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Geoarchaeological Studies at the Dog Creek Site, Northern Yukon

by

Julie Anne Esdale

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled GEOARCHAEOLOGICAL STUDIES AT THE DOG CREEK SITE, NORTHERN YUKON submitted by Julie Anne Esdale in partial fulfillment of the requirements for the degree of Master of Science.

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Abstract

The Dog Creek archaeological site contains evidence of post-depositional stratigraphic and palaeoenvironmental changes from the mid Holocene to present. The original archaeological context has been altered by periglacial activity. Analysis of sediments, artifact fabric and radiocarbon dates at the site has allowed the original depositional sequence to be reconstructed. Sediments at Dog Creek have been mixed and folded by cryoturbation, frost heave and solifluction. Artifacts were buried by solifluction beginning 5,290 years ago, providing a minimum age of human occupation at the site. Pollen from the solifluction lobe gives a record of mid to late Holocene vegetation change in the Black Fox Creek area. A spruce forest existed at the site during the mid Holocene, extending the treeline north of its present day position. Arboreal pollen percentages decline while shrub taxa frequency increases from the mid Holocene to approximately 1,800 years ago. At this time, modern forest-tundra vegetation was established in the area.

Résumé

Le site archéologique de Dog Creek atteste des changements stratigraphiques et palaeoenvironnementaux qui ont caracterisé ca region de la crique Black Fox pour la période située entre l'Holocène moyen et le présent. Le contexte archéologique a été significativement modifié par l'activité périglaciaire. L'analyse des sédiments, de l'orientation des artéfacts ainsi que des dates au radiocarbone a permis de reconstituer la séquence originale de déposition des sédiments. Ces derniers on été mélangés et pliés par les processus de cryoturbation, de soulèvement cryogénique et de solifluxion, alors que les artéfacts ont été enterrés par solifluxion. Il fut possible de dater le début de ce processus à environ 5,290 ans, date qui par le fait même indiquè l'âge minimum de l'occupation humaine à Dog Creek. Les pollens recueillis dans le lobe de solifluxion on fournit des informations concernant les changements de végétation qui on pris place dans la région de la crique Black Fox entre l'Holocène moyen et l'Holocène tardif. Pendant l'Holocène moyen, une forêt d'épinettes dominait au site, plaçant ainsi la limite des arbres davantage au nord que sa position actuelle. À partir de l'Holocène moyen jusqu'a il y a environ 1,800 ans, les pourcêtages de pollens des arbres ont diminués alors que ceux des arbustres ont augmentés, créant ainsi la végétation de tundra qui prévale aujourd'hui dans la région.

Acknowledgments

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Table of Contents

List of Tables

List of Figures

List of Plates

CHAPTER 1 Introduction, Background and Methods

Introduction

Archaeological sites in high northern latitudes experience the effects of periglacial activity. Frost processes act to transform the sedimentary context of the archaeological record and can alter the cultural material. Destruction of original archaeological context makes reconstruction of the cultural record complicated (Mackay et al. 1961). In spite of this, there have been very few studies relating the effects of permafrost processes on archaeological sites (e.g. Bowers et al. 1983, Mackay et al. 1961, Texier et al. 1998).

Evaluation of periglacial processes in the archaeological record is important because of the wide variety of sites affected by them. This includes sites in permafrost areas, alpine environments and those close to previous locations of Pleistocene glaciers (northern United States, Europe and Asia). If the effects of periglacial activity are ignored, inaccurate interpretation of the archaeological record can occur. Faulty interpretations could include: 1) defining one culture on the basis of artifacts relating to separate occupations that have become mixed by cryoturbation and frost heave, 2) interpreting multiple occupation events from one stratigraphic unit that has been rolled over by solifluction or separated into components by frost heave, 3) mistaking natural retouch of bone and artifacts for cultural retouch and 4) attributing the alteration of the archaeological record to inappropriate human, animal or natural agents (Texier et al. 1998). Clearly, this issue is important to archaeologists who work at sites that commonly experience periglacial activity.

In order to evaluate the effects of periglacial processes on the archaeological record, a geoarchaeological study in conjunction with archaeological research was done at the Dog Creek site, located in the northern Yukon. The site is located in an area underlain by continuous permafrost that contains evidence of periglacial activity. The site is also important archaeologically because of its potential for containing evidence of early man in North America. It is likely that people have lived in the northern Yukon since the late Wisconsin glacial period (Morlan and Cinq-Mars 1982).

Problem and Objectives

The specific problem addressed in this thesis is to reconstruct palaeoenvironmental changes during the Holocene at the Dog Creek archaeological site and to associate cultural deposits with specific microclimatic conditions. This will be carried out by evaluating the sedimentary and vegetation record at the site and creating a context for the archaeological material.

The objectives of the geoarchaeological research carried out at the Dog Creek site and surrounding region are to: 1) interpret the complex stratigraphy of the deposits and determine which processes have been active in displacing artifacts, 2) establish the vegetative history of the site and 3) establish a site chronology with reference to the known latc Quaternary geology of the area.

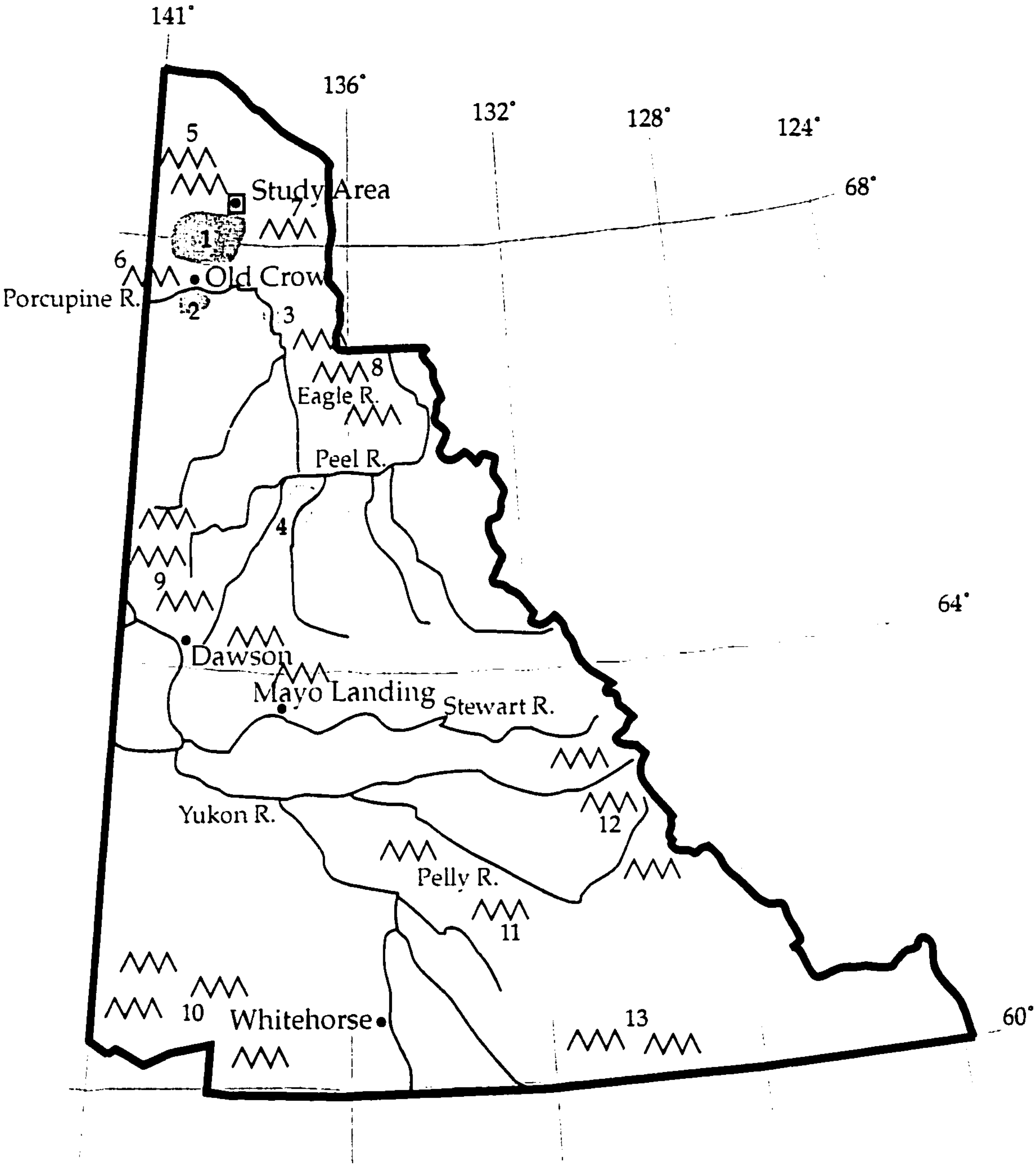
Study Area

The Black Fox Creek study area (68°18′-68°22′30″ N, 138°49′-138°57′ W) covers 45 km^2 and is located northeast of the Old Crow Basin in the northern Yukon (Figure 1, 2). This area contains the Dog Creek archaeological site (NcVi-3) (68°21′28″ N, 138°51′53″ W), which is located on a ridge overlooking Black Fox Creek which flows into the Old Crow Basin from the northeast (Figure 2). Dog Creek is located in the newly formed Vuntut National Park under Parks Canada and Vuntut Gwitchin First Nations jurisdiction.

Regional Framework

Physiography and geography

The Dog Creek site and surrounding area lies on the edge of two physiographic regions, the Old Crow Plain and Porcupine Plateau (Figure 3). The Old Crow Basin in the Old Crow Plain is approximately 300 m above sea level. The land rises northeastward from the basin towards the Dog Creek site on the Porcupine Plateau at 450 m, 25 km away. Twenty kilometres northeast of the Dog Creek site, at the edge of the Barn Range, elevation reaches 750 m (Wahl et al. 1987). The landscape of the northern Yukon changes from a low, tectonically controlled basin in the south to scattered bedrock ridges, to mountains that



1- Old Crow Basin 2- Bluefish Basin 3- Bell Basin 4- Bonnet Plume Basin
5- British M. 6- Old Crow Range 7- Barn Range 8- Richardson M. 9- Ogilvie M.
10- St. Alias M. 11- Pelly M. 12- Selwyn M. 13- Cassiar M. ☐ Study area

Figure 1. Map of the Yukon with basins and ranges.

