90 B.P. (GSC-2341, Table 2). No fossils of spruce occur in this sample, but another sample from a section just upstream from the Hungry Creek section shows that spruce was growing in the region by 8700 years ago (GSC-2971, Table 2).

HH62-9: Noisy Creek

A section on the east side of Bonnet Plume River, *ca.* 2.2 km upstream from the mouth of Noisy Creek (Fig. 2, loc. 6) is typical of the Pleistocene succession in the northern part of the basin. There, about 10.5 m of olive-yellow gravel is overlain in upward succession by 9.2 m of grey gravel, 1.1 m of silty clay and fine-grained sand, 7.6 m of till and 11.4 m of silt and silty clay. Pebbles and cobbles of the olive-yellow gravel comprise about 80% grey to olive grey and minor maroon and brown quartzite, 10% grey to black chert, with the remainder quartz, diabase and soft siltstone. Carbonate rocks are lacking, but occasional skeletal remains of siliceous carbonate pebbles are present. The grey gravel comprises about 65% quartzite and 25% limestone and dolomite, plus calcareous sandstone and siltstone, with the remainder chert, diabase and quartz.

The single till at Hungry Creek, Noisy Creek and other sections in Bonnet Plume Basin records a single advance of Laurentide ice across the area. That advance, here called Hungry Creek glaciation, extended to the all-time Laurentide maximum shown in Figure 2, and it was responsible for the diversion of Peel River northward into the drainage of Porcupine River (see Geomorphology, above). The date of 36 900 years ago from beneath Hungry Creek till is incompatible with an early Wisconsinan or older age for the till as previously suggested by Hughes (1972). Implications of the date with respect to the chronology of glacial events northward along Richardson Mountains and Yukon Coastal Plain, and the chronology of sedimentary sequences in the basins of the non-glaciated area, are discussed under Geological History.

PALEOECOLOGY

The Hungry Creek section is especially rich in fossils. Pollen has been recovered from a suite of samples taken at Station 3, and some important vertebrate remains were found in the gravel of Unit 1. Most notable are the well-preserved remains of insects, and plant macro-remains such as seeds, fruits, achenes, and mosses. Not only do these fossils suggest certain conclusions concerning the environmental history of the basin, but, as indicated earlier, they play an important role in our reasoning concerning the geological history of the section and the entire region.

Plant and insect macrofossils from various levels and stations are listed in Tables 5 and 6; pollen counts (all from Station 3) appear in Table 4. Samples 76-52, 76-53 come from Unit 1; sample 76-26 from is Unit 2a; samples 76-27 through 76-49 are from Unit 2b; and sample HH7 is from Holocene sediments (Fig. 3). The levels for the pollen samples are indicated by the headings in Table 4 and are also shown in Figure 3 and Table 1.

The content of macrofossils was quite low in some samples. This was true particularly of sample 76-26 from Unit 2a at Station 3 and to a lesser extent of samples 76-44 and 76-46 from the upper part of Unit 2b. Hence, little importance should be attached to the absence of certain fossils in these samples. Unit 1, comprising gravel, has very few organics, but a silt lens at Station 5 has yielded enough macrofossils (sample 76-52) to allow meaningful comparisons with the rich assemblages of Unit 2b. Thus the absence of certain taxa in 76-52 is probably significant.

In the study of the macrofossils every attempt was made to eliminate sampling and processing bias. One of the variables which cannot be fully accounted for is sample size. The most organic part of the section is Unit 2b, and it is the part of the section which has yielded some of the most diverse assemblages. The sample from Unit 2a at Station 3 (Fig. 3, Table 1) was small and comes from a level in which organics were well dispersed. This is probably the chief reason why the number of fossils in sample 76-26 is low and the preservation marginal. The same can be said of samples 76-44 and 76-46 from the upper part of Unit 2b.

Sample 76-49 from Unit 2b at Station 2 is the most intensively studied insect sample from the section because it was initially a large sample, was the subject of an honours thesis (Craig, 1977), and had special importance since the sample level was radiocarbon-dated. The diversity of the insect fauna is probably due more to the intensity of study than to any inherent property of the organics at the sample

TABLE 4. Hungry Creek Pollen Samples

	Station 3, Unit 2b, Hungry Creek Sample Levels						Reid Lake Surf.	
	8.0m	11.3m	14.0m	15.7m	16.5m	17.1m	1	2
Abies				+			1.2	1.2
Tsuga heterophylla typ.							+	
Tsuga mertensiana typ.							+	
Pinus	+	+	+	2.9	1.5	3.3	6.8	9.6
Picea	37.1a	47.8	63.2	44.5a	60.3	51.0a	49.5	52.1
Juniperus	+		2.2	1.7	1.5	1.4		
Betula	19.6	11.8	9.9	9.2	5.0	10.7a	25.1	21.7
Alnus	11.3	4.8	3.8	6.4	3.5	4.7	12.5	13.3
Celtis							+	
Carya					+			
Salix	1.5		1.6			+	1.6	+
Ericales	4.6	13.2	3.8	7.5	5.0	8.8	+	+
Empetrum				1.2	1.5	3.3		
Cyperaceae	10.8a	2.6	6.0	11.8a	9.0	7.0a	+	+
Gramineae	+	1.8	5.5	4.6	5.5	4.7	+	+
Artemisia	3.0	8.8	1.1	+	+	+	+	+
Tubuliflorae	2.1	1.3		+	+	+	+	+
Liguliflorae	+	+	+	+	+	+		
Oxyria digyna				1.7				
Polygonum bistorta typ.		+				+		
Polygonum lapathifolium typ.				+	+			
Chenopodiaceae-Amaranthaceae	+	+		+		+		
Caryophyllaceae	1.5	1.3						
Ranunculaceae		1.8						
Ranunculus					+			
Aconitum					+			
Cruciferae	+	+	+	2.9a	+	+		
Saxifraga stellaris typ.	+		+					
Rosaceae	+	4.0		+				
Rosa typ.							+	
Umbelliferae			+					
Shepherdia canadensis							+	
Cornus stolinifera typ.		+						
Onagraceae							+	
Epilobium		+			+			
Phlox	1.5							
Polemonium					+			
Typha				+		+		
Potamogeton				1.2	+	+		
Lemmna				+	+			
Myriophyllum	+							
POLLEN SUM:	195	228	182	173	199	215	946	428
Indeterminate Pollen	11.9	20.0	14.8	15.0	19.0	25.6		
Sphagnum	16.0	31.0	23.1	13.9	8.0	18.6	+	+
Undet. trilete			4.5			7.9	+	
Selaginella	+			1.7	2.0	2.0		
Lycopodium annotinum typ.		4.0	2.2	4.6	4.5	2.0		
Lycopodium selago typ.		+		+	1.5	+		
Lycopodium	3.0				2.0			
Botryococcus	4.0	3.0	3.9	2.3	+	2.0		
Pediastrum	4.0	3.0	3.3	+				
Pre-Quaternary Palynomorphs		>100	6.0	>100	50	64		

NOTES: Analysis by C.E. Schweger and T. Habgood. Number = percent of POLLEN SUM: + = 1% or less; a = aggregates of grains. Samples from 4.76m, 4.95m, 5.25m, 5.50m, 5.80m, 6.80m, 9.4m, 12.2m, 13.0m, 14.6m and 15.4m were processed but proved to be either sterile (or nearly so), or contained only pre-Quaternary palynomorphs. Reid Lake (63°23'N; 137°15'W) surface samples are from moss polsters in a mixed spruce-pine forest stand.

level. Plant macrofossils were not within the scope of Craig's study of sample 76-49; therefore little significance should be attached to the lower diversity of identified plant taxa compared to other samples from the same unit.

Pollen

Table 4 presents preliminary results of pollen analyses of Hungry Creek samples. Seventeen samples from Units 2a and 2b at Station 3 were processed; six samples were countable, and the remainder were sterile or nearly so, or contained only pre-Quaternary palynomorphs. The latter condition existed for all samples processed from Unit 2a, which is somewhat unusual as the lithologies were clay and silt. In contrast, several polleniferous samples came unexpectedly from sandy levels of Unit 2b.

For the countable samples, the pollen and spores fall into two distinct classes, well preserved and poorly pre-

TABLE 5. Hungry Creek plants

Unit No.*	1		2a	2b									6
Sample No.	52	53	26	27	28	29	31	33	35	44	46	49	HH7
FUNGI													
Fungal Sclerotia			+ +						+			+	
ALGAE													
CHARACEAE													
Chara sp.			+						+		+		
BRYOPHYTA													
SPHAGNACEAE													
Sphagnum fuscum (Schimp.) Klinggr.									+				
Sphagnum sect. *Acutifolium* Wils.										+			
DITRICHACEAE													
Distichium capillaceum (Hedw.) B.S.G.									cf.				
Ditrichum flexicaule (Schwaegr.) Hampe									1cf.				
DICRANACEAE													
Dicranum acutifolium (Lindb. & Arnell) C. Jens.									+				
Dicranum groenlandicum Brid.									1				
Oncophorus sp.									1				
POTTIACEAE													
Barbula acuta (Brid.) Brid.									1				
Didymodon rigidulus Hedw.										1			
Tortella fragilis (Drumm.) Limpr.									1				
BRYACEAE													
Bryum pseudotriguetrum (Hedw.) Gaertn., Meyer & Scherb.									1				
Bryum sp.									1				
Pohlia sp.									1				
MNIACEAE													
Cinclidium latifolium Lindb.									1				
Cinclidium stygium Sw.									+				
Mnium marginatum (With.) Brid. *ex* P. Beauv.									1				
Mnium sp.										1			
Plagiomnium ellipticum (Brid.) Kop.									+				
MEESIACEAE													
Meesia longiseta Hedw.									1				
Meesia triquetra (Richt.) Ångstr.									1	+			
Paludella squarrosa (Hedw.) Brid.									1				
AMBLYSTEGIACEAE													
Amblystgium varium (Hedw.) Lindb.									+				
Calliergon giganteum (Schimp.) Kindb.									+	+ +			
Calliergon richardsonii (Mitt.) Kindb. *ex* Warnst.									+				
Calliergon stramineum (Brid.) Kindb.									+				
Calliergon trifarium (Web & Mohr) Kindb.									+				
Calliergon sp.									+				
Campylium stellatum (Hedw.) C. Jens. var. *stellatum*									1				
Drepanocladus aduncus var. *kneiffii* (B.S.P.) Mönk									1				
Drepanocladus crassicostatus Janss.									+	+			
Drepanocladus exannulatus (B.S.G.) Warnst.									+				
Drepanocladus fluitans (Hedw.) Warnst									1				
Drepanocladus lycopodioides var. *brevifolius* (Lindb.) Mönk.									1				
Drepanocladus pseudostramineus (C.Müll.) Roth									+	+			
Drepanocladus revolvens (Sw.) Warnst.										1			
Drepanocladus tundrae (N. Arnell) Loeske										+			
Drepanocladus vernicosus (Lindb. *ex* C. Hartm.) Warnst.									1				
Drepanocladus sp.									+				
Scorpidium scorpioides (Hedw.) Limpr.									+				
BRACHYTHECIACEAE													
Brachythecium turgidum (C.J. Hartm.) Kindb.									+				
Eurhychium pulchellum (Hedw.) Jenn.									+				
Tomenthypnum nitens (Hedw.) Loeske									+	1			
HYPNACEAE													
Hypnum bambergeri Schimp.									1				
Hypnum pratense Koch. *ex* Brid.									+				
RHYTIDIACEAE													
Rhytidium rugosum (Hedw.) Kindb.									+				
HYLOCOMIACEAE													
Hylocomium splendens (Hedw.) B.S.G.									+				
VASCULAR PLANTS													
EQUISETACEAE													
Equisetum sp.	+								+				
PINACEAE													
Picea sp. (needles)			+	+ + !		+ p	40%	+ !	+	+ +			
Picea sp. (seeds)								+	+				
Larix sp. (cone)												+	

TABLE 5. Hungry Creek plants (*continued*)

Unit No.*	1		2a	2b									6
Sample No.	52	53	26	27	28	29	31	33	35	44	46	49	HH7
SPARGANIACEAE													
Sparganium hyperboreum Laest.							+	+!					
NAJADACEAE													
Najas flexilis (Willd.) R&S				++!		+	1.2%	+	+?			+	
Potamogeton Richardsonii (Benn.) Rydb.									+				
Potamogeton sp.				+		6.3%							+
ALISMACEAE													
Sagittaria sp.				+									
GRAMINEAE													
Glyceria sp.							1.3%		+				
Gramineae undet.			+				1.3%			+			
CYPERACEAE													
Carex sp. (achenes)	++	+	+	+		+	27.5%	+	+	+		+	+
Carex diandra Schrank				cf					cf	cf			
Carex canescens L.								cf					
Carex aquatilis Wahlenb.	+	+						+		+			+
Eriophorum sp.						+							
Eleocharis palustris/uniglumis typ.				+				+	+	+			
Scirpus sp.					+		+						
Scirpus validus Vahl.										+			cf
ARACEAE													
Acorus sp.							?						
Calla palustris L.						+	+						
JUNCACEAE													
Luzula sp.			+										
SALICACEAE													
Salix sp.			+										+
BETULACEAE													
Betula sp.							3.8%	+	+				
Betula (shrub typ.)						+!	+		+	+			
Betula (arboreal type.)							+						
Alnus sp.							0.6%						
Alnus crispa Ait.				+		+			+				
POLYGONACEAE													
Oxyria digyna (L.) Hill		+	+				0.6%						
Polygonum sp.							0.6%						
Polygonum lapathifolium L.				+	+	+	+						
CHENOPODIACEAE													
Chenopodium sp.			?					?		+	?		
Corispermum sp.			+										
CARYOPHYLLACEAE													
Caryophyllaceae undet.	+		+	+									
Stellaria typ.			+										
Melandrium sp.						+							
Melandrium apetalum (L.) Fenzl			cf					cf					
NYMPHAEACEAE													
Nuphar sp.							+						?
Brasenia Schreberi Gmel.							0.6%						
CERATOPHYLLACEAE													
Ceratophyllum demersum L.								+					
RANUNCULACEAE													
Ranunculus lapponicus L.								+					
Ranunculus sp.	+	+	+										
Ranunculus trichophyllus Chaix.							1.3%						
PAPAVERACEAE													
Papaver sp.		+											
CRUCIFERAE													
Cruciferae undet.	+		+						+	+	+		
Draba sp.			cf										
ROSACEAE													
Dryas integrifolia Vahl									?				
Rubus idaeus L.				?			3.8%		+				
Potentilla palustris L.		+		+		+	1.3%		+	+			
Potentilla sp.	+	+	+				1.8%	+		+			
VIOLACEAE													
Viola sp.							0.6%?						
HALORAGACEAE													
Hippuris vulgaris L.	+			+			1.3%			+			
Myriophyllum sp.									+				+

TABLE 5. Hungry Creek plants (*continued*)

Unit No.*	1		2a	2b									6
Sample No.	52	53	26	27	28	29	31	33	35	44	46	49	HH7
ERICACEAE													
Andromeda polifolia L.				+		+	1.3%		+				
Empetrum nigrum L.			+				0.6%						
Arctostaphylos sp.				?									
PRIMULACEAE													
Androsace septentrionalis L.	+												
GENTIANACEAE													
Menyanthes trifoliata L.		+		+		+		+	+				
LABIATAE													
Mentha sp				+					+				
COMPOSITAE													
Achillea sp.			+				+						
Taraxicum sp.							1.8%		+	+			
UNDET. "Seeds"							1.3%						

* For station location of individual samples, see Table 1 (e.g. Samp. 26 = 76-26, Unit 2a, Station 3).