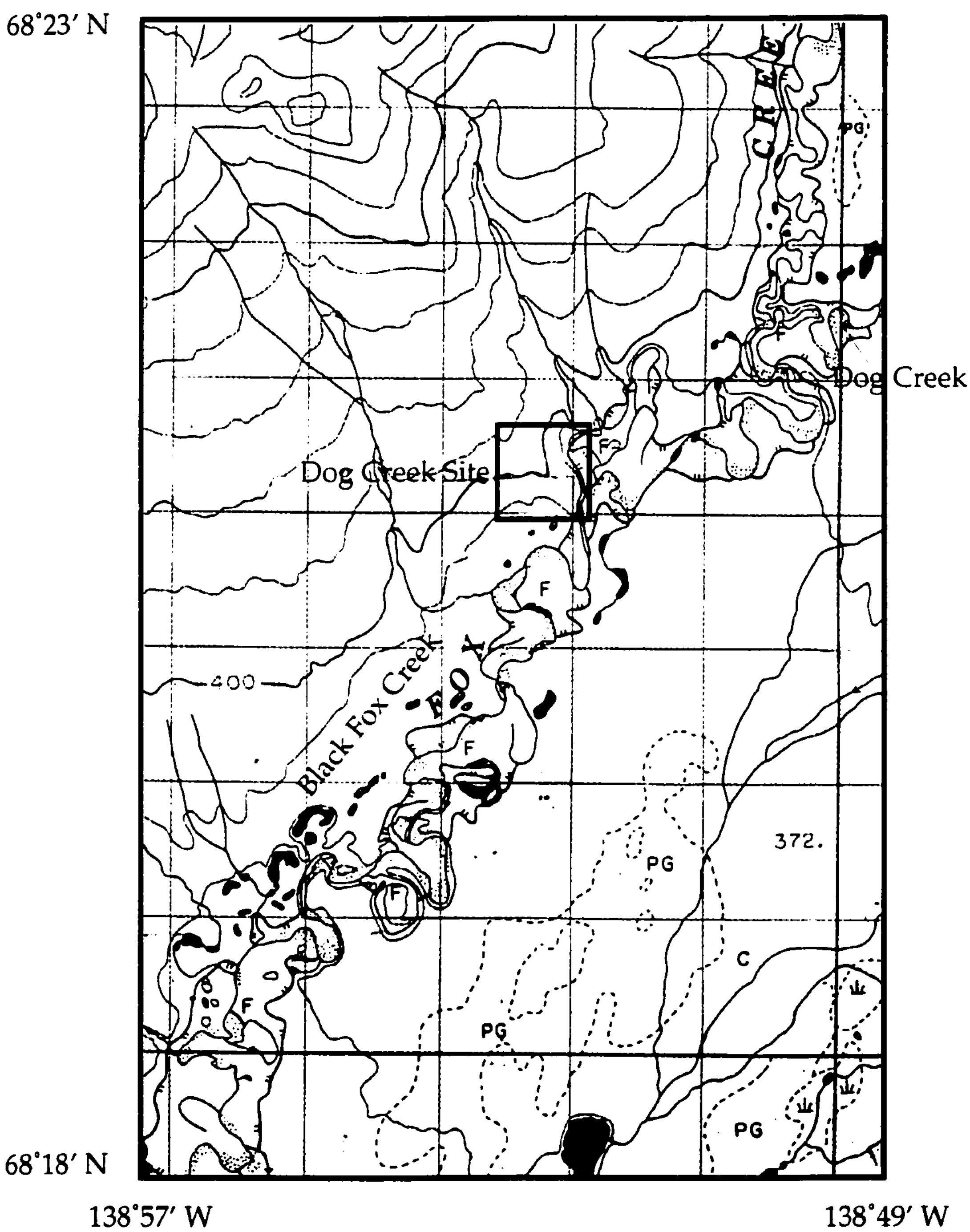


Figure 2. The Black Fox Creek study area and Dog Creek archaeological site.

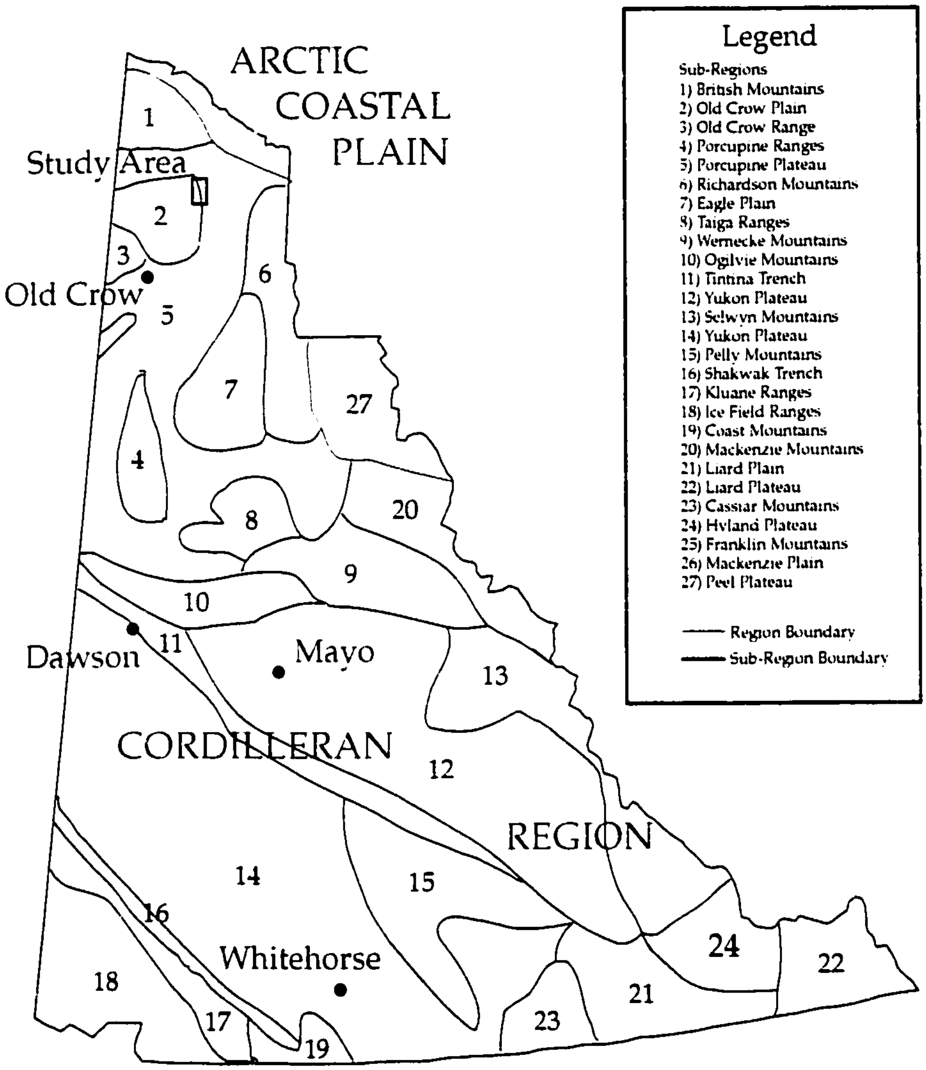


Figure 3. Physiographic regions of the Yukon (after Dept. Energy, Mines and Resources 1974).

exceed 1000 m in elevation in the north. The Old Crow Flats area is characterized by thermokarst lakes, meandering rivers and peat lands (Ortman and Norris 1980, Ovenden 1985). Following the Black Fox Creek upstream towards the British Mountains, the landscape is better drained than the Old Crow Basin and is characterized by exposed bedrock ridges, meandering rivers and alluvial floodplains containing small lakes.

Drainage

Drainage in the area today begins in the Barn and British Mountains and flows southwest and south into the Old Crow Basin and surrounding area, known as the Porcupine Drainage Basin (Ortman and Norris 1980). This basin extends across 61,000 km^2 of the northern Yukon and 57,000 km^2 in northeastern Alaska (Dept. Energy, Mines and Resources 1974). The three main drainage rivers (from east to west) that flow into the Old Crow Basin are Johnson Creek, Black Fox Creek and Timber Creek. These join the Old Crow River at the northeast end of the basin, which then flows southward into the Porcupine River, just south of the Old Crow Flats.

Climate

The Yukon experiences a sub-arctic continental climate. Arctic air flow from the Pacific and Arctic Oceans does not reach the area because it is blocked by mountains (Wahl et al. 1987). Air flow from oceanic sources largely comes from the Gulf of Alaska. The continental climate is characterized by large temperature extremes on day to annual scales (range of extremes of 98.9°C in maximum and minimum air temperatures), low air moisture (relative humidity averages 83% and moisture content 16%) and light precipitation (200-300 mm) (Wahl et al. 1987).

The study area is located on the edge the Porcupine-Peel Basin climate area bordering the Northern Mountains climate region (Wahl et al. 1987). The Porcupine-Peel Basin is characterized by long cold winters (October-May) and short summers. A weather station at the village of Old Crow has recorded the annual average daily temperature of -10°C. The average monthly temperatures and precipitation and extremes are shown in Figure 4. January 1997 average temperatures were -34.2°C while July temperatures were 14.5°C (Yukon Bureau

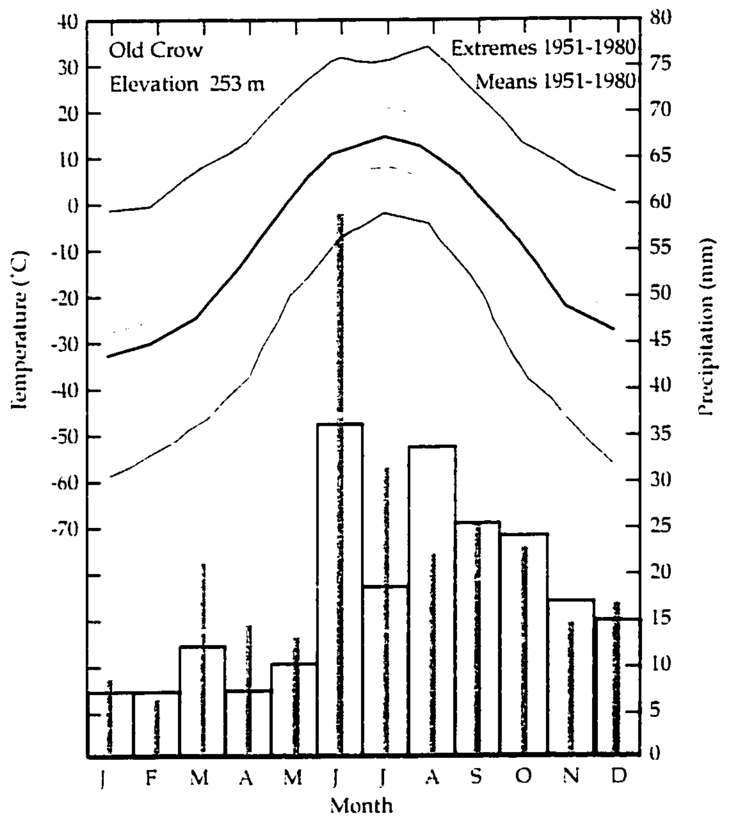


Figure 4. Temperature and precipitation means and extremes (Wahl et al. 1987).

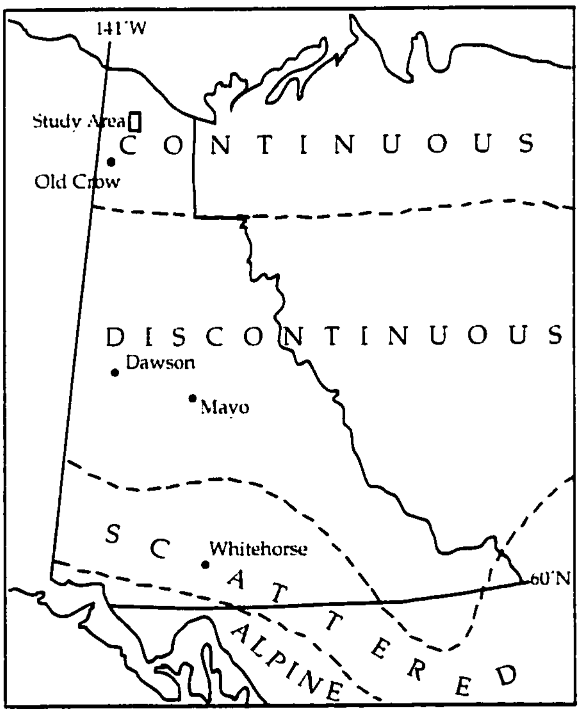


Figure 5. Permafrost regions of the Yukon (after Brown 1978).

of Statistics 1998). On average (from 1951-1980) Old Crow experiences 232 days of winter (temperatures averaging below 0°C), 86 days of summer (temperatures averaging above 0°C) and 63 frost free days.

The Ogilvie Mountains, south of the Porcupine-Peel Basin, block Pacific Ocean air masses causing low precipitation (200-300 mm per year) in the Old Crow Basin. In the Northern Mountains region, precipitation is greater, 300-400 mm per year, because precipitation is dropped before air streams can travel further into the interior. Winter temperatures are milder at these higher elevations due to inversion[1] but summers can be cool and variable (Wahl et al. 1987).

Permafrost

The Yukon is characterized by areas of scattered, discontinuous and continuous permafrost (Figure 5). The presence of permafrost is defined arbitrarily on mean annual ground temperatures of less than -5°C (Brown 1970) or can be defined as ground that has been below 0°C for at least two years (Burn 1993). The extent of permafrost increases with increasing elevation and latitude (Brown 1970). The Dog Creek site is located in the area of continuous permafrost. Vegetation cover, aspect and moisture levels all influence the depth of the active layer in the continuous permafrost zone. Here, the active layer generally extends up to a metre during the thaw season. At Dog Creek, the active layer thickness is over 1.5 metre and reaches to bedrock. In less exposed areas (flood plains covered with trees and mosses) the active layer is shallower (<30 cm).