Bryophytes identified by J. Janssens
Vascular plants identified by J. Matthews
1. = single fragment (Bryophytes only)
\+ = taxon present
\+ + = taxon abundant
! = well preserved
? = fossil not well enough preserved for positive identification
cf = fossil well enough preserved for identification but either not comparable to named taxon or critical study needed.

Percentage for Samp. 31 based on a sum of 160 seeds

served, without gradation between. Some of the pollen grains occurred as aggregates of grains, indicating a proximal source and only a single depositional cycle. *Picea* and Cyperaceae, two of the types represented by aggregates, were also represented by exceptionally well-preserved macrofossils (Table 5).

All of the Unit 2b spectra have high percentages of *Picea* (37.1 to 63.2%), much higher than occur in most surface samples from northern Yukon (Cwynar, 1980; Schweger, pers. obs.). Comparable spruce values do occur in surface samples from Reid Lakes in central Yukon (63°23′N, 137°15′W) (Table 4). The upper three samples in the series also display percentages of *Pinus* (< 1 to 3.3%) which are somewhat higher than the trace amounts normally seen in northern Yukon samples. This pine pollen is undoubtedly from a distant source, although these values suggest that the pine pollen sources were closer during deposition of Unit 2B than at present. *Pinus contorta* is now found approximately 150 km to the south. Surface samples from Reid Lakes, within the pine limit in central Yukon, contain only slightly more pine pollen (7 and 10%) than the Hungry Creek samples.

Alnus and *Betula* percentages are low in all samples, ranging from 3.5 to 11.3 percent and 5 to 19.6 percent respectively. Even the highest alder values in the sequence (cf. sample at 8 m) are lower than those usually found in surface samples from northern Yukon taiga sites (Cwynar, 1980) but are comparable to values recorded at Reid Lake (Table 4). Furthermore, even though the percentage of alder pollen in the sample at 8.0 m is low, the macrofossil sample from the same level contains *Alnus crispa* seeds. The implications of this paradox are discussed below.

Salix pollen occurs only in small amounts, while pollen of Ericales is relatively abundant in all samples. These values are sufficiently high to indicate local plant communities with high cover values for Ericaceae taxa.

Cyperaceae is the most abundant NAP taxon (2.6 to 11.8%), with *Artemisia* (< 1 to 8.8%) and Gramineae (<1 to 5.5%) next in importance.

Several of the taxa occurring at trace levels are from aquatic plants. One of them, *Typha,* probably does not grow as far north as Bonnet Plume Basin today. Presence of *Potamogeton* and *Myriophyllum* locally is confirmed by macrofossil evidence. Two other aquatic forms which occur at levels above trace values are colonies of the aquatic algae, *Botryococcus* and *Pediastrum*. Their percentages are high enough to distinguish these samples from most others in northern Yukon (Lichti-Federovich, 1973, 1974; Cwynar, 1980; Schweger, pers. obs.). Ripple cross-laminations in the organic-bearing fine sand layers of Unit 2b make it clear that the sediment was deposited by a moderate current, whereas the abundance of aquatic taxa in the pollen and plant macrofossil assemblages seems to signal a lake or pond environment. This combination of inferred depositional environments suggests a delta with low gradient distributaries bordered by levees, and with shallow lakes and ponds behind the levees. In such an environment, terrestrial organics carried by a distributary can be deposited into an adjacent lake or pond as a splay deposit where a levee is breached. Alternatively, during major floods, aquatic organics can be flushed from the lakes or ponds into the distributaries.

The pollen results do not display any obvious percentage trends indicative of local environmental changes or regional climatic events. Boreal forest vegetation covered the Bonnet Plume Basin during the interval represented by Unit 2b.

Bryophytes

Unit 2b at Station 3 has yielded some of the most remarkable bryophyte assemblages yet seen from east Beringian sites (Table 5; Janssens, 1981a:Reports 434-435). Sample 76-35 is richer in species than any sample studied from the region; yet no single taxon is dominant (i.e., all of the taxa are represented by approximately equal numbers of fragments), and there are no obvious differences in the degree of preservation, which is uniformly excellent. The mosses from sample 76-35 are clearly allochthonous, but their state of preservation rules out the possibility that multiple cycles of rebedding are represented.

The fossil mosses represent communities ranging from lakes and minerotrophic fens to rock outcrops (*Mnium marginatum*) and dry upland habitat (*Tortella fragilis* and *Barbula acuta*) and the ecotonal areas separating such communities (*Paludella squarrosa*). Even some arctic-alpine species are present (e.g. *Drepanocladus lycopodioides* var. *brevifolius* and *Hypnum bambergeri*).

One of the mosses (*Hylocomium splendens*) is a good indicator of spruce forest. This species has two distinct growth forms: one, monopodially branched, is found in arctic-alpine exposed habitats and the other, a luxurious sympodially branched form, is always associated with boreal forest. All of the Hungry Creek fossils belong to the latter type and thus they imply that spruce forests grew near Hungry Creek during deposition of the upper part of Unit 2b.

Vascular Plants

Although not as diverse taxonomically as are the bryophyte assemblages from samples 76-35 and 76-44, the vascular plant macro-remains from the various Hungry Creek samples do stand apart from those in other Alaska-Yukon assemblages by the abundance of fossils and particularly their preservation. Many of the *Carex* fossils still possess perygynia, a rare condition in alluvial samples. This shows that the fossils cannot have been transported far before burial, and redeposition is out of the question. The excellent state of preservation of the *Carex* and other vascular plant fossils in Unit 2b indicates that, like the bryophytes, most if not all of them are allochthonous, but the majority probably come from contemporaneous plant communities proximal to the site of deposition.

A single poorly preserved spruce needle was found in sample 76-26 from Unit 2a at Station 3. No spruce macroremains, either seeds or needles, were recovered from samples 76-52 and 76-53, both of which come from Unit 1. As indicated above, the size of sample 76-52 is large enough to make such "negative evidence" potentially significant.

In contrast to Units 1 and 2a, many of the assemblages from Unit 2b contain abundant spruce needles, a few seeds and even an occasional cone fragment. The needles from sample 76-27 are well preserved, as they also are in 76-31 in which spruce needles account for 40% of all plant macrofossils (Table 5). A few of the needles are charred (hence very fragile), further evidence that they are not rebedded.

Several of the plants from Unit 2b are not known to occur as far north as Bonnet Plume Basin today. One of these is a water plant, *Najas flexilus*, the fruits of which occur in several Unit 2b samples (Table 5). Matthews (1975) suggested that the occurrence of such fossils in northern Yukon may indicate a warmer climate than at present because the current known northern limit of the species is in Alberta. But Porsild and Cody (1980) surmise that *Najas* does occur farther north, and their conclusion is supported by the find of what appear to be modern *Najas* fruits in dredge samples from lakes near Sans Sault Rapids on the Mackenzie River (L. D. Delorme, pers. comm.). Recently *Najas flexilus* fruits have been found in 9970-year-old pond sediments (GSC-3133) from a site in the Eagle meltwater channel across the divide from Bonnet Plume Basin, and well-preserved *Najas* fossils also occur at the base of a terrace sequence dated at 9190 years B.P. in Bell Basin (cf. sample HH75-9-2 in Table 7). In both contexts the fossils are associated with macrofossils and pollen which show that *N. flexilus* grew in an open tundra-like environment with *Populus* as the only abundant tree. In other words, *N. flexilus* may be able to live in areas significantly to the north of the presently known collection sites; consequently its fossils can no longer be considered as unequivocal evidence for warmer-than-present climate.

Two other plants in the assemblages also seem to suggest warmer climate. One of them, *Brasenia schreberi*, from sample 76-31, is a species of water plant which is rare even as far south as Alberta (Moss, 1971). However, only a single poorly preserved fossil was found, and it must also be noted that the distribution of this species, like that of many other water plants, may not be as direct a function of regional climate as it is for many terrestrial taxa. The probable significance of the *Brasenia* fossil is also tempered somewhat by the fact that we now know that *Brasenia* grew in a tundra (?) pond in western Alaska approximately 8000 years ago (J.V. Matthews, unpub. Plant Macrofossil Rpt. 80-12, Geological Survey of Canada). Nevertheless, the *Brasenia* fossil shows once again (Matthews, 1974) that floristic surprises may occur in Pleistocene macrofossil assemblages.

Polygonum lapathifolium is another example. It is usually thought of as an introduced "weed" in the north (Hultén, 1968),yet its fossils (macro-remains and pollen) occur at Hungry Creek and several other Pleistocene and Holocene localities in Alaska, Yukon, and Northwest Territories (Matthews, 1974).

Many of the plants listed for Unit 2 in Table 5, such as *Mentha, Polygonum lapathifolium, Calla palustris, Ranunculus lapponicus, Scirpus validus,* and the arboreal plants (which include tree birch), are typical of boreal and taiga rather than tundra. With the exception of *Oxyria digyna,* none of the plants in the list are restricted to tundra. *Oxyria* fossils were most abundant in the small assemblage from Unit 2a at Station 3 and sample 76-53 from Unit 1 at Station 5. But well-preserved fossils of this species occur in sample 76-31 and several others from Unit 2b; therefore we must assume that open, scantily vegetated sites similar to some tundra biotopes existed in the lowlands near Hungry Creek. Some of the insect fossils have similar implications.

Insects

Most of the Hungry Creek samples contain unusually large concentrations of insect fossils. As is often the case most are from beetles (Coleoptera), but several other orders including arachnids such as spiders and mites are also represented (Table 6). The insect fossils were generally well preserved, some with heads and pronota still articulated, scales still present on some of the weevil fossils, and only a few specimens with the postmortal punctures typical of fossils from sand or sediments exposed to prolonged weathering.

With the exception of *Pterostichus punctatissimus* (a tentative determination), all of the insect fossils from samples 76-52, 76-53 and 76-26 (representing Units 1 and 2a) refer to species which are either obligate or facultative tundra inhabitants. *Amara alpina, Carabus truncaticollis* (? ident.), and *Diacheila polita* are typical examples. While it is generally correct to say that such species are tundra indicators, specimens are occasionally collected below treeline. For example we have collected *A. alpina* at a grassy opening well below treeline at Klo-kut near Old Crow, and *Diacheila polita,* a beetle whose fossils are often taken as proof-positive of tundra, has been taken by one of us (JVM) from a lowland bog in forested interior Alaska and from a bog site near the Klo-kut locality. In all such cases the beetles were living at microsites which tend to duplicate their typical alpine or tundra habitat. In northern Yukon such sites commonly occur on the floodplains and sparsely vegetated bluffs of the larger rivers.

None of the Unit 1 samples contains obligate forest species, but as indicated earlier the only sample for which this observation has any significance is 76-52. Sample 76-53 contains fossils of *Amara glacialis,* a species normally found on the banks of tundra rivers.

The majority of insect fossils from Unit 2b represent species such as *Trechus apicalis, Amara quenseli, Bembidion grapei, Pterostichus hudsonicus, Agonum quinquepunctatum, Bembidion morulum, Micropeplus laticollis, Syntomium,* and *Acrotrichus* which are not often found in tundra regions. In addition several of the samples contain bark beetles (Scolytidae) and/or weevils which are associated with trees.

A few of the taxa listed are not currently known from northern Yukon, and thus might be viewed as evidence for warmer climate than the present one at Hungry Creek. One of these, *Notiophilus sylvatica,* occurs in coastal British Columbia and southern Alaska, sometimes in alpine areas (Lindroth, 1961; D. Schwert and D. Kavanaugh, pers. comm. 1980), but has not as yet been collected in Yukon. Since it lives in some areas above treeline, its absence from Yukon is difficult to explain. Nevertheless, we suspect that more intensive collecting will show that it is present there, but as a rarity.

Two other taxa that might until recently have been interpreted as suggesting a warmer climate are the ground beetles *Pelophila rudis* and *Chlaenius niger.* The former is a rare boreal species previously unknown in western Canada (Lindroth, 1961). But it has recently been collected at Inuvik, N.W.T. (N. Stork, pers. comm. 1981), so likely also resides in northern Yukon. The northernmost record for *C. niger* is Fort Smith in the Northwest Territories, some 5.5 degrees latitude south of Bonnet Plume Basin. However, a fragment of an elytron of the species occurred in modern thaw lake sediments from the Old Crow Basin (the same thaw lake sample listed in Table 7); hence, *C. niger* may actually range well north of Hungry Creek. These two examples illustrate the danger of basing climatic conclusions on fossils of insect species whose present distribution is not well known.

Unit 2b also contains fossils of *Amara alpina, Amara bokori, Bembidion umiatense, Pterostichus vermiculosus, P. caribou, P. similis, P. sublaevis,* and *Tachinus brevipennis.* All are usually found in tundra regions. One might argue that their presence indicates that the assemblages contain rebedded insect fossils, but the excellent preservation of the fossils rules this out. The tundra species may have drifted downstream into the forest region from alpine tundra, but it seems more likely that the mixture of tundra and boreal fossils indicates the presence locally of open tundra-like communities near Hungry Creek. Such areas, if they had dry, sandy substrates, could have harboured *Pterostichus nearcticus* and *Harpalus amputatus,* both of which are present in Unit 2b assemblages. They would also have been the locus for other xeric species such as *Lepidophorus lineaticollis* and perhaps even *Morychus.*

Vertebrates

In 1972, an organic silt lying within the basal non-glacial gravel (Unit 1) at the downstream end of the Hungry Creek section (Station 1) was wet-screened and yielded darkly stained rodent remains. Among these, ground squirrel *(Spermophilus* cf. *S. parryi)* and collared lemming (*Dicrostonyx* sp.) are perhaps most significant in that they suggest the occurrence of well-drained areas near the site before deposition of the overlying varved glacial lake sedi-

TABLE 6. Hungry Creek Insects

Unit No.*	1		2a	2b									6
Sample No.	**52**	**53**	**26**	**27**	**28**	**29**	**31**	**33**	**35**	**44**	**46**	**49**	**HH7**
HETEROPTERA													
SALDIDAE													
Genus sp.									+				
HOMOPTERA													
CICADELLIDAE													
Genus?								+	+				
COLEOPTERA													
CARABIDAE													
Carabus chamissonis Fisch.	+												
Carabus truncaticollis Eschz.	+?						2.3%		+?				
Pelophila rudis Lec.				+									
Notiophilus sylvaticus Eschz.									+				
Notiophilus sp.							2.3%						
Diacheila polita Fald.	+			+	+	+		+	+			+	
Elaphrus sp.									+				
Dyschirius sp.						+		+	+			+	
Trechus apicalis Mtsch.				+		+	+		+			+	
Trechus sp.				+					+				
Bembidion grapei Gyll.									+				
Bembidion sordidum Kby.						+							
Bembidion umiatense Lth.				+									
Bembidion morulum Lec.												+	
Bembidion spp.				+		+	2.3%	+					+
Pterostichus nearcticus Lth.				+									
Pterostichus (Cryobius) sp.		+				+	4.6%	?	+	+		+	
P. (Cryobius) similis Mann.												+	
P. (Cryobius) hudsonicus Lec.							+		+			+	
P. (Cryobius) pinguedineus Eschz.												+	
P. (Cryobius) ventricosus Eschz.												+	
P. (Cryobius) caribou Ball					+		16.2%	cf				+	
P. (Cryobius) brevicornis Kby.									+			+	
Pterostichus haematopus Dej.	?			+					cf				
Pterostichus punctatissimus Rand.		?											
Pterostichus vermiculosus Men.				+									
Pterostichus sublaevis Sahlb.		+						+					
Pterostichus sp.			?										
Agonum (Europhilous) sp.									+				
Agonum quinquepunctatum Mtsch.									+				
Agonum sp.					?							+	
Amara alpina Payk.	+	+		+	+			+	+			+	
Amara bokori Csiki												+	
Amara (Curtinotus) sp.		+		+		+		+					
Amara (s.st.) sp.		+		+									
Amara glacialis Mnh.		+											
Amara quenseli Schon.												+	
Harpalus amputatus Say									+				
Harpalus sp.				+									

TABLE 6. Hungry Creek Insects (*continued*)

Unit No.*	1		2a	2b									6
Sample No.	52	53	26	27	28	29	31	33	35	44	46	49	HH7
Trichocellus mannerheimi Sahlb.					+								
Chlaenius niger Rand.									+				
DYTISCIDAE													
Hydroporus sp.	+					+			+	+		+	
Colymbetes sp.						+			+		+		
Genus?							2.3%		+				
NOTERIDAE													
Genus?									+				
GYRINIDAE													
Gyrinus sp.							+						
HYDROPHILIDAE													
Helophorus sp.				+									
Cercyon herceus Smet.					+		+		+				
Genus?													+
HYDRAENIDAE													
Ochthebius sp.	+			+		+	+	+	+				
Hydraena sp.									+				
STAPHYLINIDAE													
Micropeplus laticollis Makl.									+				
Syntomium sp.									+				
Oxytelus sp.												+	
Bledius sp.				+					+			+	
Arpedium sp.											+	+	
Olophrum sp.						+						+	+
Olophrum rotundicolle (Sahlb.)								+	+			+	
Olophrum boreale Gyll.							2.3%		+				
Olophrum latum Makl.									+			+	
Boreaphilus sp.									?				
Micralymma sp.	cf	cf		cf		cf	2.3%	cf	cf	cf	cf		
Stenus sp.	+	+		+		+	4.6%	+	+	+			
Lathrobium sp.									+			+	
Euaesthetus sp.									+				
Quedius sp.								cf					
Tachyporus sp.									+				
Tachinum brevipennis Sahlb.							2.3%		+				
Tachinus sp.		+	+			+		+	+	+		+	
Gymnusa sp.									+				
Aleocharinae, genus?						+		+				+	
SILPHIDAE													
Silpha sp.	+					+							
LEIODIDAE													
Colon sp.									?				
PTILIIDAE													
Acrotrichus sp.							+						

TABLE 6. Hungry Creek Insects (*continued*)

Unit No.*	1		2a	2b									6
Sample No.	**52**	**53**	**26**	**27**	**28**	**29**	**31**	**33**	**35**	**44**	**46**	**49**	**HH7**
SCYDMAENIDAE													
Genus?	+					+			+	+			
SCARABAEIDAE													
Aphodius sp.				+					+				
BYRRHIDAE													
Simplocaria sp.	+			cf								+	
Morychus sp.	+	+		+	+		9.3%		+				
Cytilus sp.				?									
Curimopsis sp.							2.3%					+	
ELATERIDAE													
Genus sp.	+												
COCCINELLIDAE													
Genus sp.	+			+					+				
LATHRIDIIDAE													
Genus?								+				+	
CHRYSOMELIDAE													
Donacia sp.								+	+		+		
Chrysolina basilaris (Say)				+		+			+				
Chrysolina sp.		+	+				2.3%						
Chrysomela sp.		+											
CURCULIONIDAE													
Apion sp.								+	+				
Sitona sp.	+												
Lepidophorus lineaticollis Kby.	+	+		+		+	23.2%	+	+ +	+			
Vitavitus thulius Kiss.	+			+			2.3%		+				
Hypera sp.	+												
Lepyrus sp.	+		+			+							
Pissodes sp.				?			?						
Hylobius sp.									+				
Notaris sp.							2.3%						
Dorytomus sp.									?				
Rhynchaeneus sp.		+		+		+						+	
Cleoninae, genus?		+		+			2.3%	+	+	+			
Ceutorhynchus sp.	+												
Genus?							2.3%						
SCOLYTIDAE													
Scolytus sp.						+	+					+	
Carphoborus sp.				+		+		+	+				
Genus				+			2.3%		+				
TRICHOPTERA													
larval fragments										+			
DIPTERA													
Fam., Genus??						+						+	

TABLE 6. Hungry Creek Insects (*continued*)

Unit No.*	1		2a	2b									6
Sample No.	52	53	26	27	28	29	31	33	35	44	46	49	HH7
TIPULIDAE													
Tipula sp.									+			+	
XYLOPHAGIDAE													
Xylophagus sp.									+				
HYMENOPTERA													
Undet.							4.6%						
Cynipoid?	+												
SCOLIIDAE													
Genus?												+	
ICHNEUMONOIDEA													
Genus?									+				
FORMICIDAE													
Formica sp.							2.3%		+				
Camponotus sp.							2.3%						
ARACHNIDA													
ORIBATIDAE													
Cepheus corae Jacot				cf			+	cf	cf				
ARANEIDA sp?													
Lycosidae				?					+				
CRUSTACEA													
CLADOCERA													
Daphnia sp.						+	+				+		
BRYOZOA													
Cristatella mucedo Cuvier						+				+			
Plumatella sp.												+	

* For station location of individual samples see Table 1 (e.g. Samp. 26 = 76-26, Unit 2a, Station 3)
Identifications by J. Matthews
+ = taxon present
++ = taxon abundant
For other symbols see Table 5
Percentages for Samp. 31 based on sum of 43 individuals.

ments. A few postcranial elements tentatively referred to lemming (?*Lemmus* sp.) and vole (?*Microtus* sp.) also came from this unit, as did four lemming-like scats. The contents of the latter may be worth future analysis if they can provide further information on the environment of Unit 1 time.

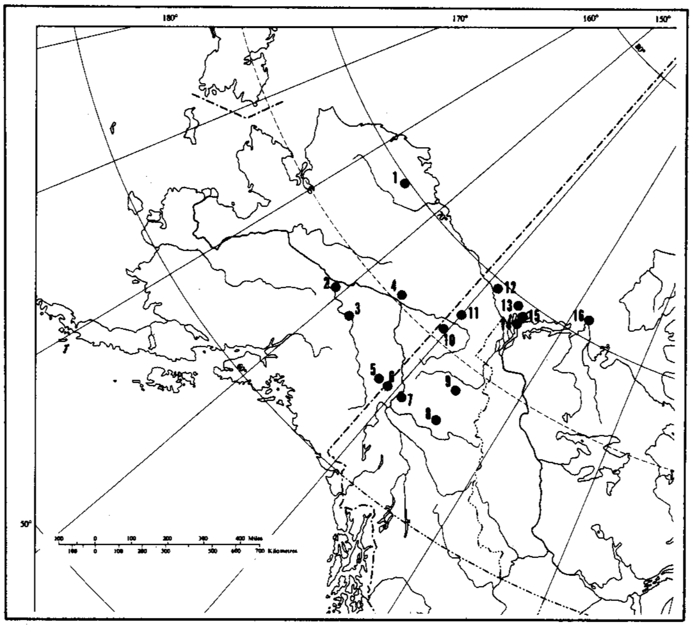

FIG. 5. Pleistocene wild ass (*Equus (Asinus)* sp.) localities in northern North America (Alaska, Yukon Territory and Northwest Territories). Black dots represent one or more specimens. Most are referable to the Yukon wild ass (*Equus (Asinus) lambei*). It is worth noting that, during the peak of the last glaciation, herds of Yukon wild asses probably lived on exposed coastal shelf areas that are now the southern portion of the Beaufort Sea (see, for example, localities 12 to 16). Localities: 1. Ikpikpuk River, Alaska (Harington, 1977). 2. Tofty, Alaska (Repenning *et al.*, 1964; Harington, 1977). 3. Fairbanks area, Alaska (Harington, 1977). 4. Venetie, Alaska (Péwé and Hopkins, 1967). 5. Lost Chicken Creek, Alaska (Harington, 1980b). 6. Sixtymile area, Y.T. (Harington, 1977). 7. Dawson area, Y.T. (Harington and Clulow, 1973). 8. Dublin Gulch, Mayo area, Y.T. (this paper). 9. Hungry Creek, Y.T. (this paper). 10. Bluefish Cave, Y.T. (Cinq-Mars, 1979; this paper). 11. Old Crow area, Y.T. (Harington, 1977). 12. Herschel Island, Y.T. (this paper). 13. "Immerk" (man-made oil-drilling platform in the Beaufort Sea), N.W.T. (Harington, 1978). 14. Tununuk, N.W.T. (Harington, 1978). 15. Ya-Ya Lake, Richards Island, N.W.T. (Harington, 1978). 16. Baillie Island, N.W.T. (Harington, 1978).

In 1979, Hughes collected the front of a horse mandible (including all incisors and Lp2), which was found in place in the gravel of Unit 1 between Stations 2 and 3. The specimen (NMC 35851; Fig. 6) is referable to an extinct ass-like horse, probably the Yukon wild ass (*Equus (Asinus)* cf. *E. lambei*). Heavy wear on the teeth (see, for example, Silver, 1969), and the fact that there is no evidence that canine teeth were ever present, indicate that the jaw is from a very old mare. NMC 35851 is smaller in almost all measurements than other Yukon wild ass specimens to which it was compared, and this is attributed to the "shrinkage" in size of teeth that often occurs as wear on the occlusal surface progresses. The closest matches for the

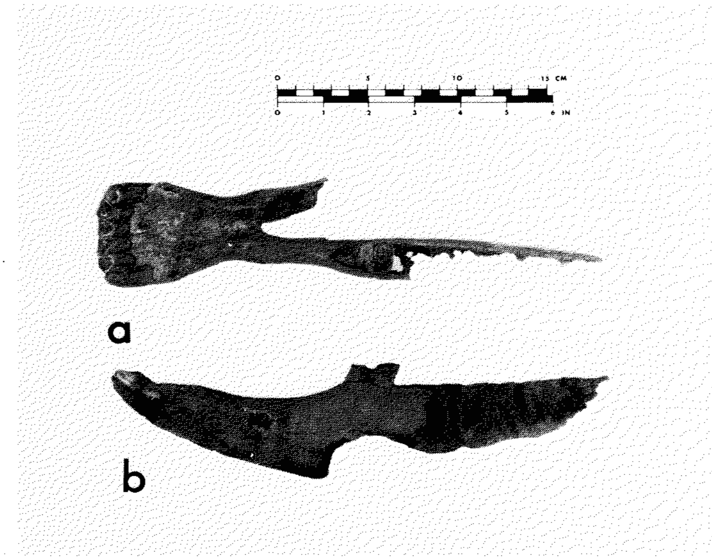

FIG. 6.a. Occlusal view of anterior mandible fragment with all incisors and Lp2 of *Equus (Asinus)* cf. *E. lambei* (NMC 35851) from Hungry Creek, Y.T. (HH72-54). Alveoli of the left cheek tooth row are partly preserved between p2 and m2. Note heavy wear on tooth surfaces, indicating an old individual.