Soils

The continuous permafrost zone is dominated by Cryosolic soils with scattered Brunisols in the southern portion of the region (Figure 6). The Old Crow Basin contains Gleysolic Turbic Cryosols reflecting extremely poorly drained conditions and active freezing pressures (Canadian System of Soil Classification 1987, Hughes et al. 1993). Orthic and Regosolic Turbic Cryosols

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[1] Inversion refers to the reversal of a normal temperature profile due to radiation loss at the earth's surface.

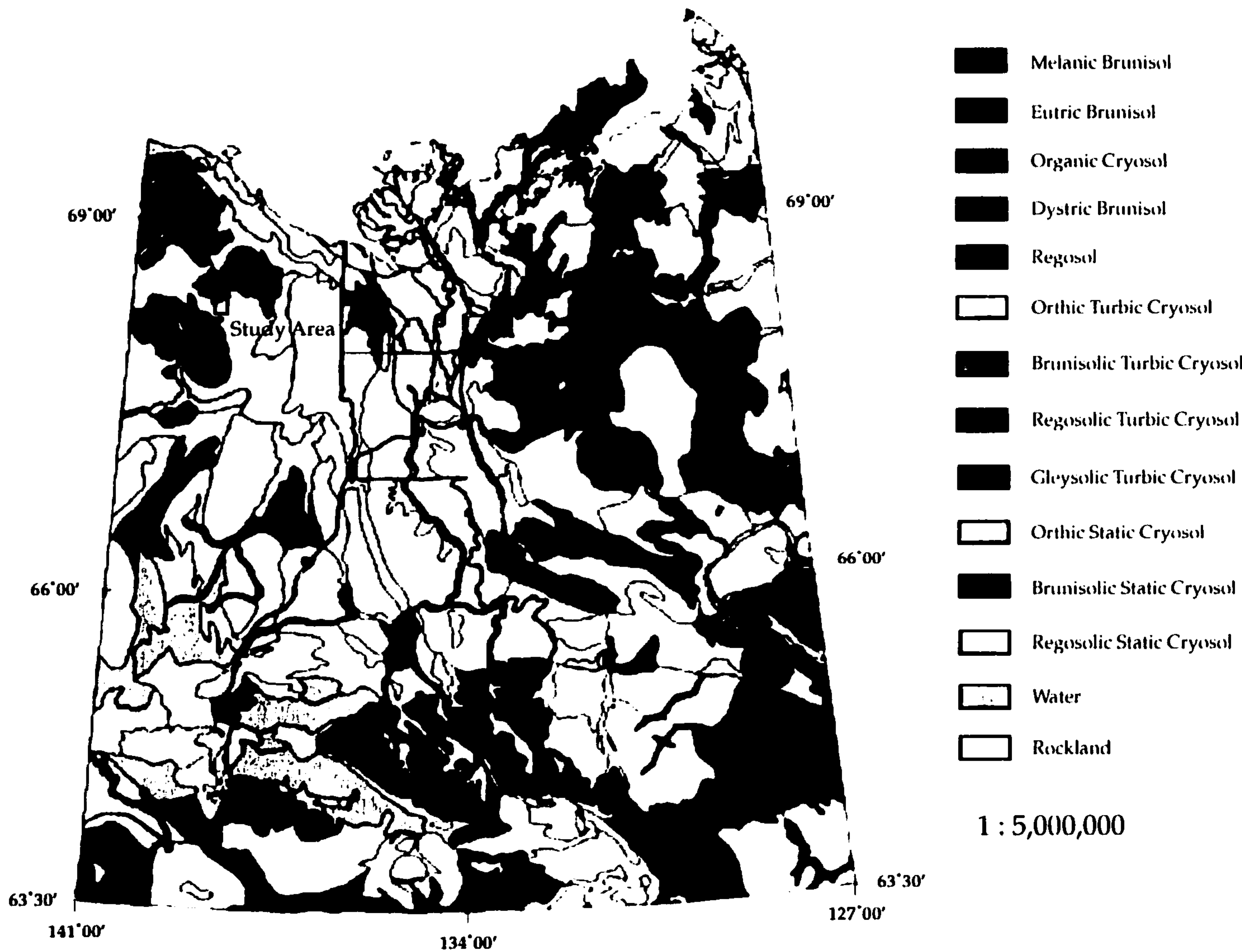


Figure 6. Soils of northwestern Canada (Hughes et al. 1993).

occur to the north of the basin on ridges. Soils on bedrock ridges are associated with sorted polygons, stripes and other periglacial features (Hughes et al. 1993).

Vegetation

There are three main vegetation zones in the Yukon (Figure 7). These include the boreal forest zone in the southern Yukon, tundra landscapes in the north and central Yukon and open woodlands to the north and east. In the study area, the landscape is dominated by tundra conditions. Ground cover at the Dog Creek site consists of small shrubs, flowering plants, grasses and mosses. Shrubs and bushes include birch *(Betula glandulosa)*, alder *(Alnus crispa)*, willow *(Salix spp.)*, juniper *(Juniperus horizontalis?)* and heath family plants (Ericaceae) such as blueberry and salmonberry. Wildflowers are dominated by the pink family (Caryophyllaceae), members of the pea family (Fabaceae) such as *Astragalus spp.*, and members of the aster family (Asteraceae) including *Artemisia spp.*, Grasses, sedges and bryophytes *(Sphagnum spp.)* comprise the bulk of the vegetation. Black spruce *(Picea mariana)* and larger willow and birch stands follow the river valleys, including Black Fox Creek, north of the treeline in the northern Yukon.

Bedrock and tectonics

The study area is underlain by Pre-Cambrian crystalline rocks. The bedrock geology overlying the Pre-Cambrian basement consists largely of sedimentary and volcanic rocks. Many of these strata have been folded and faulted resulting in the Northern Cordilleran Mountains (Richardson, Mackenzie, Ogilvie and St. Elias Ranges) (Ortman and Norris 1980). The study area is bordered by Mesozoic and Palaeozoic rocks to the north and Cenozoic strata to the south. The British and Barn mountain ranges north of the study area are made up of folded limestones, sandstones and shales which are largely Cretaceous to Carboniferous in age. Faulting in the area has taken place since the middle Palaeozoic but most of the uplift and folding is Tertiary (Ortman and Norris 1980). The bedrock geology of the Old Crow Basin is hidden due to thick cover by Quaternary sediments. Inferences from seismic profiles show that the Quaternary deposits are underlain by terrestrial Tertiary sequences unconformably overlying late Cretaceous to Devonian sandstones, shales and limestones. A series of northwest/southeast trending normal and reverse faults

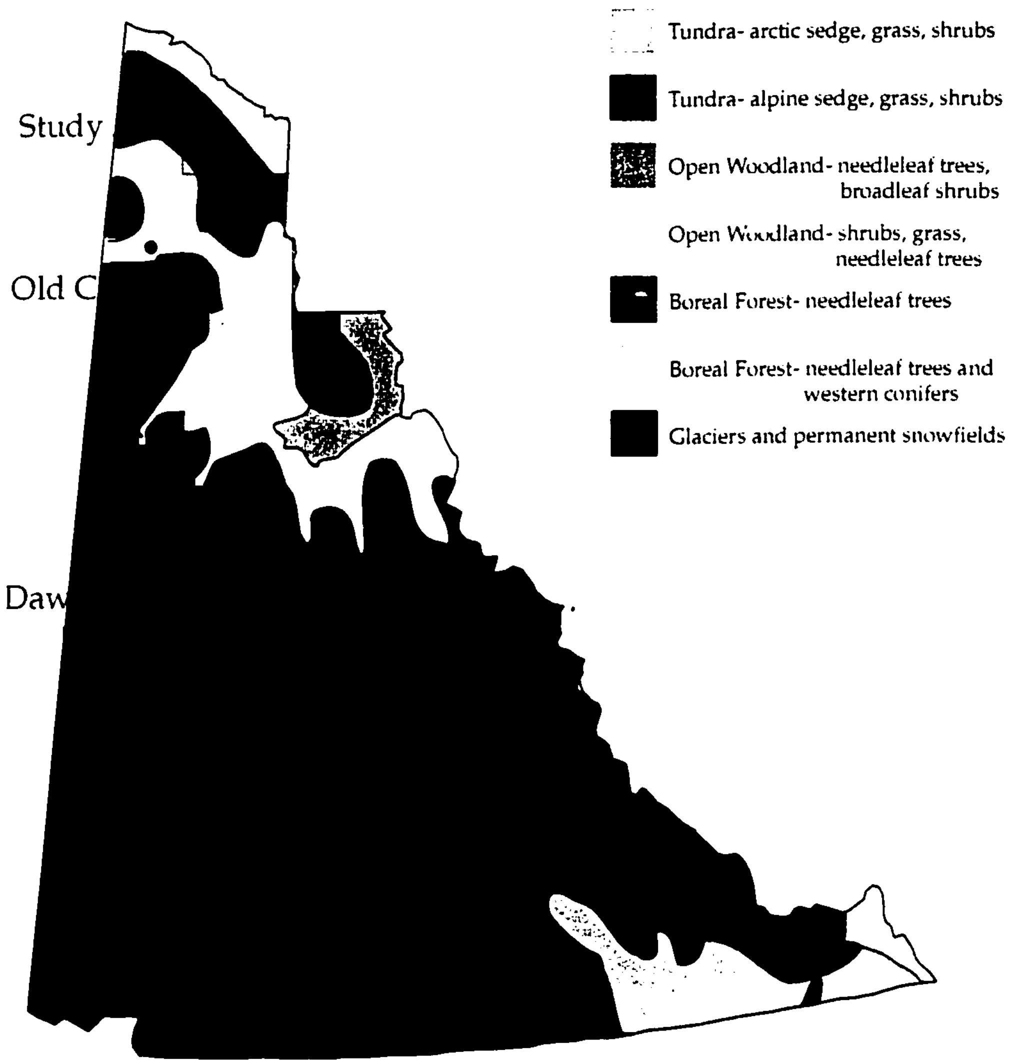


Figure 7. Vegetation regions in the Yukon (after Dept. Energy, Mines and Resources 1974).

cut the basin through Proterozoic to Quaternary strata (Morrell and Dietrich 1993).

Surficial geology

The type of Quaternary deposits found in the Yukon are largely controlled by the extent of Pleistocene glaciers. Most of the northern Yukon was free from both continental and mountain glaciers during the Pleistocene (Hughes 1972). The Old Crow, Bluefish and Bell Basins are filled with late Pleistocene lake deposits (Hughes 1972). Areas outside of these basins are covered with thin aeolian silts or alluvium. In the southern Yukon, glacial deposits are abundant. Till in the form of moraine from various Pleistocene glaciations (pre-Reid, Reid and McConnell glaciations) covers much of the landscape (Hughes et al. 1993).

Previous Research

Quaternary geology

The surficial geology of the Yukon has been mapped by the Geological Survey of Canada. Report and map 1319A shows surficial deposits north of 65° latitude mapped at 1:500,000 by O. L. Hughes (1972). The area of the Yukon south of 65° latitude was prepared by Hughes et al. (1969). Pleistocene glacial limits and flow patterns are shown in Map 6-1968 (1:1,000,000) (Hughes et al. 1969). The Yukon coastal plain has been mapped (map and report 1503A) by V. N. Rampton (1982) at 1:250,000.