FIG. 6.b. Left side of a mandible fragment of *Equus (Asinus)* cf. *E. lambei* (NMC 35851) from Hungry Creek, Y.T. (HH72-54). Note that the wear on the Lp2 is nearly to the roots.

specimen (Table 8) are with two excellently preserved Yukon wild ass skulls, the holotype (USNM 8426) and NMC 34803 -- both from Gold Run Creek in the Dawson area of Yukon, and both considered to represent old females (Harington and Clulow, 1973). NMC 35851 is significant because it appears to be the earliest record of a wild ass from Yukon Quaternary deposits. The geologically oldest known specimen of the Yukon wild ass is from Venetie, Alaska, and it may be of Illinoian age (Fig. 5). Because Yukon wild asses probably had habitat requirements like their closest living relatives, the Asiatic wild asses (*Equus (Asinus) hemionus*), it may be inferred that NMC 35851 indicates the presence of forb steppelands in the Hungry Creek region during the period when Unit 1 was being deposited. This paleoenvironmental evidence, albeit slim, does not conflict with that indicated by the rodent and insect fossils from the same unit.

Assemblage Comparisons

One of the Hungry Creek samples (76-31) was studied quantitatively. For that purpose both plant and insect fossils were grouped as shown in Table 7 and described more fully in Appendix B.

Much remains to be learned of the ways that plant macrofossils become distributed after being shed by the mother plant (Birks, 1980). This statement is equally true of insects. As yet we know very little about the ways fossil assemblages are influenced by the biases introduced during breakdown and transportation of the fossils, but it is becoming clear that a taphonomic bias does exist (Morlan and Matthews, 1981). We especially need to know more

TABLE 7. Composition of plant and insect groups from northern Yukon samples

GROUPS	31	CRH 11-1	T.LK.	HH75 9-1	Blk. R.	CRH 44	CRH 32-1	R.B.	HH75 9-2	CRH 11-2	HH75 9-3	CRH 11-3	CRH 32-2	HH75 9-4
PLANTS														
CAREX-POTAM.	40.8	30.9	74.5	18.7	66.4	58.1	73.9		64.1	18.3	27.2	36.7	25.9	76.7
BETULA-ALNUS	4.4	8.3	1.8	20.8	23.1	16.8	1.4		18.0	4.2	+	2.5	--	+
PICEA	41.9	58.0	21.0	55.9	4.8	23.9	24.6		4.0	1.5	+	6.1	--	1.2
	(40)	(54)	(2.5)	(49)	(+)		(21.7)		(+)	(+)	(+)	(4.5)		(+)
POTEN.-CHENOPOD.	10.5	1.6	2.5	3.1	2.4	+	--		12.3	75.8	70.9	54.5	74.2	18.7
MISC. UNPLACED	2.4	2.8	+	1.2	3.3	1.2	+		1.6	+	+	+	--	3.4
Macrofossil Sum	160	181	542	277	593	184	280		?	257	327	196	143	313
INSECTS														
CRYOBIUS	27.7		31.4			10.0		12.0					13.0	
LEPIDO.-MORYCHUS	39.4		1.4			2.0		19.0					70.0	
TACHINUS	2.3		--			--		+					+	
HYGROPH.-AQUAT.	11.5		47.1			76.0		28.0					8.0	
SILPHID.	--		--			+		--					+	
APHODIUS	--		--			+		--					3.0	
MISC. PHYTOPHAG.	6.9		1.4			5.0		6.0					7.0	
FORMICID.	6.9		1.8(S)			6.0		28.0(S)					--	
MISC. UNPLACED	4.6		16.9			+		5.0					+	
Macrofossil Sum	43		70			204		89					72	

See Appendix B for definition of macrofossil groups.
Number (except sum) = the percentage in each group.
Number in parentheses (cf. *Picea* grp.) indicates the percentage of *Picea* macroremains.
"S" used with Formicid grp. indicates bark beetles were present.

SAMPLE DESCRIPTION:
31: HUNGRY CREEK SAMPLE (see Table 1 and Fig. 3.)
CRH-11-1: Modern river detritus across from Locality CRH-11, Old Crow Basin.
T.LK.: Near-shore sediments from thaw lake, Old Crow Basin.
HH75-9-1: Beach detritus across from Loc. HH75-9, Bell Basin.
Blk.R.: Beach detritus from the Blackstone River in the Ogilvie Mountains, southwest of Bonnet Plume Basin.
CRH-44: Holocene peat (8460 yrs. B.P.) from Loc. CRH-44, Old Crow Basin --predates spruce rise.
CRH32-1: Holocene alluvium (8100 yrs. B.P.) from Loc. CRH-32, Old Crow Basin.
R.B.: Ready-Bullion Bench locality, Fairbanks area, Alaska--Holocene.
HH75-9-2: Organic detritus (9190 yrs. B.P.) from base of terrace section, Loc. HH75-9, Bell Basin--predates Spruce.
CRH11-2: Organic detritus from channel deposits of Early Holocene or late Wisconsinan age, Loc. CRH-11, Old Crow Basin.
HH75-9-3: Organic detritus (13,500 yrs. B.P.), Loc. HH75-9, Bell Basin.
CRH11-3: Organic debris (31,300 yrs. B.P.), Loc. CRH-32, Old Crow Basin.
HH75-9-4: Detrital organic zone (Late Wisconsinan and > 36 000 B.P.), Loc. HH75-9, Bell Basin.

TABLE 8. Measurements of mandible with teeth of *Equus* (*Asinus*) cf. *E. lambei* (Hungry Creek, Y.T.) compared with specimens of *Equus* (*Asinus*) *lambei* (Gold Run Creek, Y.T.)

			Measurements (mm)							
Specs.	Age	Sex	1	2	3	4	5	6	7	8
1	Old	F	59.1	38.4	80.9	101.5	40.5	30.6	16.1	84.0a
2	Old	F	65.0a	42.0a	80.0	86.2	41.0a	31.6	18.2	85.6
3	Old	F	70.8	41.1	85.0	89.9	43.0	34.3	16.3	86.6

Specimens:
1. NMC 35851, Hungry Creek, Yukon Territory
2. USNM 8426 (cast of holotype), Gold Run Creek, Yukon Territory
3. NMC 34083 (formerly LUM 1.222), Gold Run Creek, Yukon Territory

Measurements:
1. Maximum width across incisors;
2. Minimum width across diastema;
3. Length of symphysis;
4. Diastema length;
5. Depth of mandible at mental foramina;
6. p2 length;
7. p2 width;
8. alveolar length, p2-p4.

a = approximate

assemblages are influenced by the biases introduced during breakdown and transportation of the fossils, but it is becoming clear that a taphonomic bias does exist (Morlan and Matthews, 1981). We especially need to know more about how the paleoenvironmental signal is attenuated in alluvial and lacustrine depositional systems since most of the samples under study represent such depositional environments. One approach is to study plant and insect macroremains as they are transported and deposited using flumes and other apparatus. Another is to collect "macrofossil" surface samples and compare them with the fossil assemblages as Glaser (1978) has done. Table 7 compares the relative abundance of the insect and plant macrofossil groups of sample 76-31 from Hungry Creek with several such modern "surface" assemblages. Three of them (CRH11-1, HH75-9-1 and Blk.R.) are allochthonous organics found on the sandy shorelines of rivers in northern Yukon, and another (T. Lk.) is from the shore of a thaw lake (informally named "Square Lake") in Old Crow Basin.

The table also includes the percentages of macrofossil groups in other fossil assemblages. Four of them are of Holocene age. Two of those (CRH32-1); HH75-9-2) are from organic alluvium; one (R.B.) from colluvium; and one (CRH 44) from the peaty sediments of a small tundra pond. The aquatic aspect of this last sample is evident from the abundance of fossils of the *Carex-Potamogeton* and Hygrophilous-Aquatic groups. High percentages of the former may be misleading, however, because as discussed above under "Pollen," remains of aquatic plants may be flushed from ponds into alluvial systems during floods. Such a phenomenon probably explains the high percentage of the *Carex-Potamogeton* group in alluvial samples such as CRH32-1, and it warns us against the assumption that the high percentage of *Carex-Potamogeton* in the Hungry Creek sample implies lacustrine conditions.

Table 7 also groups fossils from several late Pleistocene samples. One of these (CRH11-3) is from ripple cross-laminated sand very similar to the sediments of Unit 2b at Hungry Creek. A common characteristic of all of these late Pleistocene samples (one that sets them off most clearly from the others in the table, including the Hungry Creek sample), is high percentages for the *Potentilla-Chenopodium* group.

A scan of Table 7 shows that the sample most like the one from Hungry Creek is CRH11-1, the detritus from the modern river bar in the Old Crow basin. It has abundant *Picea* and a high percentage of the *Carex-Potamogeton* group and low percentages of *Betula-Alnus*. The only real difference is that in the Hungry Creek sample the value for the *Potentilla-Chenopodium* group is higher, though not nearly as high as in the late Pleistocene samples. It is also clear from the table and from recast of Glaser's macrofossil data presented in Matthews (in press) that the Hungry Creek sample differs from those representing shrub tundra and forest tundra. Instead sample 76-31 clearly indicates a boreal environment, perhaps one in which trees were interspersed with open sites. Of interest is that it displays some of the same taphonomic biases seen in modern alluvial assemblages.

We are less confident in comparing the insect assemblages because the sample sizes are so small. A provisional observation is that the Hungry Creek assemblage is not similar to any of the others. It has more fossils of *Lepidophorus-Morychus* and fewer of the Hygrophilous-Aquatic group than the thaw lake sample and CRH44. Although it does contain bark beetles and tree-associated weevils such as *Pissodes* and *Hylobius*, the percentage of the Formicid group is not nearly as high as in the taiga samples (R.B.). The only sample which displays higher percentages of the *Lepidophorus-Morychus* group than sample 76-31 is CRH32-2, which in turn is typical of most Late Pleistocene samples from Alaska-Yukon. Sample 76-31 insects definitely indicate a boreal environment, but quite likely one with local open tracts similar to those that occur on the floodplains of some existing northern Yukon rivers.

Two features of the Hungry Creek pollen spectra cause them to resemble other interstadial spectra from Yukon Territory. One of these is the high percentage of spruce pollen. Similar percentages, usually far higher than those in surface samples from the same area, occur in samples from various sections in Old Crow Basin (Lichti-Federovich, 1973) and one section in Bluefish Basin (Lichti-Federovich, 1974). We have studied the stratigraphy of many of the same sections from which Lichti-Federovich's samples originally came and now are in a better position than she was to relate the pollen data to the late Pleistocene glacial sequence. The upper part of all Old Crow exposures and the one Bluefish exposure contain a unit of glaciolacustrine clays that is known on the basis of radiocarbon dates to be at least partly correlative with the Hungry Creek Till. Most sections also reveal evidence of a brief period of erosion and warmer climate (the start of the Boutellier Interval of Hopkins, in press) which we know from dates on an underlying tephra and from both radiocarbon and Uranium-Thorium dates to have occurred between 56 000 and 100 000 years ago (Westgate *et al.*, 1981; Morlan, 1980; J. Bischoff, pers. comm. 1981). Most of Lichti-Federovich's diagrams show a rise of spruce to levels higher than present ones in the parts of the sections provisionally assigned to the Boutellier Interval (Morlan, 1980; Matthews, 1980). Dates on autochthonous peats from two localities indicate that one of the peaks of spruce during the Boutellier Interval occurred prior to 41 000 years ago. Some of the macrofossils associated with this period of relative warmth show, like a few of those at Hungry Creek, that the climate was as warm as today. An important conclusion from the Hungry Creek data is that warm periods also seem to have occurred during the Boutellier Interval after 37 000 years B.P.

Another similarity between the Hungry Creek spectra and those from other northern Yukon sites is their low percentage of alder pollen. Alder is much more abundant in surface samples from northern Yukon (Cwynar, 1980; Schweger, pers. obs.) and the forested parts of Alaska (Nelson, 1979). Mid-Wisconsinan samples which commonly contain ample percentages of spruce and birch usually show much lower alder percentages. The combination of pollen and macrofossils from Hungry Creek Unit 2b shows that alders were growing there despite their meagre contribution to the pollen rain.

Some of the features of the Hungry Creek paleoecological record are difficult to reconcile with data from other parts of Yukon. The bryophyte fossils from sample 76-35 imply a climate warm enough for spruce forests, whereas bryophytes, vascular plant remains, pollen and insect fossils of approximately the same age at some Old Crow Basin sites now under study suggest a much colder, drier climate (Janssens, 1981b). The reasons for these discrepancies are not known. Old Crow is north of the Bonnet Plume Basin, but this is unlikely to be the sole explanation for the discrepancy. In Siberia the interval equivalent to the Mid-Wisconsinan has been shown to include several rather drastic climatic fluctuations (Kind, 1967). If this were true also in eastern Beringia, a reasonable explanation of the differences between some of the Old Crow samples and those at Hungry Creek would be that they represent different times within a period of rapidly fluctuating climate. But this explanation is satisfactory only if the Hungry Creek section, particularly Unit 2b, represents a relatively short period of time, i.e. centuries or millennia rather than tens of thousands of years (see Discussion).

MICROFLAKES

In November 1980, while examining samples collected by Morlan in 1976 for insect and plant macrofossil analysis, Matthews noticed lithic particles of peculiar shapes and thinness among the rounded sand grains. A systematic search of other samples from the Hungry Creek section revealed the presence of such angular particles, in various quantities, in most samples from Unit 2b but in none of the samples from Units 1 or 2a. These angular lithic fragments (Fig. 7) exhibit conchoidal fractures that indicate detachment from other lithic particles by impacts rather than by frost spalling or some other such process, and we will refer to them as microflakes.