Hughes (1972) has interpreted a pre-Laurentide (Illinoisan) glacial advance into the northern Yukon along the eastern edge of the Richardson Mountains. Subsequently, there have been at least two Laurentide (Wisconsin) advances from the east to the Bonnet Plume Basin in the central Yukon. Ice moved westward across the Peel Plain and was then deflected to the north and south along the eastern edge of the Richardson Mountains. Regional drainage was blocked by the Laurentide ice sheet and collected in the Bonnet Plume Basin with an outlet through the Palmer Lake channel. Overflow from the Bonnet Plume Basin drained into the Old Crow, Bell and Bluefish Basins. Pleistocene sediments exposed in these basins include non-glacial sediments sandwiched between two glaciolacustrine units, the latter with beach ridges. The two lacustrine units were originally thought to represent two Laurentide glacial advances (Hughes 1972). The lower lacustrine unit was later interpreted to be of Pliocene age based on palaeomagnetic, stratigraphic and palyological studies that took place as part of the Yukon Refugium project (Schweger 1989). Geochronological evidence demonstrated that the deposits had reversed polarity (it is thought to have been deposited before 730,000 years ago at the Bruhnes-Matuyama boundary) and pollen of extinct forms of *Larix minuta* and *Picea spp.* were discovered within the deposits (Matthews et al. 1987, Schweger 1989). The Pliocene lacustrine sediments may have represented three separate lake filling events of tectonic origin (Schweger 1989).

Extensive work on continental and valley glacial limits in the north and central Yukon has taken place, since original mapping of glacial deposits, by Duk-Rodkin and Hughes (1991) and Lemmen et al. (1994). Only minor valley glaciers inhabited the Richardson and British Mountains during the late Wisconsin (Hughes 1972). A Geological Survey of Canada Map of glacial limits of the Yukon is presently in press by Duk-Rodkin (n. d.).

Quaternary geological work is presently being carried out by B. Lauriol on beach ridges and thaw lakes in the Old Crow Basin (Lauriol, B., Department of Geography, University of Ottawa, pers. comm. 1997). Extensive studies on the relationship between periglacial processes and karsting in bedrock limestones around Old Crow and Bluefish Basins has been completed (Cinq-Mars and Lauriol 1985, Lauriol et al. 1997a, Lauriol et al. 1997b, Roberge et al. 1986). Lauriol (1988) has also studied cryoplanation terraces in the mountains around the Old Crow Basin and associated periglacial processes such as gelifluction and frost shattering.

Archaeology

The Porcupine River Basin may contain archaeological evidence of human occupation for the last 25,000 years. A summary of the cultural sequence from late glacial to modern times of the interior northwest of Canada is given by Wright (1995). Summaries of the archaeological sites and culture history for the Porcupine Basin/Old Crow Flats area are by R. E. Morlan and J. Cinq-Mars (1982), W. N. Irving and J. Cinq-Mars (1974) and Greer and Le Blanc (1983).

The earliest evidence of people living in eastern Beringia (40,000-25,000 B.P.) is greatly debated. Evidence consists of modified bone found in redeposited context along point bars of the Old Crow River. The bone is thought to be culturally modified because of green bone flake fractures and cut marks (Morlan and Cinq-Mars 1982). Both the lack of reliable primary context and possibility of natural mechanisms of bone fracture have been used to argue against people being in the region at such an early date. The lack of sites and paucity of reliable data prevents this evidence from being assigned to a cultural tradition (Morlan and Cinq-Mars 1982).

The Palaeo-arctic culture is more widely accepted as representing the first people living in the northern Yukon (Dumond 1977). The culture consists of sites dated 8,000-12,000 years B.P., and possibly older, found from Alaska into eastern Yukon. The Palaeo-arctic culture combines two broadly contemporaneous traditions with different artifact technologies. The presence or absence of a microblade component is the differentiating factor between the traditions (Wright 1995).

Artifact assemblages that include microblade cores, microblades, burins and bifacial tools are often assigned to the Denali complex (Wright 1995). This technology has been traced back to cultures in Siberia. Sites in Alaska such as Dry Creek, Healy Lake and the Putu site put dates of the Northwestern Palaeo-Arctic tradition back as far as 11,500 B.P. The Bluefish Caves site in Bluefish Basin has dates for microblade industries of at least 13,500 B.P. and artifacts at lower stratigraphic levels dating to 25,000 years ago. The Dog Creek site also revealed microblades, microcores, burins and fluted material suggesting a late Pleistocene to early Holocene age (Greer and Le Blanc 1992).

Sites dating to this same period, or slightly earlier, but lacking microblades have been called part of the northern Cordilleran tradition (Clark 1983). This tradition is characterized by leaf-shaped points, blades (not microblades), burinated flakes and fluted points. It has been hypothesized that this tradition is ancestral to Palaeo-Indian fluted point technology further south. The northern Cordilleran tradition ends by about 10,000 B.P. (Clark 1983).

The middle Holocene (8,000-4,000 B.P.) cultural traditions are not well understood in the northern Yukon and Alaska due to the lack of sites dated to this time period. There is some evidence, however, of the spread of microblade technology south from Alaska (Wright 1995). Wright (1995) suggests the name Early Northwest Interior culture for sites existing during this period. Clark (1983) calls the sites lacking microblades at this time part of the late northern Cordilleran tradition. Fluted points are also lacking during this period but similar looking lanceolate points lacking fluting may be related to earlier styles (Clark 1983).

Archaeological survey and excavation in the northern Yukon has revealed sites such as Bluefish Caves, Dog Creek, Engigstciak, Ahtrai and Kikavichik Ridge that contain artifacts typologically dating to the late Pleistocene and early Holocene (Cinq-Mars et al. 1991, Morlan and Cinq-Mars 1982). Systematic archaeological research in the Old Crow Basin area began taking place on a large scale from 1965-1975 with W. N. Irving, J. P. Cook, R. E. Morlan and J. Cinq-Mars who surveyed portions of the Porcupine River (Irving 1984). This research led to the development of the Northern Yukon Research Program interdisciplinary project, which concentrated on documenting the archaeology, geology and palaeoecology of the Old Crow and Bluefish Basins (1975-1980) (Irving and Beebe 1984). The Dog Creek site was discovered during helicopter survey in 1975 as part of the Northern Yukon Research Program project. The site was originally test excavated and surveyed from 1976-1979. Important artifacts discovered included microblades, microblade cores and a fluted point. Further interdisciplinary research took place at the site during the summers of 1997 and 1998, directed by R. Le Blanc of the Yukon Beringian Working Group.

Palaeoenvironmental reconstruction

Palaeoenvironmental research, largely through pollen and macrofossil analysis, has been carried out in the northern Yukon and surrounding regions. Pollen records from lakes in the Yukon, Northwest Territories and Alaska (Figure 8) span the late glacial period to modern times. Results of these studies are summarized here.

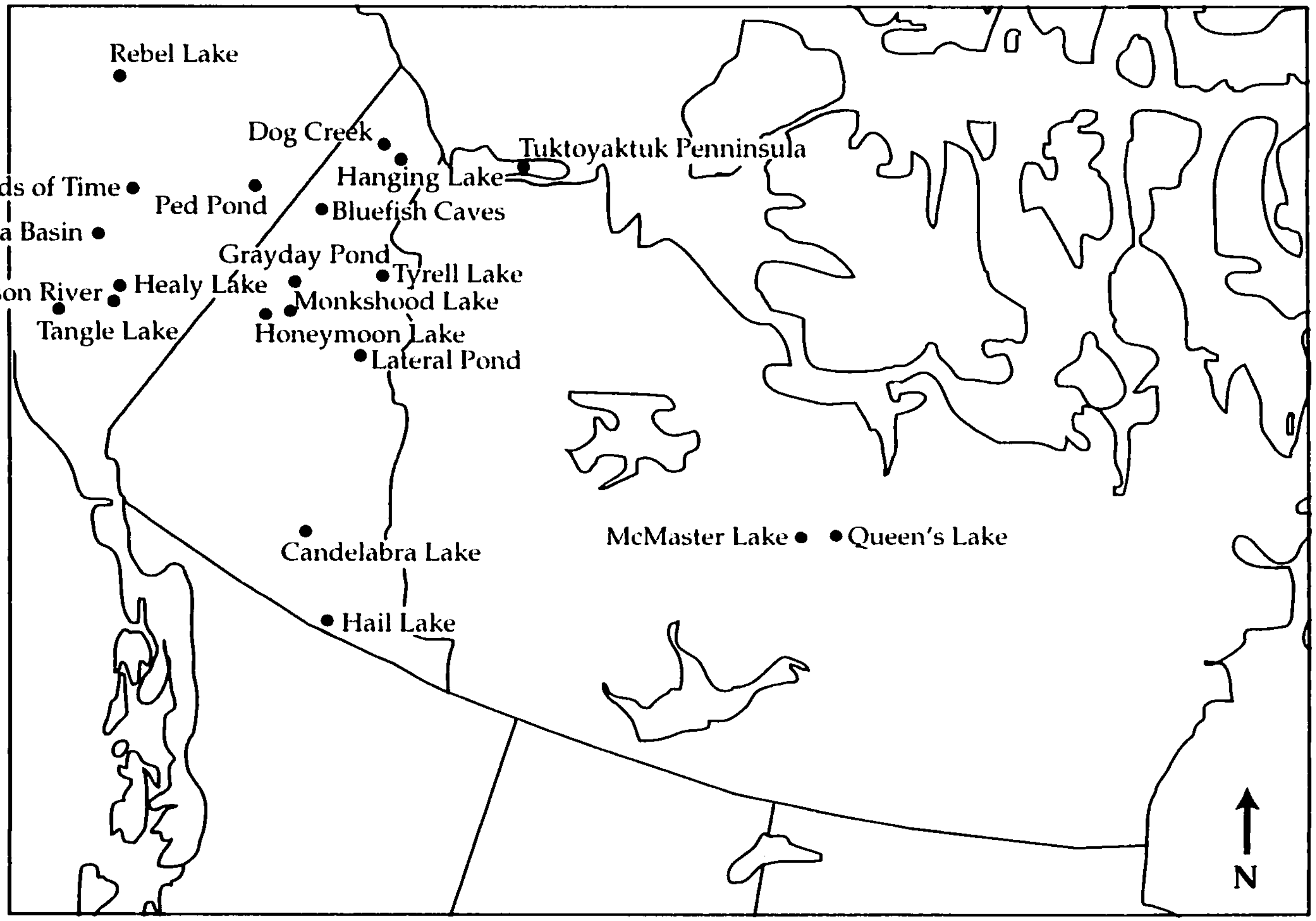


Figure 8. Sites in Alaska, the Yukon and Northwest Territories with palaeoenvironmental data.

Schweger (1982, 1997) has synthesized the late glacial palaeoecology of the northern Yukon with respect to its geographical position at the eastern edge of Beringia. Debate revolves around the nature of eastern Beringian vegetation and its capability of supporting Pleistocene megafauna. L. C. Cwynar and J. C. Ritchie advocate a tundra vegetation much like today's in the northern Yukon and Northwest Territories whereas other palaeoecologists, including C. E. Schweger, have evidence that there was sufficient grass and herb taxa to classify the landscape as a steppe environment.

According to Cwynar (1982), Cwynar and Ritchie (1980) and Ritchie (1982) there is significant evidence in the eastern most portion of Beringia for a poorly productive tundra environment. Hanging Lake, Doll Creek and Lateral Pond pollen records show that while grasses are present, influx values of Graminae and *Artemesia* are very low, close to those of present day. This evidence suggests that the vegetation represents an unproductive herb tundra rather than a nutrient rich, steppe tundra biome inhabited by Pleistocene mammals (Ritchie and Cwynar 1982).

Contrary to Cwynar and Ritchie (1980) and Ritchie and Cwynar (1982), Schweger (1997) states that it is probable that full late glacial conditions in eastern Beringia could support grazing megafauna. He suggests that influx values may not accurately represent production and that full glacial soils in the area (Rego Brown soils) were much more productive than present day Cryosols. Climate models also suggest that eastern Beringia may have been dryer than western Beringia which could account for low influxes at Hanging Lake and Lateral Pond (Schweger 1997).

Sites in Alaska dating to the late glacial period also suggest a low pollen influx at this time, but only as low as influx from Holocene grasslands in Manitoba (Lamb and Edwards 1988). Pollen cores from Isabella Basin (Matthews 1974) and Kaiyak Lake (Anderson 1982, Lamb and Anderson 1988) in east-central Alaska portray a dominance in grass and herb vegetation. Matthews (1974) supports a steppe vegetation in the area sustained by reworking of nutrient rich loess deposits.

Near the end of deglaciation (14,000-11,000 B.P.) there is a marked increase in shrub birch shown in the pollen influx records at lake sites in the northern Yukon and Alaska (Anderson and Brubaker 1993, Cwynar 1982, Edwards and Brubaker 1986, Edwards et al. 1984, Ritchie 1982, 1984, 1986, Ritchie and Hare 1971). Cwynar (1982) reconstructs vegetation at this time as changing from a herb tundra to a closed birch-shrub tundra with an increased plant diversity. Cwynar interprets that the climate at the end of the Pleistocene had warmer summers with more precipitation than today. Increased moisture rather than temperature may have caused the change to shrub tundra. Ritchie (1982) suggests the evidence at Doll Creek supports a slow warming trend initiating the development of a heath birch tundra. This is corroborated at Sands of Time and Rebel Lakes in Alaska which show a dominance in birch in late Pleistocene pollen records (Edwards et al. 1985). Sites including Ped Pond show warming evidence at this time with increases in *Populus*, *Juniperus* and *Typha* in the records.

There is substantial evidence in the Yukon for the advance of the treeline and general increase in arboreal taxa frequencies during the early Holocene. Evidence from Grayday Pond, Honeymoon Lake, Monkshood Pond and Bluefish Caves clearly demonstrates that spruce and poplar trees were present far north of their present day locations during the early Holocene (Cinq-Mars 1979, Cwynar and Spear 1991). Burn (1997) suggests that the treeline was at least 100 km north of its present position along the Tuktoyaktuk coast land as early as 10,000-11,000 B.P. Although climatic warming is evident in Alaskan pollen records, the spruce treeline did not advance into the region until much later (Lamb and Edwards 1988).

Early Holocene vegetation has been interpreted as transitional forest tundra zone comparable to the modern forest tundra. From 8,500 to 6,000 B.P. most areas show a closed spruce forest similar to modern boreal forest vegetation (Ritchie and Hare 1971). Alaskan sites including Ped Pond, Tangle Lake, Rebel Lake and Isabella basin all contain boreal vegetation by the end of this time period (Anderson and Brubaker 1993, Edwards and Brubaker 1986, Edwards et al. 1985, Matthews 1974). This, as well as the treeline being present along the arctic coast, is clear evidence of an early Holocene warming period

(Burn 1997). Indicator taxa of warmer environments such as *Typha* and *Populus* are also present at these sites (Cwynar 1982). Ritchie and Hare (1971) suggest that summer temperatures were 5°C higher than at present and that the growing season was increased by 30 days. This period in the northern Yukon coincides with Milankovitch predictions of maximum summer solar radiation (Ritchie 1984, Ritchie et al. 1983).

During the mid Holocene, subarctic Canadian and Alaskan pollen records show a decrease in arboreal taxa and a gradual transition to modern conditions (Anderson and Brubaker 1993). In general, through the mid Holocene, alder and black spruce percentages rise replacing white spruce and birch (Ritchie and Hare 1971). The disappearance of spruce forest in the northern subarctic and replacement by shrub tundra demonstrates a cooling episode during the mid Holocene (Cwynar and Spear 1991). This temperature decrease coincides with climate simulations for the mid Holocene. Climate models suggest a decrease in solar radiation in the summer months and an increase during the winter which would cause general cooling conditions (COHMAP Members 1988). January and July temperatures were greater in the mid Holocene than at present, but had decreased from the early Holocene (Bartlein et al. 1998, Kutzbach et al. 1993b, Kutzbach et al. 1998). By 4,500 years ago, a modern vegetation biota existed at Healy Lake and Johnson River in eastern Alaska (Anderson 1975) and by about 3,000 B.P., modern vegetation conditions were established in northern Yukon.

Methodology

1. Field Methods

Excavation

Archaeological excavation methods (Fladmark 1978) were used for collecting artifacts, collecting samples and exposing sedimentary profiles. Excavation took place using hand trowels to uncover arbitrary and natural stratigraphic levels. During the 1997 field season, 10 cm arbitrary levels were excavated. Excavation by stratigraphic units took place during the summer of 1998. Each excavation unit was 1 m^2 in size. Units were tied in to a grid constructed over a 1978 grid system on the Mid-ridge. Grid north was 30° west of magnetic north.

Artifacts were recorded using three point provenience: depth below an arbitrary datum, northing (measuring in cm towards the north) and easting (measuring in cm towards the east). Trend and plunge (see fabric below) was also taken from all elongate artifacts. Screening of back dirt for artifacts out of provenience took place during the 1997 field season using a 0.5 cm mesh.

Fabric analysis

Fabric analysis measures the three dimensional orientation of elongated clasts in space. Trend is measured in degrees between 0° and 360° in horizontal space. Plunge, the degree of displacement from horizontal (0°-90°) was measured with the clinometer on a Brunton compass. Trend is measured in the direction of plunge. Elongate clasts with a 2:1 ratio of principal axes are most useful for recording fabric. Artifacts, such as projectile points and flakes, are ideal for fabric analysis because this ratio almost always exists. Measurements on rocks and artifacts were taken in situ (Appendix V). Fabric measurements from each stratigraphic unit were plotted on equal area (Schmitt) nets using the graphics program Stereonet 4.5.1 by Allmendinger (1988-1992). The stereonets show trend along the circumference of the circle from 0-360° and plunge from the outside of the circle to the center from 0-90°.

Fabric analysis is frequently used in Quaternary studies to determine till genesis and flow direction of glaciers (Haldorsen and Shaw 1982, Domack and Lawson 1985). The method has also been used in archaeological studies measuring movement of artifacts in modern solifluction lobes by Texier et al. (1998) and in periglacial environments by Bennedict (1970). Fabric analysis is being used here to determine if movement of sediment has occurred which would cause alignment of clasts and artifacts.

Sampling

Bulk sediment samples were taken from stratigraphic profiles at the Dog Creek site and on transects of the area. Bulk sediment samples were used for grain size and loss on ignition analysis (Appendix I). These samples were also taken for the extraction of pollen for vegetation reconstruction and organic matter for radiocarbon dating. Bulk samples were collected in four litre plastic bags from each sedimentary layer of every excavation unit. Moss pollsters were also collected on the ground surface from various areas around the site for analysis of modern pollen rain.

Description of profiles

Profiles of excavation units were described in detail, drawn and photographed with 35 mm color slide film and 35 mm black and white film. Descriptions of each stratigraphic unit were based on a method described by Rutter (1997). These included unit thickness, cohesiveness, color, contacts, texture, coarse clast lithology, carbonate content, primary sedimentary structures, secondary sedimentary structures and organic content (Appendix IV).

The ability of the beds to remain vertical without support and their resistance reflects the cohesiveness, or resistance to deformation, of a sediment. Cohesiveness was recorded on a scale of 1-5, defined as: 1-uncohesive, 2- slightly cohesive, 3-cohesive, 4-extremely cohesive and 5- rock like cohesiveness. Color was described using the Munsell Color Chart System and included hue, value, chroma, moisture state and whether a fresh or weathered surface was being described. Only freshly exposed surfaces were described in the excavation profiles. The descriptions corresponding to the Munsell number system (e. g., light yellowish brown) were also recorded.

Upper and lower contacts were described using terms such as sharp, gradational, wavy and truncated. Texture was approximated in the field and included the percentage of clasts greater than 4 mm as well as the grain size of the matrix (e. g. silt, sand, silty clay). The lithology of coarse clasts (>4 mm) was visually identified at the site. The type of reaction (strong vs. weak) to 10% HCl was noted to estimate the presence of carbonate minerals in the matrix. Primary sedimentary structures were lacking in the sedimentary units but several secondary structures such as frost cracks and bioturbated surfaces were evident and described. Soil development was described using criteria from the Canadian System of Soil Classification (1987). Presence of organic material was estimated by the color and texture of the matrix.

Mapping

Quaternary deposits and landforms were mapped by interpreting airphotos A22880-5 and A22880-6, identifying features from a helicopter, digging pits and walking transects.

2. Lab Methods

Pretreatment of samples and grain size analysis

All sediments were pretreated before grain size analysis was performed. This method was prepared by E. T. Little (Little, E. T., Department of Earth and Atmospheric Sciences, University of Alberta, pers. comm. 1998) after Barrett and Brooker (1989), Lu and An (1998) and Sheldrick and Wang (1993).

1. Sediments were sieved through a 2 mm mesh to remove all clasts and large aggregated particles.

2. About 50 g of each sediment sample was measured in a 250 ml beaker, dried over night at 65°C and re-weighed. The dry sediment weighed between 45 g - 50 g. Distilled or de-ionized water was added to samples to submerge the sediment.

3. To remove calcite, 25 ml of 10% HCl (hydrochloric acid) was added to the submerged sediments. Samples were heated under 250 W heat lamps. HCl was added in 5 ml increments to the sample until reaction to HCl ceased (Barrett and Brooker 1989). Samples were transferred into 250 ml bottles, centrifuged and rinsed three times with distilled water. Centrifuging took place in a large capacity IEC Centra CL3 centrifuge, with a rotation speed of 4,000 rpm, for 10 minutes.

4. Sediments were then removed from centrifuge bottles and put in 600 ml beakers. To remove organic matter, about 10 ml of 30% H_2O_2 (hydrogen peroxide) was added to the samples submerged with distilled water (Sheldrick and Wang 1993). Samples were heated under lamps and stirred occasionally. H_2O_2 was added to sample until the reaction ceased. Many of the samples were extremely organic rich and required up to 100 ml of hydrogen peroxide before all organic matter was removed. Sediments were transferred into centrifuge bottles and rinsed three times. The centrifuge was set at a speed of 4,000 rpm for 20 minutes.

5. Mechanical and sonic dispersion methods were used prior to sieving. After rinsing, sediments were submerged with distilled water in 250 ml beakers.

Samples were mechanically mixed with an electronic mixer at low speed while sitting in a sonic water bath for 5 minutes.

6. Sediments were then wet sieved through a 250 μm mesh. The portions of the samples measuring <250 μm were collected in 600 ml beakers and dried in an oven at 65°C. Sediments measuring >250 μm were collected in 50 ml beakers and dried separately. When all sediments were dry, weights were taken for the >250 μm and <250 μm fractions.

7. Six grams of the sediments measuring <250 μm were then dispersed for sedigraph analysis by soaking in 50 ml of 1% $NaPO_3$ (sodium metaphosphate) for 5 minutes and placed in a sonicator. These samples were then put into a sedigraph (SediGraph 5100 V3.01). Settings included an analysis temperature of 35.5°C, liquid properties based on a 0.05% sodium metaphosphate solution, liquid density of 0.9939 g/cm^3 and a Reynolds number of approximately 27. The Reynolds number refers to the relationship between laminar and turbulent flow in the fluid (Boggs 1995). Cumulative mass percent finer was measured at 0.5 phi intervals from 2 ø (250 μm) to 10 ø (0.98 μm). The sand-silt boundary was delimited at 4 ø (63 μm) and the silt-clay boundary was at 8 ø (3.91 μm). Graphs were produced on a log scale showing: 1) cumulative mass percent finer versus spherical diameter (μm), 2) mass population versus spherical diameter (μm) and 3) log probability of mass percent finer versus spherical diameter (μm). Cumulative mass percent finer versus spherical diameter graphs show the most useful information concerning grain size and sorting.

8. The portion of the sediment >250 μm was then dry sieved through seven screens, #120 (125 μm), #140 (105 μm), #170 (90 μm) and #230 (63 μm). The amount of sediment in each sieve was weighed to one hundredth of a gram.