During the microscopic sorting of dozens of sediment samples from various sedimentary environments we had often seen lithic materials of the sort normally found in fluvial deposits, but we had never encountered such angular, thin, conchoidally fractured fragments. Many previously studied samples, most of them from Old Crow Basin, were re-examined in a deliberate search for microflakes, but none was discovered. Having established that the Hungry Creek microflakes were unusual, our search for an explanation of them began with an examination of the literature on sand surface textures. It was quickly apparent that these microflakes lay outside the normal range of variation in roundness or sphericity reported for natural deposits of any genesis (see discussion in Blatt *et al.*, 1980:75ff.). With reference to Powers's (1953) roundness classes, for example, the microflakes are even more angular than his "very

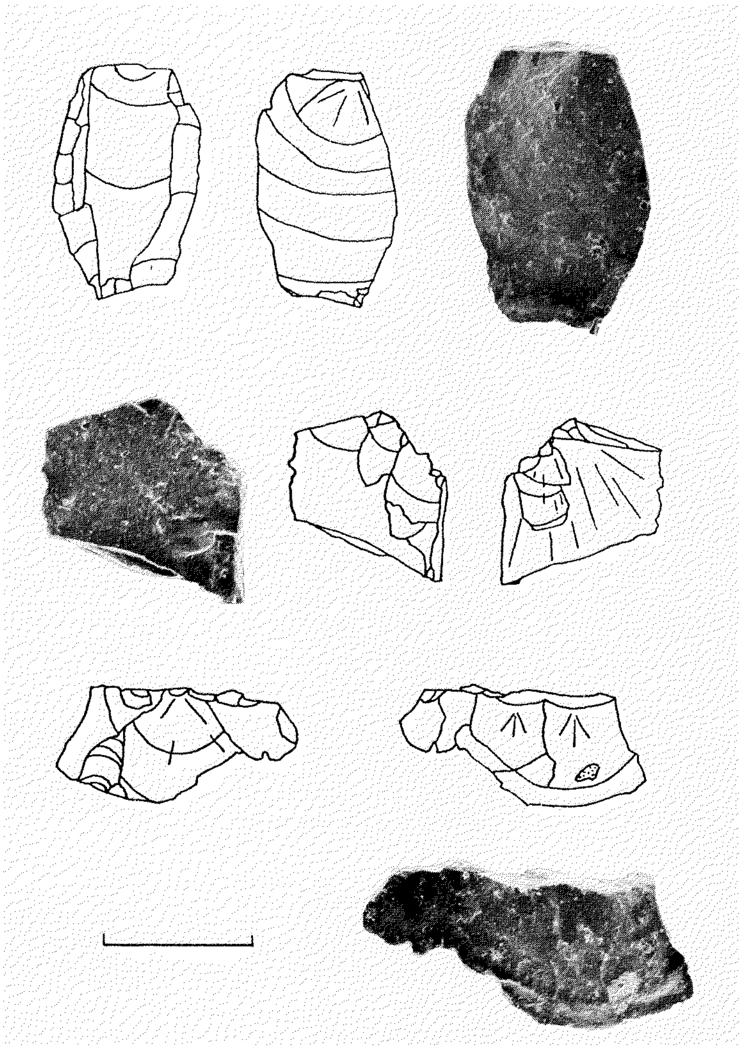

FIG. 7. Microflakes from Unit 2b at Hungry Creek (sample 76-49). Drawings and scanning electron micrographs represent the dorsal (left) and ventral (right) surfaces of each of the three flakes. Scale bar (1 mm) applies only to the drawings.

angular'' category. Furthermore, the conchoidal fracture attributes on the Hungry Creek microflakes are never obscured or degraded by abrasion or other processes such as those illustrated by Krinsley and Doornkamp (1973). In addition, the microflakes appear to lack most of the other features that normally characterize sand grains: upturned plates, V-shaped pits, dish-shaped concavities, cleavage planes, etc. The only particles illustrated by Krinsley and Doornkamp (1973) that are similar to the Hungry Creek microflakes are in their Figures 119, 121, and 122 which present quartz experimentally crushed in a jaw crusher.

Other characteristics of the Hungry Creek samples likewise suggest that the origin of the microflakes may not be natural. A natural agency that could produce such microflakes should also deposit associated ''microcores'' from which the flakes were detached. Appropriate sized, but rounded, sand grains are abundant in the samples, but non-rounded grains with negative scars that would suggest the origin of the flakes are absent. Fluvial sorting of flakes from cores seems unlikely unless the microflakes were detached from cores larger than the particle size range of the samples. A relatively high-energy fluvial environment would seem to be required to produce large numbers of unweathered, highly angular, tiny flakes, but the nature of the bedding, the excellent state of fossil preservation (see above), and the absence of abrasion, polish, or frosting on the microflakes imply that very low-energy environments are represented by these sediments. This implication is consistent with the excellent state of macrofossil preservation described above.

There is very little coarse sediment in these samples. The samples were washed on a screen stack comprised of 12, 42, and 80 mesh sieves (1.40, 0.355, 0.180 mm sieve openings, respectively). The 12 mesh sieve trapped small amounts of lithic material among which no microflakes have been seen, and the 42 mesh sieve trapped only sand-size lithic particles among which there are abundant microflakes in some samples. The 80 mesh fraction has not been examined since the samples were originally sieved in the field on a 40 mesh screen through which much of the finer fraction would have been lost.

Hence, not only are there no microcores in the samples and no appropriate impactors to produce microflakes, but also there is a very clean sorting of the microflakes within a narrow particle size range. Furthermore, there is no intergradation between microflake and non-microflake with respect to fracture attributes or degree of rounding. Finally, there appear to be distinctive lithic types among the microflakes, most of which are cherts and quartzites, some forms of which do not appear among the stream-rolled sand grains. These considerations suggest that the microflakes were derived from a source distinct from that which provided the sand grains to the Hungry Creek locality.

A possible explanation for the origin of the microflakes is that they are by-products of stone tool manufacture. The manufacture of stone tools by means of percussion or pressure flaking produces thousands of tiny fragments of stone in addition to larger flakes. In a recent study of this ''microdebitage,'' Fladmark (in press) noted that as much as 20% by weight of pressure flaking detritus may be less than one millimeter in maximum dimension; numerically, more than 99.5% of hard-hammer percussion detritus falls into this size range. Fladmark (in press) lists the following generic attributes as typical of microflakes: highly angular forms; transparency or translucency; often larger than the mean particle size in sieved samples; usually regular geometric shapes; usually some aspects of conchoidal fracture; and often seen close to the surface plane of the microscope slide or other container.

The Hungry Creek microflakes exhibit all these attributes, and they appear to be indistinguishable from microflakes produced experimentally from obsidian and chert by means of percussion flaking. Recent experience shows that microflakes can be found on many if not all undisturbed archaeological sites (e.g. Cinq-Mars, 1979; Fladmark, in press). Hence, it is possible that the microflakes were derived from one or more archaeological sites situated on the floodplain or delta surface represented by these Hungry Creek sediments. Such an hypothesis could account for the narrow particle size range of the microflakes, the absence of microcores, the occurrence of distinctive lithic types not seen in the associated sand, and the lack of rounding and abrasion on the microflakes. The selective redeposition of these small microflakes could have occurred in the low-energy fluvial environment represented by the sediments in which they were found, or could have been caused by aeolian deflation of an archaeological site from which the microflakes were transported. The fact that the microflakes are concentrated in some samples but do not appear in others shows that their source was not available to all the sedimentary regimes represented at Hungry Creek, but when it was available the source was probably not far away.

Seven samples from Unit 2b at Station 3 and one from Unit 2b at Station 2 have yielded microflakes. No microflakes have been found in a Unit 2a sample from Station 3 (76-26) or in the lowest Unit 2b sample from that station (76-27). Nor have microflakes been found in any of the Unit 1 samples. Within the seven-sample series from Unit 2b at Station 3, the microflakes are relatively rare in the lowest ones (around 9 m), are more common in the 10-11 m range, remain common in the 14-15 m range, and decline in numbers at 17 m, just below the till of the Hungry Creek glaciation. These are qualitative estimates which would be difficult to refine or to replace by a quantitative analysis without further sampling.

It may be significant that the microflakes do not occur in the Unit 1 gravel where the higher energy of the fluvial environment might be expected to produce them. Furthermore, if the microflakes are actually by-products of flint-knapping, it is not surprising that they do not appear in the varved deposits of Unit 2a since these sediments were laid down in close proximity to Laurentide ice. Their appearance at the 9 m level within Unit 2b, 1.5 m above the base of the unit, and their persistence in samples throughout the remainder of Unit 2b, could mean that the microflakes signal the arrival of human residents and perhaps continuity of human occupation throughout the temporal interval represented by this portion of the Hungry Creek sequence. Unfortunately, we have no way to measure the duration of that temporal interval. If the Unit 2b sediments represent only a few centuries, it might be reasonable to suppose that a single archaeological site is the source of all the microflakes in the section. On the other hand, a longer period of time could be represented by Unit 2b, allowing the possibility that more than one archaeological site supplied microflakes to the Hungry Creek deposits.

A return to the Hungry Creek section might seem to be a logical step in the search for more and better archaeological evidence, but there is relatively little likelihood that this section actually exposes undisturbed archaeological deposits. Furthermore, Bonnet Plume Basin offers very few exposures of mid-Wisconsinan age. Hence, it may not be possible to improve the quality of our hypothesized mid-Wisconsinan archaeological record in this area.

A second northern Yukon locality, on Eagle River, northwest of Bonnet Plume Basin and downstream from the Eagle River discharge channel, has also produced microflakes in samples of Upper Pleistocene sand. The section, designated HH80-12, exposes a unit of ripple cross-laminated silt and sand overlain in upward succession by 1 m of silty clay, 3.5 m of sand, 2.5 m of clay, and 0.5 m of peat. Near the base of the cross-laminated silt and sand, 8 m below the surface, rich concentrations of organics were sampled in two lots about 5 m apart horizontally. One lot represents allochthonous organics in sand, but the other represents a block of mosses that was transported intact and redeposited with the sand. Even a preliminary examination of the samples revealed the presence of microflakes like those found in Hungry Creek Unit 2b. At HH80-12, however, the concentration of microflakes is much higher than in any of the Hungry Creek samples. These preliminary findings prompted us to revisit HH80-12 during the 1981 field season when we found that the microflakes could be recognized with the aid of a hand lens or pocket microscope. Casual observations in the field suggest that microflakes are abundant throughout at least 4 m of the HH80-12 sequence, and they may span a zone as much as 8 m thick from which a series of bulk samples was collected for quantitative analysis of sand grain morphology. If the microflakes proved to be ubiquitous at HH80-12, it would seem mandatory to identify a natural agency to account for them. In that event we would seem to be searching for a process of sand grain reduction not previously reported in the literature. The recognition of such a process could place severe constraints on archaeological uses of microflakes in fluvial deposits as indicators of former cultural activity.

GEOLOGIC HISTORY

New evidence from Bonnet Plume basin, particularly from Hungry Creek section with its sub-till organic deposits, necessitates major reinterpretation of the Pleistocene history and chronology of both glaciated and unglaciated northern Yukon as interpreted by Hughes (1972). Here it is appropriate to summarize what can be inferred of the history of Bonnet Plume Basin, and then to point out the possible implications for the glaciated area northward along Peel Plateau and the east slope of Richardson Mountains, as well as the unglaciated area to the west. A rigorous examination of the correlation between the glaciated and unglaciated areas must await documentation in subsequent papers which will provide detailed stratigraphic and chronologic data for the unglaciated area.

Hungry Creek section, the only section in Bonnet Plume Basin at which sub-till organic deposits have been recorded, provides the best basis for discussion of Pleistocene history of the area. The basal gravel there was deposited during a relatively cold period when treeless conditions prevailed. Gravel deposition was followed abruptly by deposition of the mainly glaciolacustrine sediments of overlying Unit 2a. Those sediments, including dropstones, indicate the near approach of an advancing Laurentide ice sheet, with damming to produce a glacial lake. No till referrable to the advance has been found in Bonnet Plume Basin. The limit therefore probably lay just east of the basin. It seems unlikely that the glacial lake was impounded at a level high enough to initiate discharge via Eagle discharge channel, but rather that it drained northward along the ice margin. Glacial lakes that drain along the impounding ice margin are prone to repeated jokulhlaup lowerings (Thorarinsson, 1939, 1957; Mathews, 1965; Alt and Chambers, 1970; Chambers, 1971; Clague, 1979), affording a possible explanation for the oscillating transition from mainly glaciolacustrine sediments of Unit 2a to mainly fluvial sediments of Unit 2b. That transition is accompanied by evidence of marked amelioration of climate. The evidence implies retreat of the Laurentide ice due to climatic warming, drainage of the glacial lake, and initiation of fluvial deposition at Hungry Creek section under climatic conditions similar to those of the present.

Unit 3 occurs as a filling in a major channel, and has a significant content of pebbles of Shield origin, suggesting deposition as outwash derived from an advancing Laurentide ice sheet that was about to overrun the locality. The approach of the ice sheet is not reflected in palynologic data from the upper part of Unit 2b. Nor are there glaciolacustrine sediments to indicate reconstitution of a glacial lake in the basin. There may therefore be a significant gap in the record due to glacial erosion.

The till of the Hungry Creek section is judged to be the same as the one seen at Noisy Creek section and at other undescribed sections in northeastern Bonnet Plume Basin. The till was deposited during Hungry Creek glaciation as Laurentide ice advanced to the all-time maximum position shown in Figure 2.

As noted earlier, a glacial lake (the extent of which has not been determined and hence is not shown on Fig. 2) extended beyond the maximum ice-frontal position around the mouth of Hart River. With retreat of the ice-sheet the northern part of Bonnet Plume Basin was occupied by the glacial lake, but the Hungry Creek site was apparently slightly above the glacial lake level, and subject to only local ponding after the ice retreated. Peat formation did not begin at the Hungry Creek locality until about 9000 years ago, shortly before or at about the time that spruce re-invaded the region. However, radiocarbon-dated sediments on a terrace north of Peel River opposite the mouth of Bonnet Plume River (Fig. 2, loc. 7), indicate significantly older retreat of ice from Bonnet Plume Basin. The sediments, inset some 80 m below the surface of glaciolacustrine sediments that blanket the northern part of the basin, are dated at 10 600 ± 180 years B.P. (GSC-2393, Lowden and Blake, 1979:29). Downcutting of Peel River could not have begun until Laurentide ice had retreated eastward about to the junction of Peel and Snake Rivers to allow northward drainage of the glacial lake. Depending upon the time required for glacial retreat and downcutting, the Hungry Creek locality may have been ice-free several millennia before 10 600 years B.P. Indeed, early retreat is demanded by the late-glacial chronology of Mackenzie Valley which indicates that the vicinity of Fort Good Hope, some 250 km to the east (the general direction of ice retreat), was ice-free by 11 530 radiocarbon years ago (MacKay and Mathews, 1973).