Evaluation of pretreatment and grain size analysis

Pretreatment of sediments and soils is necessary for accurate grain size analysis. Organic matter and carbonates often prevent adequate dispersal of particles, which can lead to an exaggerated amount of coarse grain sizes. Removal of carbonates and organic matter provides an accurate account of grain sizes of mineral matter. Lu and An (1998) demonstrated the differences in grain size results between samples that had been pretreated by various dispersal methods. Pretreatment methods included: 1) soaking sample overnight in distilled water, 2) dispersal with sodium hexametaphosphate only, 3) removal of organic matter with hydrogen peroxide only, 4) removal of carbonates with hydrochloric acid only, 5) removal of organic matter, carbonates, dispersal with sodium hexametaphosphate and ultrasonic mechanical dispersal and 6) mechanical ultrasonic dispersal only.

Lu and An (1998) conclude that there is a wide range in grain size results using the different dispersal methods on the same sample. In general, the authors found that ultrasonic dispersal of a sample that has soaked in distilled water resulted in the smallest grain size. Genrich and Brenner (1972) also found that ultrasonic vibration for 15 minutes without any chemical additions was adequate for dispersal. Chemicals such as sodium hexametaphosphate were only useful for short intervals of sonication (<5 minutes). Nelson (1983) found sonication and electric mixing of a sample soaked in 4% calgon solution to be the most effective dispersal mechanism. The method using hydrogen peroxide to remove organics, hydrochloric acid to remove carbonates, calgon and sonic dispersal was used in this study because samples were either extremely rich in carbonates (>30%) or extremely rich in organic matter (>35%). It was necessary to remove these components to determine the grain size of the sediments.

The sedigraph method was used because of its accuracy in measuring small grain sizes (<30 µm), as most of the samples studied were dominated by silt and clay sized particles. The sedigraph uses a beam of x-rays to determine the concentration of particles in suspension as they settle through time. Coates and Hulse (1985) evaluated the sedigraph against the hydrometer, pipette and hydrophotometer methods. They found that although the sedigraph speeded up the measuring time for the <2 µm sized particles in the sample and accurately measured small grain sizes, the sedigraph method was not the most precise or most consistent. Precision between sub-samples was poor because of the small amount of sample required and because larger grain sizes (50-100 µm) were not consistently measured with the sedigraph. Precision in repetition of one sample, however, was excellent. In general, Coates and Hulse found that the hydrometer was the best method for measuring grain size but that the sedigraph worked well for samples with abundant clay sized particles. Since this was the case for the samples in this study, the sedigraph proves to be a reliable method of grain size analysis. Results are found in Appendix II.

Organic and carbonate content

Loss on ignition was used to determine the percentage of organic matter and calcium (or calcium-magnesium) carbonate in samples (Appendix III). Loss on ignition is a reliable method of calculating percentage of organic matter and carbonate that works by burning off these components.

1. One to two grams of each sample was placed in small pre-weighed ceramic crucibles. Three sub-samples of each sample were used for comparative purposes. Samples were heated at 65°C overnight to remove all water. Samples were then weighed. This dry weight was used as the basis for all calculations.
2. Twenty-four samples (at a time) were placed in a muffle furnace and heated for one hour at 550°C to burn off all organic carbon. Samples were then cooled in a glass desiccater to prevent absorption of water and weighed. The difference between this weight and the dry weight corresponds to the amount of organic carbon ignited.
3. The samples were then put back into the muffle furnace and heated for one hour at 1,000°C to burn off carbon dioxide from carbonate minerals. Samples were then cooled in a glass desiccater and weighed. The difference between this weight and the weight after the 550°C heating equals the amount of carbon dioxide driven off.

This method was based on Dean (1974) who evaluated its precision and accuracy against several other methods. Dean found loss on ignition to be both accurate and precise for measuring organic carbon which begins to ignite at 200°C and is completely ignited by the time the muffle furnace temperatures reach 550°C. The loss on ignition method was tested for precision in this study using 25 sub-samples of an organic rich sediment. Figure 9 shows the percent organic carbon and percent carbonate matter in each of the 25 sub-samples of Sample 40. Sub-sample 40-10 was disregarded because it had an anomalously high percentage of carbonate material. It is likely that there was a limestone pebble left in the matrix. The amount of organic carbon in the matrix of each

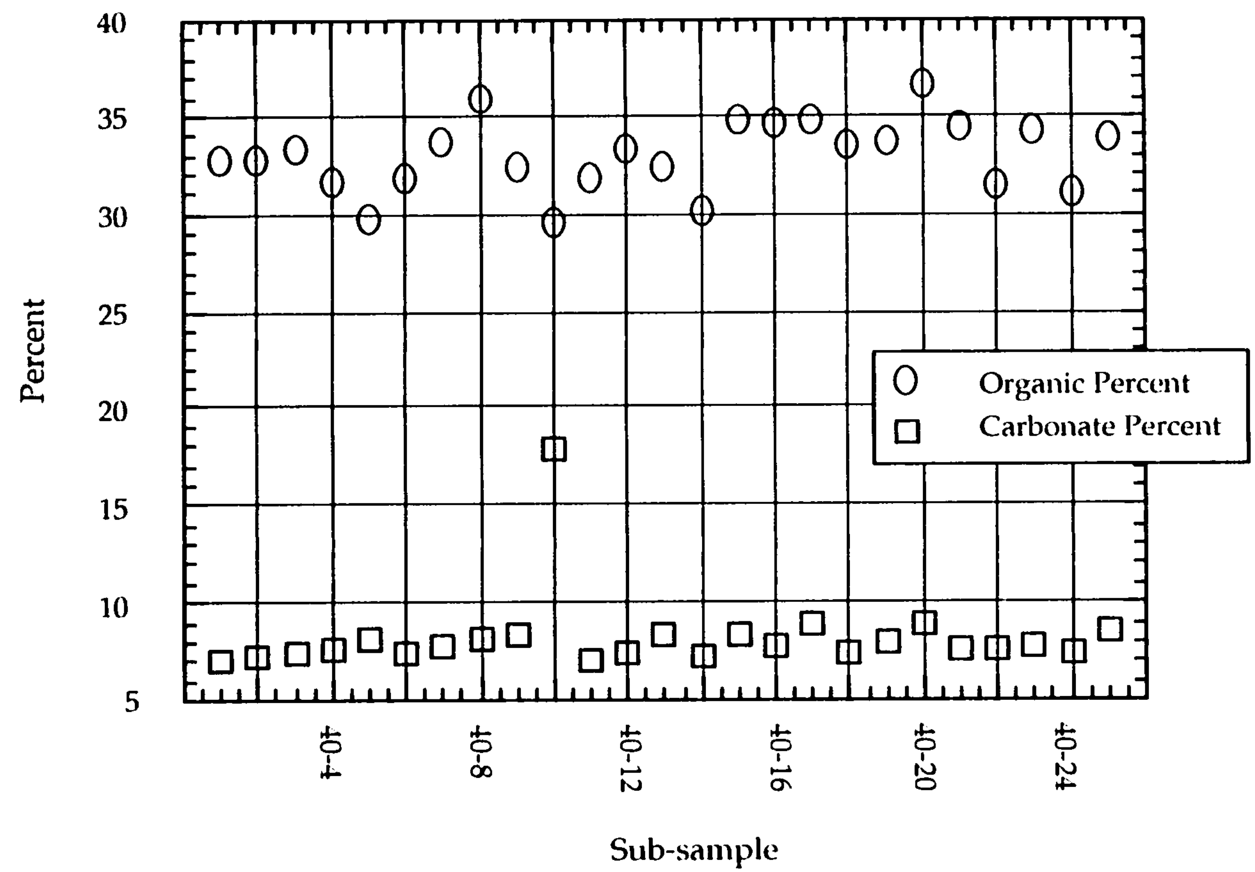


Figure 9. LOI precision test. Twenty-five sub-samples of sample 40 were measured for the percent of of organic carbon and the percent of carbonate in the matrix.

sub-sample varied from 29.69% to 36.71% with an average of 33.15% and a standard deviation of 1.83%. There was a 7.02% variation in amount of organic carbon. This demonstrates that the precision from loss on ignition pertaining to the amount of organic matter in the sub-samples is not very high.

Dean (1974) found that carbonates begin to evolve CO_2 at about 700°C and that most of the CO_2 is removed by the time the furnace reaches 850°C. Dolomites evolve carbon dioxide at lower temperatures (700°-750°C) than calcite (800°-850°C). Loss on ignition does not differentiate between dolomite and calcite. It was assumed that most of the carbonate present in these samples is derived from the underlying limestone bedrock and is therefore dominantly calcite. Dean's precision in 25 samples was 3.07%. Carbonate precision was found to be very good in the present study. The range of carbonate was from 7.005%-8.941% with an average of 7.675% and standard deviation of 0.537%. The range of values was only 1.936%. This helps to demonstrate that the loss on ignition method is reliable and useful for measuring $CaCO_3$ content.

The amount of weight loss from the second ignition (550°-1,000°C) does not directly reflect the amount of carbonate in the sediment. It represents the amount of CO_2 evolved. The fraction of CO_2 in carbonate is 44%. To calculate carbonate percent, the value must be divided by 0.44. Although the precision in carbonate loss on ignition is good, accuracy can be affected by lattice water found in clays. Lattice water can begin to evolve at high temperatures from 550°-1,000°C. Samples that are high in clay often show a 3-4% loss on ignition reflecting a loss of lattice water rather than carbon dioxide from carbonates (Dean 1974).

Pollen processing

Two types of samples, sediment samples and moss pollsters, were processed for their pollen. Pollen processing methods were based on those from the University of Alberta, Department of Anthropology pollen laboratory. Results are found in Appendix VI.

Processing sediment samples:

1. Approximately 10 g of sediment was measured into a glass 250 ml beaker. To remove excess organic matter, 10% NaOH (sodium hydroxide) was added to the

sample and boiled for 5 minutes. The sample was then put in centrifuge tubes, centrifuged and the excess liquid was decanted. This step was repeated until the decant liquid was yellow colored or a maximum of 5 times. Excessive wash with NaOH eventually harms pollen grains.

2. Samples were then rinsed and washed through a fine screen. The screened material was concentrated by centrifuging and decanting excess liquid.

3. Two lycopodium tablets were then added to each sample (batch number 710961). Hydrochloric acid (10%) was added to dissolve carbonates in the sample and in the lycopodium tablets. The samples were then centrifuged to decant HCl and rinsed.

4. For heavy liquid separation of minerals in the sample, clean zinc bromide ($ZnBr_2$) was poured into a 100 ml graduated cylinder. The density of the liquid was measured with a hydrometer. If the reading was greater than 2, water was added. If the reading was less than 2, water was boiled off to increase density. Zinc bromide was added to the centrifuge tubes containing the samples in an amount 1.5 times greater than the sediment. Tubes were capped and shaken for 1 minute to evenly distribute the liquid. Tubes were then centrifuged for 20 minutes. The decanted liquid was poured over glass filter paper under a vacuum to separate pollen and the remaining sample from zinc bromide liquid. Glass filter papers with the remaining samples were placed in plastic centrifuge tubes.

5. Hydroflouric acid (48% HF) was added to the plastic centrifuge tubes to dissolve silica in the samples and the glass filter papers. The tubes were boiled in a hot water bath for one hour. Samples were then centrifuged, decanted and rinsed twice.

6. Samples were then put into small glass centrifuge tubes. Ten millilitres of HCl was added to each tube and boiled. This step removes white precipitate of colloids that remain in samples from the HF step. Immediately upon boiling, samples were removed from heat, centrifuged and decanted. This step was repeated until colloids no longer clouded the sample. Samples were then rinsed.

7. The next step, acetolysis, removed the remaining organic matter and stains and cleans pollen for counting. Because the acetolysis mixture reacts violently with water, samples were first dehydrated by rinsing with glacial acetic acid. The

acetolysis solution (1 part concentrated H_2SO_4 to 9 parts acetic anhydride) was added to samples in centrifuge tubes. These samples were heated in a hot water bath to boiling. Samples were then centrifuged and decanted. This step was repeated if abundant organic matter remained in the sample. The sample was then rinsed with glacial acetic acid and then with water.

8. Ethanol was added to cover the sample. The sample was mixed, centrifuged and decanted. Tertiary butyl alcohol (TBA) was added to the sample, mixed, centrifuged and decanted.
9. A small amount of TBA was then added to cover the sample and the sample was poured into a 2.5 ml vial.
10. Silicone fluid was added to vials so that the pollen would not dehydrate before analysis could be done.