There is additional circumstantial evidence that suggests the Hungry Creek glacier retreated from the basin well before 10 600 B.P. This comes from basal dates on core sequences from two lakes which are dammed by lateral moraines thought to have been built by the Hungry Creek glaciation. The oldest date from Lateral Pond (Fig. 2, loc. 8) (Cwynar and Ritchie, 1980) is 15 200 years (GSC-2758, Table 2) while another unnamed pond of similar origin in the Doll Creek valley (Fig. 2, loc. 9) has yielded a basal date of 16 000 (J. Ritchie, pers. comm. 1981; GSC-2690, Table 2). It is unlikely that deposition of the fine-grained sediments that contained the dated organic material would have occurred while ice still stood at the position of the moraines bordering the lakes; hence, the Hungry Creek glacier had probably retreated from the limit shown in Figure 2 by 16 000 years B.P.

Stratigraphic units beneath Hungry Creek till at Noisy Creek section and elsewhere in northeastern Bonnet Plume Basin have not been correlated with sub-till units of Hungry Creek section. For present purposes, the critical import of the former sections is that they contain only a single till, supporting the view that the basin has undergone only one advance of Laurentide ice,

Hughes (1972) had considered the maximum glaciation in Bonnet Plume Basin (here called Hungry Creek glaciation) to be early Wisconsinan or older. Diversion of Peel River plus glacial meltwater northward into Porcupine River drainage via Eagle River discharge channel, impoundment of a glacial lake in Bell, Bluefish and Old Crow basins and deposition of an early Wisconsinan or older glaciolacustrine unit (best displayed in Bluefish Basin) were correlated with that maximum glaciation. Reassignment of the maximum, i.e. Hungry Creek glaciation, to late Wisconsinan age is in accord with our current interpretation of the stratigraphy and chronology of Bluefish and Old Crow basins. In those basins, the only glaciolacustrine event that we have been able to verify is late Wisconsinan in age. An earlier lacustrine stage in the Bluefish Basin, assigned by Hughes (1972) to the early Wisconsinan, is now thought to be of non-glacial origin.

Acceptance of a late Wisconsinan age for the glacial lake stage implies of necessity a major correlative advance of Laurentide ice into McDougall Pass (Fig. 1). The present elevation of the pass is only 1040 ft. (317 m). Seismic soundings by J.M. Hunter (pers. comm. 1980) suggest that the level was about 565 ft. (170 m) before the pass was first glaciated. A late Wisconsinan advance would be required to dam McDougall Pass and force westward discharge of the glacial lake across the site of the Ramparts of Porcupine River which initially had an elevation of about 1300 ft. (395 m). Present evidence appears to favour retention of Hughes's (1972) correlation of the maximum glaciation at McDougall Pass with that in Bonnet Plume Basin, and reassignment of both to the late Wisconsinan. However, that reassignment creates conflicts with dated events elsewhere, as discussed in the following.

An ice sheet standing at the all-time limit of glaciation (Hughes, 1972: Map 1319A) must have covered the entire Mackenzie Delta region, yet marine shells from Gary Island and near Kendall Island, both on the periphery of the delta, have been dated at > 35 000 years old (GSC-562; Lowden *et al.*, 1971:305) and > 37 000 years old (GSC-690; Lowden *et al.*, 1971:305), respectively. For both localities the shells are judged to post-date the last glaciation of the area (see comments on dates by D.E. Kerfoot and J.G. Fyles), seemingly precluding expansion of Laurentide ice to the all-time maximum in late Wisconsinan time.

Hughes (1972) correlated till exposed on the lower reaches of Rat River east of McDougall Pass (Fig. 1) with the maximum glaciation, then thought to be early Wisconsinan or older. That correlation was supported by radiocarbon dates of > 38 600 (GSC-120; Dyck and Fyles, 1964:173) and > 38 300 years B.P. (GSC-204; Dyck *et al.*, 1965:38) on wood and organic detritus from silt overlying the till; those same dates invalidate the correlation if the maximum glaciation is late Wisconsinan. Unit 2a at Hungry Creek, if correctly interpreted as indicating an early Wisconsinan Laurentide advance that was less extensive than the maximum Hungry Creek advance, is a potential correlative of the till at Rat River section.

The limit of maximum glaciation near the north end of Richardson Mountains appears to merge with the limit of Buckland glaciation, the maximum glaciation on Yukon Coastal Plain (Rampton, in press). Our assignment of the maximum glaciation of the Richardsons to the late Wisconsinan then seems to be in conflict with Rampton's assignment of the Buckland glaciation to the early Wisconsinan. However, it is significant that Rampton's data indicate only that the Buckland must be > 22 000 years B.P. If the Buckland is only slightly > 22 000 B.P., it may yet be correlative with the Hungry Creek glaciation, which, as indicated above, occurred between 37 000 and 16 000 years ago.

A final conflict arising from reassignment of the maximum Hungry Creek glaciation to the late Wisconsinan involves a terrace section of Snake River, east of Bonnet Plume Basin (Fig. 1, loc. A). There, organic silt overlies about 3 m of boulder gravel and is overlain by about 17 m of gravel. Wood from the base of the silt has been dated at > 31 000 years B.P. (GSC-181; Dyck *et al.*, 1965:38). Hughes (1972:9) pointed out that if no erosional disconformity exists above the silt, then the locality has not been glaciated in the last 31 000 years, hence the maximum glaciation took place > 31 000 years ago. Wood believed to be from the same silt horizon has since been dated at > 35 000 years B.P. (GSC-2956). The locality is some 100 km east of Hungry Creek section and some 135 km east of the maximum limit of Laurentide glaciation. It is virtually impossible that Laurentide ice could have advanced over the Hungry Creek site sometime after 36 900 years ago (as implied by GSC-2422, Table 2), advanced a further 35 km to the Laurentide limit, then retreated 135 km eastward to Snake River by a time > 35 000 years ago. Tentatively, we favour the interpretation that the Snake River site has been overridden by Laurentide ice since deposition of the dated organic silt, but that an overlying till is lacking because of either non-deposition or subsequent erosion.

Reassignment of the maximum Laurentide glaciation to the late Wisconsinan forces reassessment of a lower, more easterly limit that Hughes (1972) considered to be the late Wisconsinan maximum. That limit, defined on the basis of moraines and ice-marginal channels that appear to mark a single continuous ice front, must be reinterpreted to mark either the limit of a readvance or a still-stand during glacial retreat following the Wisconsinan maximum.

DISCUSSION

On the basis of evidence from the Hungry Creek section, particularly the 36 900-year-old date (GSC-2422), we have concluded that the most extensive glaciation of the region occurred during the early part of late Wisconsinan time. Previously this event, here named the Hungry Creek Glaciation, was thought to be of early Wisconsinan or even pre-Wisconsinan age. The conclusion required a choice between two incompatible radiocarbon dates. Either the 36 900-year-old date was spuriously young by reason of contamination by "young" carbon, or the > 40 000 year date (GSC-2401), from a stratigraphically higher unit, was based on recycled "old" wood. Wood that produced the 36 900-year-old date had been collected from a fresh, recently thawed exposure and showed no evidence of contamination, hence there was no basis for questioning the date. The wood used for the > 40 000-year-old date, on the other hand, was markedly rounded and was associated with manifestly recycled detrital coal, supporting although not proving the interpretation that the wood was recycled from an "old" deposit.

The late Wisconsinan age assignment fits better than an early Wisconsinan or older age with our evolving reinterpretation of the stratigraphy and chronology of Old Crow and Bluefish basins. As will be documented in subsequent reports of this series, both basins contain glaciolacustrine sediments that began to accumulate about 30 000 years ago when meltwater was diverted into the Porcupine drainage by ice in the Bonnet Plume basin and ice blocking McDougall

Pass. Since we believe that the Hungry Creek glaciation was responsible for this diversion, that glaciation cannot be older than late Wisconsinan in age. Dates on cores from lakes held in by moraines presumed to have been constructed by the Hungry Creek glacier when it stood at its maximum limit suggest that it was retreating by 16 000 years ago.

The fact that the maximum glaciation of Bonnet Plume Basin occurred during the late Wisconsinan has profound implications for the glacial history of the entire east side of the Richardson Mountains. In particular, the Hungry Creek record raises some important questions concerning the glacial history of McDougall Pass (Fig. 1), the other principal conduit of glacial meltwater into the Porcupine system. The stratigraphy of McDougall Pass and the Rat River (N.W.T.) drainage was the subject of detailed field investigations in 1981 and will form part of a future Ph.D. dissertation by N. Catto, Department of Geology, University of Alberta.

Even without the till of Unit 4, Hungry Creek would represent a benchmark site because of the paleoenvironmental information gleaned from Unit 2. Various types of data, including the sediments themselves, suggest that it marks a shift from a glacial to an interstadial climate. During the height of the interstadial (Unit 2b), spruce forest, as well as plants and insects that apparently do not live in Yukon today, occurred in the Bonnet Plume Basin. Climate must have been similar to the present, but the vegetation may have been characterized by numerous dry openings (possibly most prevalent on the floodplains) that supported insects now found commonly in tundra biotopes.

Deposition of Unit 2b was obviously followed by a period of climatic deterioration, as implied by the till of Unit 4, but not before a period of local downcutting and filling by the sand and gravel of Unit 3. Other than the fact that Unit 3 contains pebbles of Shield origin and resembles outwash, we know little about the climate during its deposition.

Unit 5 has provided little evidence of the climatic conditions prevailing during the interval between retreat of Laurentide ice from the site and the beginning of deposition of the peat of Unit 6. Cryoturbation of the sediments (if observed involutions are indeed due to cryoturbation) could have developed in a climate ranging from somewhat warmer to much colder than that of the present.

Unit 6 is also poorly studied. It represents the start of surface peat formation, apparently only shortly before spruce forest moved into the basin. Future work on Unit 6 promises to be repaid by a complete record of Holocene environmental fluctuations in the basin.

Obviously the Hungry Creek section offers many opportunities to advance our knowledge of the environmental history of northern Yukon. Units 3-5 have not been sampled at all. Unit 1 is poorly studied, and even Unit 2, the focus of the paleoecological part of the report, requires more detailed sampling (e.g., large scale screening for microvertebrate remains). But even though the data presented are preliminary, they do allow a first approximation of mid-Wisconsinan climatic conditions.

We are tempted to view the Hungry Creek sequence as representing the entire mid-Wisconsinan interstadial, starting with an early Wisconsinan glacial lake (Unit 2a), followed by deposition of alluvium in a forested environment (Unit 2b), and ending once again with a glacial climate (Unit 4 till). However, some lines of evidence suggest that only a portion of the mid-Wisconsinan interstadial is represented by Unit 2b. The amino acid D/L ratios imply that Unit 2b dates to at least part of the interval between 10 000 and 50 000 years ago, and the single ratio from Unit 1 also appears to fall within that range. Mid-Wisconsinan sites located elsewhere in northern Yukon record complex paleoclimatic oscillations punctuated by climate cold enough for formation of permafrost. Hence, the single mid-Wisconsinan warming event preserved in Hungry Creek Unit 2b may represent only a fragment of a more complex paleoclimatic history.

The fossils of Units 2a and 2b and the gradational character of the boundary between them suggest that the two units together represent no more than a small part of the mid-Wisconsinan, and possibly only the beginning of one of the warm intervals within that extended period of time. In effect, Hungry Creek Unit 2 may represent a relatively short time interval, centered on 37 000 years B.P., that is telescoped into a thick sequence of sediments to a degree not often seen in sections from other areas of Yukon.

The discovery of chert microflakes in sediments of Unit 2b poses an historical and theoretical question quite independent of the paleoecological record. As mentioned above, the interpretation of the microflakes is still uncertain, but only two alternatives seem worth consideration at the present time. Either they represent a relatively unusual geologic process related in some manner to glaciofluvial discharge or they comprise by-products of stone tool manufacture by human societies otherwise undetected thus far in the mid-Wisconsinan of Bonnet Plume Basin. Since no analogue for glaciofluvial production has yet come to our attention, whereas well-documented analogues are associated with artificial stone working, it seems worthwhile to explore, if only for the sake of discussion, the implications of the microflakes as hypothesized archaeological objects. Their discovery at Hungry Creek may represent more than a mere geographic extension of evidence for early man in the Yukon Territory, since it could expand the search into the glaciated region where hitherto the prospect of success has been deemed very low. The probability of mid-Wisconsinan deposits being preserved at all is much lower in the glaciated than in the non-glaciated areas. However, where mid-Wisconsinan sediments are fortuitously preserved and exposed, as at Hungry Creek, the overlying till constitutes no greater impediment to the search for archaeological material than does the glaciolacustrine sediment overlying artifact-bearing beds in the Old Crow Basin to northwest.

A search for microflakes involves minimal effort in the laboratory when samples are being processed for plant macrofossils and insect remains. Therefore routine checking of all known and suspected mid-Wisconsinan deposits in the Yukon and western District of Mackenzie seems warranted. A clearer interpretation of these tiny fragments of chert will probably emerge from the collation of their occurrences in a variety of sedimentary contexts.

We are aware that in all sections of this paper more questions are raised than answered and that our efforts may seem to represent a rudimentary (as opposed to preliminary) understanding of the subject. We went to Hungry Creek in 1976 with the expectation of confirming and enlarging on a stratigraphic framework already well defined from previous work in the Old Crow and Bluefish Basins. To our surprise Hungry Creek revealed evidence that eroded the very foundations of our initial working hypotheses. Thus it is quite proper that Bonnet Plume Basin, at one time considered by us as only a peripheral topic in the study of the basins in the Porcupine drainage, should now become the starting point for this series of reports. Hungry Creek has considerably sharpened our focus on the problem of developing a coherent picture of the late Pleistocene history of northern Yukon.