Processing moss pollsters:

The process for processing pollen from moss pollsters was similar with the following changes:

1. Moss pollsters were washed with water. The residue from the pollsters was washed into a 250 ml beaker. Pollen and other residual material from wash water was concentrated by centrifuging and decanting water.
2. 10% NaOH was then added to centrifuge tubes containing the sample. Tubes were boiled for 5 minutes. The sample was then centrifuged and the NaOH decanted. This step was repeated once. Samples were then rinsed with distilled water.
3. Same as step 3 in sediment sample process.

As there were few mineral grains in the pollen pollster, steps involving heavy liquid, hydroflouric acid and hydrochloric acid were eliminated.

4. Acetolysis procedure (See step 7 above).
5. See step 8 above.
6. See step 9 above.
7. See step 10 above.

Pollen analysis

Both modern pollen and ancient pollen samples were examined from the Dog Creek site. Modern pollen from moss pollsters and oxbow lake sediments was counted to establish the modern pollen rain. Older pollen was extracted from the buried soils on the Mid-ridge and counted to reconstruct ancient vegetation.

At least 200 pollen grains were counted and identified from each processed sample (Appendix VI). Grains were identified to genus or family using the Key to Pollen and Spores in Alberta by T. Habgood (1985) and Pollen Analysis by Moore et al. (1991). Pollen was counted using a Leitz light microscope at X400 magnification (10x ocular and 40x objective lens). Transverses across the microscope stage were taken from left to right. Paths were recorded so that counting would be systematic and non repetitive.

A pollen percent diagram was constructed for samples from the Mid-ridge using the Microsoft Excell spreadsheet program. The calculated pollen sum contains trees, shrubs and herbs. Bryophyte spores are given in percent, unconstrained by the pollen sum. The total pollen sum includes trees, shrubs, herbs and all bryophyte spores (including sphagnum).

Radiocarbon dating

Radiocarbon analysis was done by the IsoTrace Radiocarbon Laboratory at the University of Toronto. The results were extracted using accelerator mass spectrometry. Results were based on the average of two normal precision analyses and corrected for fractionation (natural and sputtering) using a base of $\partial^{13}C=-25‰$. The Libby ^{14}C meanlife was 8,033 years. Analysis was performed on bone, charcoal and wood fragments. Collagen was extracted from bone for ^{14}C analysis. Results were given as uncalibrated radiocarbon dates in years before present and calibrated using standard set INTCAL98 from Stuiver et al. (Radiocarbon 40#3, 1998, p. 1041) (Beukens, R. P., Isotrace Laboratory, University of Toronto, pers. comm. 1999). All dates used in this thesis are given in uncalibrated radiocarbon years before present.

CHAPTER 2 Surficial Geology of the Black Fox Creek Area

Introduction

The surficial geology of the Black Fox Creek study area (Figure 1, 2) has previously been mapped by Hughes (1972) at 1:500,000. Sediments and features were separated into three categories: Qf (Quaternary fluvial), Ql (Quaternary lake) and B (bedrock) (Figure 10). In this report, the study area is mapped at greater detail (1:50,000) to provide a regional context for the deposits and landforms found at the Dog Creek archaeological site.

The classification of landforms and surficial materials for this study is based on terminology used by Terrain Classification System for British Columbia (Howes and Kenk 1988). Surficial sediments are broken down by genesis and by morphology. Jackson (1994) has compiled a complete list of types of Quaternary deposits; only categories that are relevant to the study area will be discussed here. Descriptions of each category are based on Jackson (1994) and field observations. Categories of periglacial features were derived from Brown and Kupsch (1974) and Washburn (1980).

Plate 1 is a stereo pair of photos A22880-5 and A22880-6 delineating the study area and Dog Creek archaeological site. Two maps of the study area are presented, one showing the surficial deposits and landforms (Plate 4) and the other showing periglacial features in the area (Plate 9). A map of the surficial materials at the Dog Creek archaeological site is also given (Figure 12).

Surficial Maps of the Black Fox Creek Study Area

Map of surficial morphology and deposits (Plate 4)

The map units used in the Black Fox Creek study area are based on genesis, sedimentology and surficial morphology of deposits.

R- *Bedrock* This refers to areas with limestone bedrock completely exposed at the surface. The bedrock is largely Mesozoic and Paleozoic in age (Morrell 1993). The areas labeled bedrock are ridges unprotected by vegetation on the west side of Black Fox Creek. Completely exposed areas are only found on a scale of a few metres in the study area, but are extensive in the Barn Range to

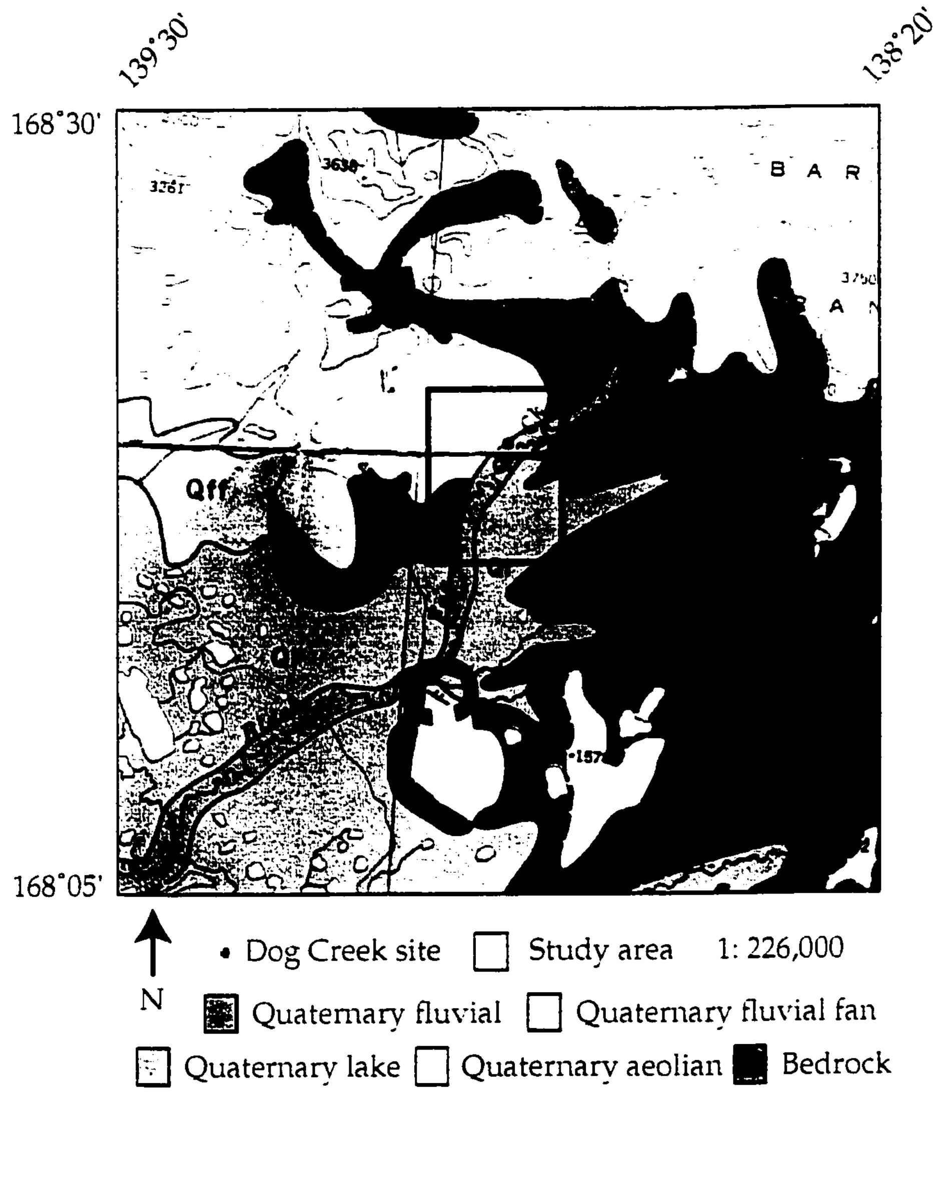


Figure 10. Map of surficial deposits along Black Fox Creek (Hughes 1972).

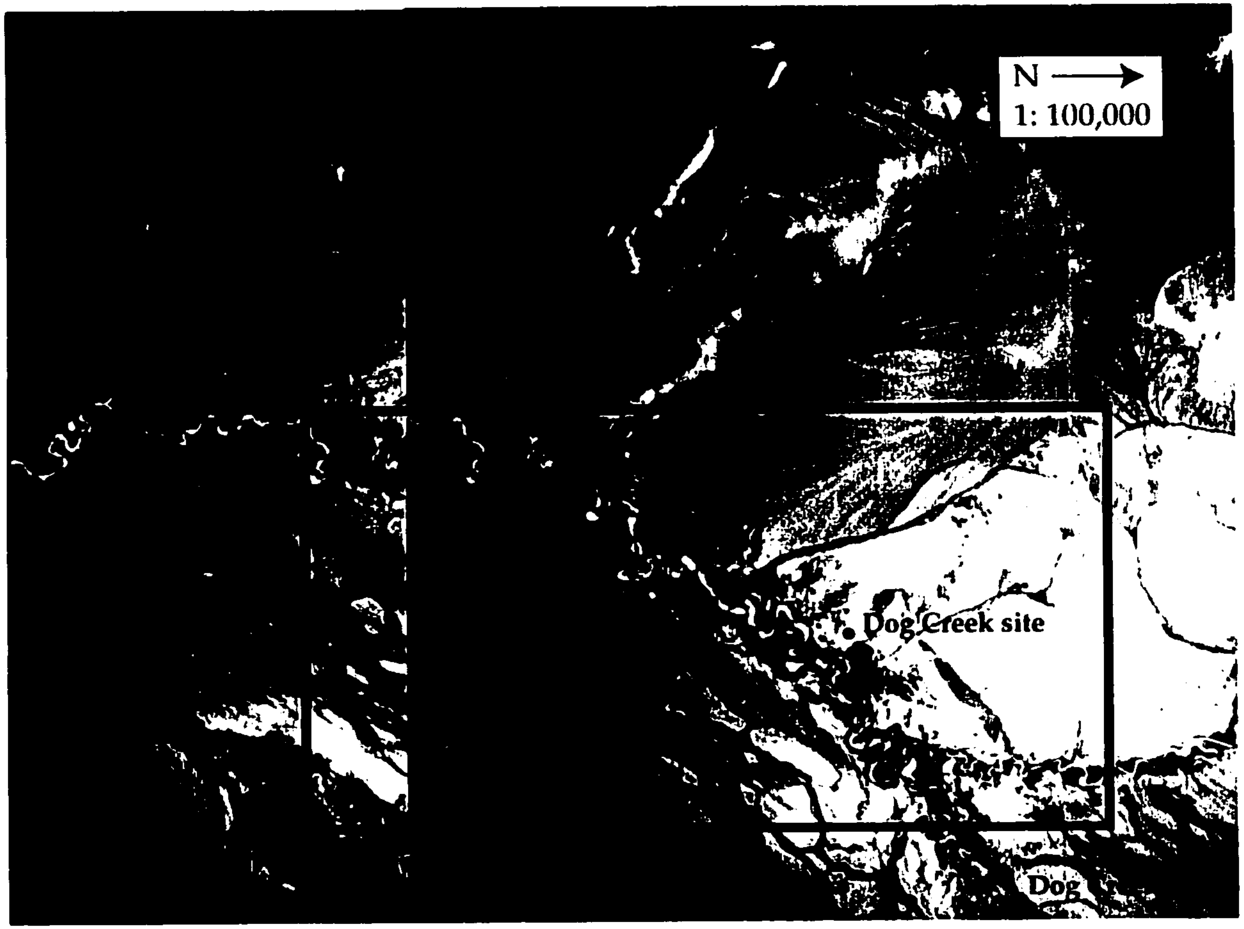


Plate 1. Air photos A22880-5 and A22880-6 showing the Black Fox Creek study area (box) and Dog Creek archaeological site.

the north. Aeolian erosion of these high areas prevents stabilization by soils and vegetation. Freeze-thaw cycles result in the fracturing and shattering of bedrock exposed at the surface. Water filling fractures in bedrock expands upon freezing causing further mechanical breakdown of the rock. Frost cracked and shattered bedrock is found in all areas where bedrock is exposed at the ground surface.