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This is Contribution No. 67 of the Yukon Refugium Project.

APPENDIX A

PREPARATION AND DERIVATIZATION OF AMINO ACID RACEMIZATION SAMPLES

Preparation

Volatile enantiomers are prepared in order to record the various amino acids by gas chromatography. Each wood sample is thoroughly cleaned with distilled water, then air dried on a plastic weighing dish. Next the sample is broken by hand into approximately 2 x 2 x 2 cm pieces and crushed using a mortar and pestle. Periodically the material is sifted through a 20 mesh screen and collected on a plastic weighing boat. The sifted wood particles are washed twice in a plastic disposable centrifuge tube using 2N HCl and twice with double distilled water. Between washings, the sample is sonicated, centrifuged, and decanted. The cleaned particles are transferred to a Buchner funnel hooked up to a water-vacuum tap and fitted with Whatman glass fibre paper (GF/A — 4.25 cm) and washed several times with double-distilled water. The filtrate is discarded, and the washed particles are collected in small plastic vials. The vials are covered and placed in a desiccator for vacuum drying taking several hours.

Derivatization

About 100 mg of washed, dried sample is placed in a glass screw-top culture tube (13 x 100 mm). Added to this is about 6-8 ml 5.5N HCl (constant boiling). The mixture is allowed to reflux at 108°C for 24 hrs in a heating block. After heating, the tube is removed and allowed to cool to room temperature. It is then centrifuged to remove particulate matter. The supernatent liquid is collected by a Pasteur pipette and transferred to a clean culture tube. Next the sample is evaporated to dryness in a Speed Vac Concentrator. Then the residue is dissolved in 1-2 ml double-distilled water and added to freshly regenerated cation exchange resin (Dowex AG 50W-X8, 50-100 mesh 7 ml). Next is added 4 bed volumes of double-distilled water and then the effluent is discarded. Two bed volumes of 3M NH_4OH is added to elute the amino acids. About 10 ml of amino acid eluate is collected in a clean 13 x 100 mm screw-top culture tube when the solvent front is about 1.5-2.0 cm from the bottom of the column. The excess NH_4OH is evaporated using a Speed Vac Concentrator. It usually takes over eight hours to evaporate to dryness.

Esterification is carried out by adding 0.1 ml isopropanol/3.5N HCl to the dried eluate. This is sonicated until dissolved, then heated at 100°C for 15 minutes in an oil bath. Then it is evaporated for about two hours in the concentrator until dry. The sample is acylated by adding 0.1 ml PFPA (pentafluoropropionic anhydride) and 0.3 ml CH_2Cl_2 (distilled). The sample is sonicated until dissolved and then heated in an oil bath at 100°C for 5 minutes. The excess PFPA and CH_2Cl_2 is cold evaporated on a Buchi rotary evaporator using liquid N_2. Next the sample is washed with 0.5-1.0 ml CH_2Cl_2 and the residue allowed to dissolve completely, then cold evaporated to dryness using a rotary evaporator. The sample is then diluted in 0.5 ml CH_2Cl_2 and filtered through a Gelman alpha-200, 0.20μ metricel filter. The derivative is now ready to be injected into the gas chromatograph. The sample may be diluted with additional CH_2Cl_2 depending upon its concentration upon injection. About 0.2 to 1.0 µl is injected. The gas chromatograph used is a Hewlett-Packard Model 5840A equipped with a FID Detector and a Chirasil-val capillary column 25 m and controlled by a digital micro-processor terminal which reports peak areas by automatic integration.

APPENDIX B

DEFINITION OF MACROFOSSIL GROUPS

In this and other recent papers on macrofossils from east Beringia (e.g. Matthews, in press) an attempt has been made to group the fossils. For the most part the groupings consist of taxa with similar habitat requirements, but the majority of groups are named according to the prevalent taxa, not the habitat type. The scheme outlined below is tentative and likely to undergo revision; nevertheless, as the text illustrates, it shows promise as a technique for standardizing assemblage data prior to attempting comparisons.

Plants

Four groups of plant fossils are recognized. The *Carex-Potamogeton* group (CAREX-POTAM.) includes fossils of plants which grow in or near water. All *Carex* achenes are included because in general when *Carex* fossils can be identified the majority of them refer to species such as *Carex diandra, C. aquatilis, C. maritima, C. atherodes, C. rostrata* and other typical wetland types. Some other plants placed in the CAREX-POTAM. group are *Scirpus, Eleocharis, Rorripa islandica, Cicuta* spp., *Sparganium* sp., *Najas, Myriophyllum, Hippuris,* and *Potentilla palustris.*

Besides fossils of *Betula* and *Alnus,* the group of that name (BETULA-ALNUS) includes *Salix* and a few other non-ericaceous shrubs. When dominated by *Salix* and *Alnus incana,* the *Betula-Alnus* group represents the shrub component of river shoreline sites. On the other hand, if most of the fossils are of dwarf birch, the group more likely represents upland shrub-tundra. That such different communities can be subsumed by the same taxon group shows clearly that the groups are not strictly ecological.

The *Picea* group includes all fossils of *Picea* and *Larix* and the Ericaceous shrubs (e.g. *Ledum, Empetrum, Chamaedaphne, Andromeda,* etc.), which commonly grow with *Picea* in acid bog communities. Obviously, this group could represent biotopes similar to those which yield fossils of the *Carex-Potamogeton* group.

In the *Potentilla-Chenopodium* group (POTEN.-CHENOPOD.) are placed fossils of taxa whose species grow primarily on open ground and upland sites. Some members of this group do not occur together today. Whether this is the result of mixing of fossil assemblages or represents actual communities lacking modern analogues must be evaluated individually for each sample. The miscellaneous class contains macrofossils which do not readily fit in any of these broad classes, either because they are too poorly preserved to permit identification to a meaningful taxonomic level or because they represent taxa with widely differing habitat requirements.

Insects

The protocol for grouping insect fossils is similar to that for plant macrofossils, but includes some classes which are based on niche rather than habitat. For example the Silphid group consists of all fossils of taxa known to be carrion feeders. The *Aphodius* group includes primarily that genus (most species of which are dung feeders) and others known to specialize in coprophagy or which usually occur near dung or other rotting debris. Like the *Aphodius* group, the *Tachinus* group is intended to emphasize the abundance of *Tachinus* fossils in some Alaska-Yukon samples (Matthews, 1974; Giterman *et al.*, in press).

The *Cryobius* group includes beetles typical of mesic tundra. Most of the species of the subgenus *Cryobius* fit this description. So too do other carabids such as *Diacheila polita*, and a few staphylinid beetles. Xeric conditions or at least xeric and poorly vegetated substrates are typically the habitat of the beetles included in the *Lepidophorus-Morychus* group (LEPIDO.-MORYCHUS). *Lepidophorus lineaticollis,* a weevil, and one or more species of the rarely collected pill-beetle, *Morychus,* are usually the primary constituents of this group. When present, fossils of *Amara alpina,* a ground beetle commonly found on rather dry tundra areas, are also included, as are the fragments of a tiny staphylinid beetle tentatively referred to the genus *Micralymma* in Table 7.

HYGROPH.-AQUAT. stands for all taxa which are hygrophilous or strictly aquatic. Included, among others, are all species of Dytiscidae, Gyrinidae, *Helophorus* (Hydrophilidae), many bog-inhabiting carabids, and staphylinids such as *Stenus, Olophrum rotundicolle,* and *Gymnussa.* The Miscellaneous Phytophagous category (MISC. PHYTOPHAG.) is a residual class for all phytophagous species not placed elsewhere. Most are weevils and chrysomelid beetles.

The Formicid. group includes fossils of ants and other taxa normally found within treeline. Bark beetles (Scolytidae) and weevils (such as *Pissodes*), which feed on conifers, constitute the best evidence of presence of trees since ants sometimes do occur in dry tundra areas.

REFERENCES

ALT, D. and CHAMBERS, R.L. 1970. Repetition of the Spokane flood. First American Quaternary Association Abstracts: 1. Bozeman, Montana.

BALL, G.E. 1966. A revision of the North American species of the subgenus *Cryobius* Chaudoir (*Pterostichus,* Carabidae, Coleoptera). Opuscula Entomologica Suppl. XXVIII. 166 p.

BIRKS, H.H. 1980. Plant macrofossils in Quaternary lake sediments. Ergebnisse der Limnologie, Beihefte, Archiv für Hydrobiologie 15:1-60.

BLATT, H., MIDDLETON, G.V. and MURRAY, R. 1980. Origin of Sedimentary Rocks. 2nd edition. New York: Prentice-Hall, Inc. 782 p.

BODALY, R.A. and LINDSEY, C.C. 1977. Pleistocene watershed exchanges and the fish fauna of the Peel River basin, Yukon Territory. Journal of the Fisheries Research Board of Canada 34:388-395.

BONNICHSEN, R. 1978. Critical arguments for Pleistocene artifacts from the Old Crow Basin, Yukon: a preliminary statement. In: Bryan, A.L. (ed.). Earily Man in America from a Circum-Pacific Perspective. Edmonton: Department of Anthropology, University of Alberta. 102:118.

———. 1979. Pleistocene bone technology in theBeringian refugium. Ottawa: National Museum of Man (Mercury Series). Archaeological Survey of Canada Paper no. 89. 296 p.

BOSTOCK, H.S. 1948. Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel. Geological Survey of Canada Memoir 247. 106 p.

———. 1967. Physiographic regions of Canada. Geological Survey of Canada Map 1254A.

BROWN, R.J.E. 1960. The distribution of permafrost and its relation to air temperature in Canada and the U.S.S.R. Arctic 13(3):163-177.

BRYAN, ALAN L. (ed.). 1978. Early Man in America from a Circum-Pacific Perspective. Edmonton: Department of Anthropology, University of Alberta. 327 p.

BURNS, B.M. 1973. The climate of the Mackenzie Valley — Beaufort Sea. Vol. 1. Environment Canada: Atmospheric, Environmental, Climatological Studies, No. 24.

———. 1974. The climate of the Mackenzie Valley — Beaufort Sea. Vol. 2. Environment Canada: Atmospheric, Environmental, Climathlogical Studies, No. 24. CAMSELL, C. 1906. Peel River and tributaries, Yukon and Mackenzie. Geological Survey of Canada Annual Report for 1904. Vol. 16, Report CC. 49 p.

CHAMBERS, R.L. 1971. Sedimentation in glacial Lake Missoula. M.Sc. Thesis, University of Montana. 100 p.

CINQ-MARS, J. 1978. Northern Yukon Research Programme: survey and excavation. Fifth American Quaternary Association Abstracts: 160-161.

———. 1979. Bluefish Cave I: a Late Pleistocene eastern Beringian cave deposit in the northern Yukon. Canadian Journal of Archaeology 3:1-32.

CLAGUE, J.J. 1979. An assessment of some possible flood hazards in Shakwak Valley, Yukon Territory. Geological Survey of Canada Paper 79-1B:63-70.

CRAIG, C. 1977. An ecological study of macrofossils from Hungry Creek, Yukon Territory. Unpublished manuscript, Geological Survey of Canada, 601 Booth Street, Ottawa.

CUMBAA, S.L., McALLISTER, D.E. and MORLAN, R.E. 1981. Late Pleistocene fish fossils of *Coregonus, Stenodus, Thymallus, Catostomus, Lota,* and *Cottus* from the Old Crow Basin, northern Yukon, Canada. Canadian Journal of Earth Sciences 18(11):1740-1754.

CWYNAR, L.C. 1980. A Late-Quaternary vegetation history from Hanging Lake, Northern Yukon. Ph.D. Dissertation, University of Toronto. 136 p.

——— and RITCHIE, J.C. 1980. Arctic Steppe-tundra: a Yukon perspective. Science 208:1375-1377.

DELORME, L.D. 1968. Pleistocene freshwater Ostracoda from Yukon, Canada. Canadian Journal of Zoology 46(5):859-876.

DYCK, W. and FYLES, J.G. 1964. Geological Survey of Canada Radiocarbon Dates III. Radiocarbon 6:167-181.

——— and BLAKE, W., Jr. 1965. Geological Survey of Canada Radiocarbon Dates IV. Radiocarbon 7:24-6.

FLADMARK, K.R. In press. Microdebitage analysis: initial considerations. Journal of Archaeological Science.

GEIST, O.W. 1952-53. Scientific investigations in the Old Crow and Porcupine River regions of Alaska and Yukon Territory. Manuscript, University of Alaska, 108 p.

———. 1955. Vertebrate paleontological reconnaissance of the Old Crow River area, Yukon Territory, Canada. Geological Society of America Bulletin 66(12)pt. 2:1702.

GITERMAN, R.E., SHER, A.V. and MATTHEWS, J.V., Jr. In press. Comparison of the development of tundra-steppe environments in West and East Siberia: pollen and macrofossil evidence from key sections. In: Hopkins *et al.* (eds.). The Paleoecology of Beringia. New York: Academic Press.

GLASER, R.H. 1978. Recent plant macrofossils from the Alaska interior and their relationship to late glacial landscapes in Minnesota. Ph.D. Dissertation, University of Minnesota. 186 p.

GRESSITT, J.L. (ed.) 1963. Pacific Basin biogeography: A Symposium. Honolulu: Bishop Museum Press. 563 p.

HARINGTON, C.R. 1975. Evidence of early man in the Old Crow Basin, Yukon Territory. The Arctic Circular 22(3):118-128.

———. 1977. Pleistocene mammals of the Yukon Territory. Ph.D. Dissertation, University of Alberta, Edmonton. 1060 p.

———. 1978. Quaternary vertebrate faunas of Canada and Alaska and their suggested chronological sequence. Ottawa: National Museum of Natural Sciences (Syllogeus 15). 105 p.

———. 1980a. Radiocarbon dates on some Quaternary mammals and artifacts from northern North America. Arctic 33(4):815-832.

———. 1980b. Pleistocene mammals from Lost Chicken Creek, Alaska. Canadian Journal of Earth Sciences 17(2):168-198.

——— and CLULOW, F.V. 1973. Pleistocene mammals from Gold Run Creek, Yukon Territory. Canadian Journal of Earth Sciences 10:697-759.

HOPKINS, D.M. (ed.) 1967. The Bering Land Bridge. Stanford: Stanford University Press. 495 p.

———. 1973. Sea level history in Beringia during the past 250,000 years. Quaternary Research 3(4):520-540.

———. In press. Aspects of the paleogeography of Beringia during the late Pleistocene. In: Hopkins *et al.* (eds.). The Paleoecology of Beringia. New York: Academic Press.

———, MATTHEWS, J.V., Jr., SCHWEGER, C.E. and YOUNG, S.B. (eds). In press. The paleoecology of Beringia. New York: Academic Press.

HUGHES, O.L. 1963. Surficial geology, Operation Porcupine. Geological Survey of Canada Paper 63-1:19.

———. 1969. Pleistocene stratigraphy, Porcupine and Old Crow Rivers, Yukon Territory. Geological Survey of Canada Paper 69-1:209-212.

———. 1970. Quaternary geology, Yukon Territory and western District of Mackenzie. In: Smith, R.A. and Smith, J.W. (eds.). Early Man and Environments in Northwestern North America. Calgary: University of Calgary Archaeological Association. 9-11.

———. 1972. Surficial geology of northern Yukon Territory and northwestern District of Mackenzie, Northwest Territories. Geological Survey of Canada 69-36. 11 p.

———, HODGSON, D.A. and PILON, J. 1972. Surficial geology and geomorphology of 106I, M, N, District of Mackenzie, N.W.T., and Yukon Territory (preliminary draft). Geological Survey of Canada Open File 97.

———HUGHES, O.L. and PILON, J. 1973. Surficial geology and geomorphology of 106L, 116N(East ½)&O, 116 P, District of Mackenzie, N.W.T. and Yukon Territory (preliminary draft). Geological Survey of Canada Open File 167.

HULTÉN, E. 1937. Outline of the history of Arctic and boreal biota during the Quaternary Period. Stockholm: Bokforlagsaktiebologet Thule. 168 p.

———. 1968. Flora of Alaska and neighboring territories: a manual of the vascular plants. Stanford: Stanford University Press. 1008 p.

INTERNATIONAL BOUNDARY COMMISSION. 1918. Joint report upon the survey and demarcation of the international boundary between the United States and Canada along the 41st meridian from the Arctic Ocean to Mount St. Elias. Washington: Government Printing Office. 305 p.

IRVING, L. 1960. Birds of Anaktuvuk Pass, Kobuk, and Old Crow: a study in Arctic adaptation. U.S. National Museum Bulletin 217:409 p.

IRVING, W.N. 1971. Recent early man research in the North. Arctic Anthropology 8(2):68-82.

——— and CINQ-MARS, J. 1974. A tentative archaeological sequence for Old Crow Flats, Yukon Territory. Arctic Anthropology 11(sup. 65-81.

———IRVING, W.N. and HARINGTON, C.R. 1973. Upper Pleistocene radiocarbon-dated artefacts from the Northern Yukon. Science 179:335-340.

JANSSENS, J.A.P. 1981a. Summaries of bryological reports: update 1981. On file in Library of Boreal Institute for Northern Studies, University of Alberta, Edmonton.

______. 1981b. Late Cenozoic bryophytes in North America: the paleoenvironmental and phytogeographic significance. Ph.D. Dissertation, University of Alberta. 450 p.

KEELEY, H.C.M. 1978. The cost-effectiveness of certain methods of recovering macrosopic organic remains from archaeological depos its. Journal of Archaeological Science 5:179-183.

KENWARD, H.K. 1974. Methods for palaeo-entomology on site and in the laboratory. Science and Archaeology 13:16-24.

KIND, N.V. 1967. Radiocarbon chronology in Siberia. In: Hopkins, D.M. (ed.). The Bering Land Bridge. Stanford: Stanford University Press. 172-192.

KONTRIMAVICHUS, V.L. (ed.) 1976. Beringia in the Cenozoic: theses of the reports of the All-Union Symposium "The Bering Land Bridge and its role for the history of Holarctic floras and faunas in the Late Cenozoic." Khabarovsk: Nauka. 570 p.

KRINSLEY, D.H. and DOORNKAMP, J.C. 1973. Atlas of quartz sand surface textures. Cambridge: Cambridge University Press. 91 p.

KVENVOLDEN, K.A. 1980. Interlaboratory comparison of amino acid racemization in a Pleistocene mollusk, *Saxidomus giganteus*. In: Hare, P.E., Hoering, T.C. and King, K. (eds.). Biogeochemistry of amino acids. Toronto: John Wiley & Sons. 223-232

LAUGHLIN, W.S. and HARPER, A.B. (eds.). 1979. The First Americans: origins, affinities, and adaptations. New York: Gustav Fischer. 340 p.

LICHTI-FEDEROVICH, S. 1973. Palynology of six sections of Late Quaternary sediments from the Old Crow River, Yukon Territory. Canadian Journal of Botany 51(3):553-564.

______. 1974. Palynology of two sections of Late Quaternary sediments from the Porcupine River, Yukon Territory. Geological Survey of Canada 74-23 6 p.

LINDROTH, C.H. 1961. The ground-beetles of Canada and Alaska, part 2. Opuscula Entomologica Supplementum 20:1-200. Lund.

______. 1961-1968. The ground-beetles of Canada and Alaska. Opuscula Entomologica Supplementum 20, 24, 29, 33, 34. Lund. 1192 p.

LOWDON, J.A. and BLAKE, W., Jr. 1979. Geological Survey of Canada Radiocarbon Dates XIX. Geological Survey of Canada Paper 79-7. 58 p.

______ LOWDON, J.A., ROBERTSON, I.N. and BLAKE, W., Jr. 1971. Geological Survey of Canada Radiocarbon Dates XI. Geological Survey of Canada Paper 71-7. 324 p.

MacDONALD, G.F. (ed.). 1975. Archaeological Survey of Canada Annual Review 1974. Ottawa: National Museum of Man (Mercury Series). Archaeological Survey of Canada Paper no. 31. 64 p.

______. 1977. Archaeological Survey of Canada Annual Review 1975 and 1976. Ottawa: National Museum of Man (Mercury Series). Archaeological Survey of Canada Paper no. 66. 113 p.

MACKAY, J.R. and MATHEWS, W.H. 1973. Geomorphology and Quaternary history of the Mackenzie River valley near Fort Good Hope, N.W.T., Canada. Canadian Journal of Earth Sciences 10(1):26-41.

MAROIS, R.J.M. (ed). 1980. Archaeological Survey of Canada Annual Review 1977-1979. Ottawa: National Museum of Man (Mercury Series). Archaeological Survey of Canada Paper no. 95. 88 p.

MATHEWS, W.H. 1965. Two self-dumping ice-dammed lakes in British Columbia. Geographical Review 55:46-62.

MATTHEWS, J.V., Jr. 1974. Wisconsin environment of interior Alaska: pollen and macrofossil analysis of a 27 meter core from the Isabella Basin (Fairbanks, Alaska). Canadian Journal of Earth Sciences 11:828-841.

______. 1975. Insects and plant macrofossils from two Quaternary expo sures in the Old Crow-Porcupine region, Yukon Territory, Canada. Arctic and Alpine Research 7(3):249-259.

______. 1980. Possible evidence of an Early Wisconsinan warm interstadial in East Beringia. Sixth American Quaternary Association Abstracts. Orono. 130-131.

______. In press. East Beringia during late Wisconsinan time: a review of the biotic evidence. In: Hopkins *et al.* (eds.). The Paleoecology of Beringia. New York: Academic Press.

McCONNELL, R.G. 1891. Report on an exploration in the Yukon and Mackenzie basins. Geological Survey of Canada Annual Report, n.s., 4:5D-163D.

MORLAN, R.E. 1973. The later prehistory of the middle Porcupine drainage, northern Yukon Territory. Ottawa: National Museum of Man (Mercury Series). Archaeological Survey of Canada Paper no. 11. 583 p.

______. 1976. The Yukon Refugium Project: 1975 field season. Quaternary Research in Canada 7:49-57.

______. 1980. Taphonomy and Archaeology in the Upper Pleistocene of northern Yukon Territory: a glimpse of the peopling of the New World. Ottawa: National Museum of Man (Mercury Series). Archaeological Survey of Canada Paper no. 94. 380 p.

______ and CINQ-MARS, J. In press. Ancient Beringians: human occupations in the Late Pleistocene of Alaska and the Yukon Territory. In: Hopkins, *et al.* (eds.). The Paleoecology of Beringia. New York: Academic Press.

______ MORLAN, R.E. and MATTHEWS, J.V., Jr. 1981. Taphonomy and paleoecology of sub-fossil insect assemblages from Old Crow River Loc. 15, north ern Yukon Territory: a preliminary report. Manuscript No. 1927, *Scientific* Records of the Archaeological Survey of Canada, National Museum of Man, Ottawa.

MOSS, E.H. 1971. Flora of Alberta. Toronto: University of Toronto Press. 546 p.

MURRAY, D. 1981 (in press). The role of Arctic Refugia in the evolution of the Arctic vascular flora — a Beringian perspective. In: Scudder, G.G. and Reveal, J.V. (eds.). Evolution Today. Proceedings of the Second International Congress of Systematic and Evolutionary Biology.

NELSON, R.E. 1979. Quaternary environments of the Arctic Slope of Alaska. M.Sc. Thesis, University of Washington. 141 p.

NORRIS, D.K. 1963. Operation Porcupine. Geological Survey of Canada Paper 63-1:17-19.

OGILVIE, W. 1890. Exploratory survey of part of the Lewes, Tat-on-Duc, Porcupine, Bell, Trout, Peel and Mackenzie Rivers (1887-88). Ottawa: Report of the Department of Interior for 1889, pt. 7: 1-114.

OSWALD, E.T. and SENYK, J.P. 1977. Ecoregions of Yukon Territory. Environment Canada: Canadian Forestry Service. 115.

PÉWÉ, T.L. 1975. Quaternary geology of Alaska. U.S. Geological Survey Professional Paper 835. 145 p.

______ and HOPKINS, D.M. 1967. Mammal remains of pre-Wisconsin age in Alaska. In: Hopkins, D.M. (ed.). 266-270.

PORSILD, A.E. and CODY, W.J. 1980. Vascular plants of continental Northwest Territories, Canada. Ottawa: National Museums of Cana da. 667 p.

POWERS, M.C. 1953. A new roundness scale for sedimentary particles. Journal of Sedimentary Petrology 23(2):117-119.

RAMPTON, V.N. In press. Quaternary geology of the Yukon Coastal Plain. Geological Survey of Canada Bulletin 317.

REPENNING, C.A., HOPKINS, D.M., and RUBIN, M. 1964. Tundra rodents in late Pleistocene fauna from Tofty Placer District, central Alaska. Arctic 17(3):176-197.

RITCHIE J.C. 1980. Towards a Late-Quaternary palaeoecology of the ice-free corridor. Canadian Journal of Anthropology 1(1):15-28.

RUTTER, N.W., CRAWFORD, R.J., and HAMILTON, R. 1980. Correlation and relative age dating of Quaternary strata in the continuous permafrost zone of northern Yukon with D/L ratios of aspartic acid of wood, freshwater molluscs, and bone. In: Hare, P.E., Hoering, T.C., and King, K. (eds.). Biogeochemistry of amino acids. Toronto: John Wiley & Sons. 463-475.

SCHWEGER, C.E. 1976. Late Quaternary paleoecology of the Onion Portage region, northwestern Alaska. Ph.D. Dissertation, University of Alberta, Edmonton. 172 p.

______ and JANSSENS, J.A.P. 1980. Paleoecology of the Boutellier non-glacial interval, St. Elias Mountains, Yukon Territory, Canada. Arctic and Alpine Research 12(3): 309-317.

SHER, A.V. 1974. Pleistocene mammals and stratigraphy of the Far Northeast USSR and North America. International Geological Re view 16:1-284.

SILVER, I.A. 1969. The ageing of domestic animals. In: Brothwell, D. and Higgs, E. (eds.), Science in Archaeology. Bristol: Thames and Hudson. 283-303.

STRUEVER, S. 1968. Flotation techniques for the recovery of small-scale archaeological remains. American Antiquity 33(3):353-362.

THORARINSSON, S. 1939. The ice dammed lakes of Iceland with particular reference to their values as indicators of glacier oscillations. Geografiska Annaler Bd. 21:216-242.

———. 1957. The jokulhlaup from the Katla area in 1955 compared with other jokulhlaups in Iceland. Jokull, Ar. 7: 21-25.

VASIL'EVSKY, R.S. (ed.). 1979. Drevnie kul'tury Sibiri i Tikhookeanskogo Basseina. (Ancient cultures of Siberia and the Pacific Basin). Novosibirsk: Nauka. 221 p.

WEIN, R.W., HETTINGER, L.R., JANZ, A.J., and CODY, W.J. 1974. Vascular plant range extensions in the northern Yukon Territory and northwestern Mackenzie District, Canada. Canadian Field-Naturalist 88:57-66.

WELCH, S.L. and RIGBY, J.K. 1971. Botanical and physiographic reconnaissance of northern Yukon. Brigham Young University Science Bulletin, Biological Series no. 14:1-64.

WESTGATE, J.A., MATTHEWS, J.V., Jr., and HAMILTON, T.D. 1981. Old Crow tephra: a new late Pleistocene stratigraphic marker across Alaska and the Yukon Territory. Abstracts with Program. Geological Society of America, 94th Annual Meeting, Cincinnati. 597.

YOUNGMAN, P.M. 1975. Mammals of the Yukon Territory. Ottawa: National Museum of Natural Sciences (Publications in Zoology 10). 192 p.

YURTSEV, B.A. 1974. Problemy botanicheskoi geografii Severo-Vostochnoi Azii. (Problems of phytogeography of northeastern Asia). Leningrad: Nauka. 159 p.