L- *Glaciolacustrine deposits* Sediments classified as glaciolacustrine are composed of silts and clays deposited in lakes fed by glacial meltwater. They occur in the study area as plains (flat lying surfaces with low relief composed of thick uniform sediments that mask underlying topography) and veneers (<1 m thick discontinuous sediment cover that fills topographic lows).

Glaciolucustrine plain (Lp) Glaciolacustrine plain sediments were identified by airphoto and helicopter survey. These deposits are found in the basin on the east side of Black Fox Creek. Although the sedimentology of these deposits was not identified, they have been labeled glaciolacustrine based on similar surface expression and lateral continuity with the Old Crow Basin glaciolacustrine plain south of the study area. The presence of peat vegetation, ice-wedge polygonal ground and thermokarst lakes are used to identify glaciolacustrine deposits.

Glaciolacustrine veneer (Lv) A glaciolacustrine veneer covers low lying bedrock on the west side of Black Fox Creek. It is recognizable where free from alluvial cover. The swale between ridges at the Dog Creek archaeological site contains accessible glaciolacustrine veneer deposits. The sediment was interpreted to be glaciolacustrine because it is a moderately sorted clay (9.6% sand, 32.4% silt and 58% clay), is black in color (10YR 1/1, moist), contains about 6.5% organic matter and 14.1% calcium carbonate and is sterile of pollen and plant macrofossils (Appendix II, III, VI).

The glaciolacustrine sediments in the map areas were formed by glacial meltwater and regional drainage which was blocked to the east by Laurentide ice (Duk-Rodkin 1999, Hughes et al. 1993). The deposits comprise the northern most arm of glacial lake Old Crow which extended up the Black Fox Creek valley during the late Pleistocene (Hughes 1972). Although the veneer of deposits in the swale at the Dog Creek site are clearly glaciolacustrine, there is insufficient evidence to suggest whether these sediments relate to proglacial lake Old Crow during the final stage of McConnell glaciation or a Pliocene structurally controlled lake (Matthews et al. 1987, Schweger 1989).

AE- *Aeolian deposits* Aeolian deposits in the area are characterized by blankets (continuous layers of sediment thicker than 1 m that are thin enough to reflect the underlying topography) and veneers of fine sand and silt over bedrock or other deposits. They are often found in low or protected areas adjacent to sediment sources including the Black Fox Creek floodplain and the Old Crow lake basin. Assuming local sources for much of the aeolian sediment in the study area, most of the deposition is Holocene in age.

Aeolian blanket (AEb) Aeolian sediments blanket ridge tops on the west side of Black Fox Creek. The deposits are interpreted to be of aeolian origin because they are very well sorted silt loams with an average 10% sand, 65% silt and 25% clay (Appendix II). The deposits generally have a color of dark greyish brown (10YR 3/2, moist), an average of 22% organic matter and 6% calcium carbonate. Deposits are massive with secondary granular structures due to soil formation. Sediments are thick (>1 m) in lows on the bedrock ridges and on gentle slopes at altitudes greater than 400 m.

Aeolian veneer (AEv) Thinner patches of aeolian sediments (20-40 cm thick) are found on the edges of the bedrock ridges where there is a slope greater than 10% or in areas with significant exposure to wind erosion. A thin layer of silt is most common in the 350-400 m altitude range immediately adjacent to the western margin of Black Fox Creek. The grain size of the sediments in the veneer is the same as in the aeolian blanket although frost heave of the underlying fractured bedrock has caused clasts to be mixed with the silt loam (<4% angular limestone clasts, pebble to small cobble size).

A- *Alluvial deposits* Alluvial deposits in the study area are characterized by coarse gravels, sands and silts deposited in the Black Fox Creek valley system in channel lags, point bars and floodplains.

Alluvial plain (Ap) Alluvial plain (or floodplain) deposits extend up both sides of the Black Fox Creek valley. There is a lateral change from coarse sands proximal to the creek bed, to finer sands, silts and clays further away. Over bank deposits are well sorted silty clay loams with 3% sand, 67% silt and 32% clay sized grains. These sediments contain 14% organic carbon and 2% $CaCO_3$. There is considerable vegetation growth on the floodplains of Black Fox Creek including spruce, willow, birch, and alder (Plate 2). Mosses and sedges grow on saturated point bars.

Alluvial terrace sediments (At) Because Black Fox Creek has not been actively down cutting, there is only one low terrace, just 50 cm above the present floodplain. It is recognizable on the airphotos because of its old ox-bow lakes and thick moss vegetation. Drainage is extremely poor on the floodplain and thermokarsting is evident.

Alluvial sediments, undivided (Au) Undivided alluvial sediments (those landforms of similar origin that can not be differentiated at the scale of mapping) include the cobble lag in the channel bottom and gravel and sand beaches on the edge of point bars. During the late summer when there is little drainage from the British Mountains, parts of the creek are dry where the river flows below surface. River sands are reworked by aeolian erosion and deposition into dunes along the sides of the creek bed (Plate 3).

C- *Colluvium* Colluvium in the study area consists of frost shattered limestone bedrock and some unconsolidated sediment that has moved downslope by gravity. Colluvial debris forms aprons (landforms incline at 10-35° angles) at the base of slopes.

Colluvial apron (Ca) Poorly sorted, clast supported diamictons, interpreted as colluvial deposits, are found as aprons at the base of bedrock ridge cliffs along the central part of the study area. The clasts consist of angular, fractured, limestone bedrock. Slopes of these aprons are generally close to the angle of repose, 20-30°. Thickness of deposits ranges from 10 cm at the top of the ridge to >2 m at the base.

O- *Organic deposits* Organic deposits along Black Fox Creek consist of mats of vegetation with little mineral sediment found on poorly drained floodplain

Plate 2. Black Fox Creek, floodplain and arboreal vegetation.

Plate 3. Stratified sand dunes in dry Black Fox Creek bed.

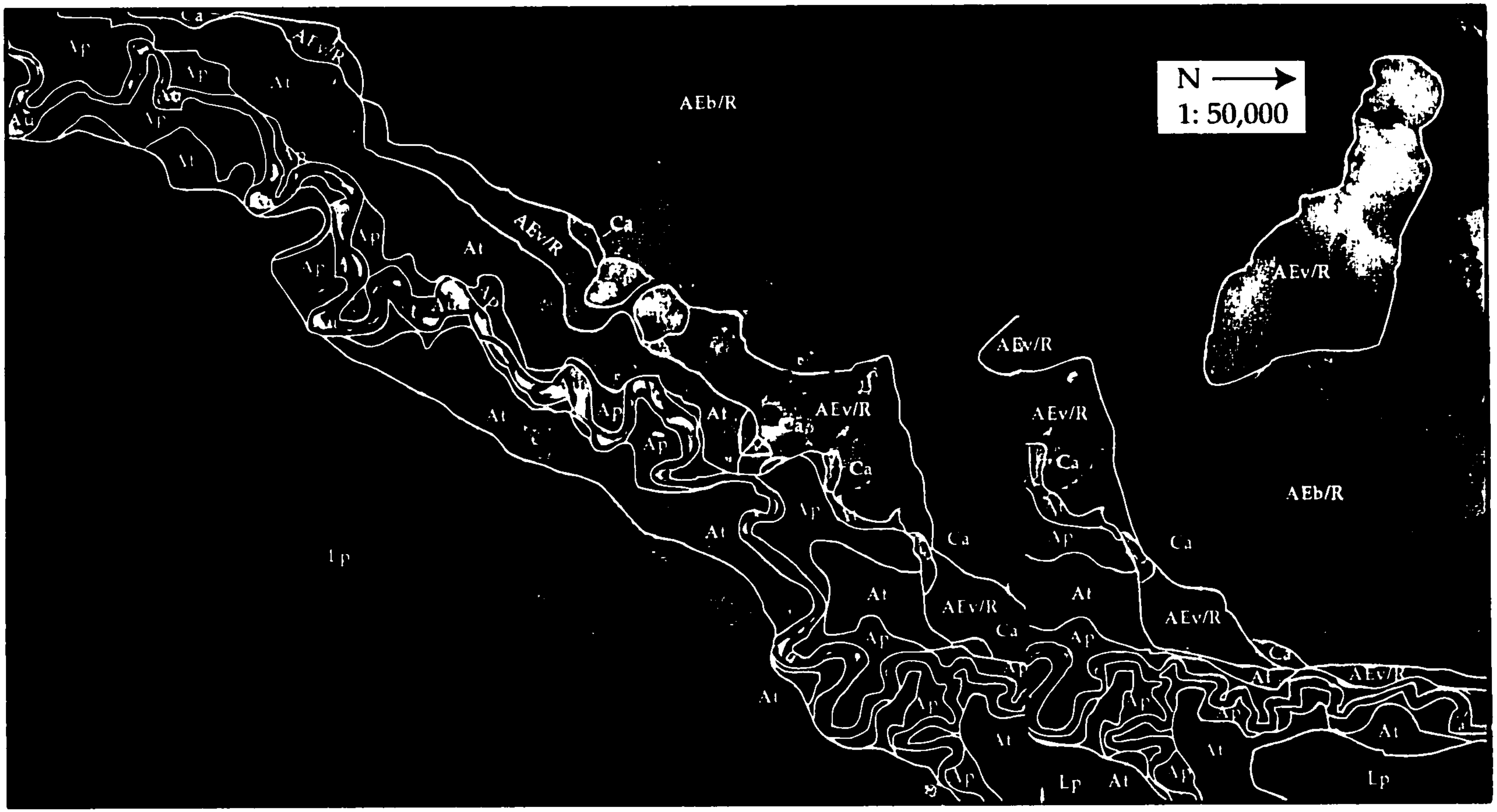
deposits. Organic accumulations are also found in the Old Crow glaciolacustrine basin overlying poorly drained silts and permafrost. Although mats of organic matter in the study are do not meet Jackson's (1994) definition of an organic deposit (being >2 m thick), accumulations of greater than 30 cm of vegetation were found on floodplains and terraces of Black Fox Creek. Permafrost at 30 cm below surface on a terrace 1 km north of the Dog Creek site prevented finding the depth to mineral matter in one of these organic deposits.

Map of periglacial features (Plate 9)

Periglacial features were mapped in the Black Fox Creek study area based on surface expression and composition (sediment, fractured bedrock, ice or vegetation). Terminology for the periglacial features has been previously described by Brown and Kupsch (1974), Washburn (1980) and others.

sc, sp, ss- *Sorted patterned ground* Sorted patterned ground in the study area consists of frost-heaved mounds of fractured bedrock rubble surrounded by finer material (aeolian silts and soil) on which vegetation grown. Patterned ground is found in three shapes depending on slope angle. Sorted circles (sc) and sorted polygons (sp) are found on relatively flat surfaces with exposed bedrock west of Black Fox Creek in the study area (Plate 5). Sorted stripes (ss) form on slopes where coarse materials and fines with vegetation are oriented in parallel lines down slope by gravity and creep.

iwp, lcp, eh- *Non-sorted patterned ground* Non-sorted polygonal or patterned ground forms in areas with sediment of fairly even grain size where no obvious sorting occurs between coarse clasts and finer sediments. Polygonal shapes are formed by thermal contraction of the ground (Washburn 1980). Non-sorted polygons form on the glaciolacustrine plain in the study area where water is abundant due to poor drainage. Ice-wedge polygons (iwp) occur when frost cracks surrounding non-sorted sediments fill with water. The water freezes and expands the troughs surrounding the polygonal forms. Ice-wedge polygons in the study area are low-centered (lcp) (Plate 6).



R- bedrock Lp- glaciolacustrine plain Lv- glaciolacustrine veneer AEb- aeolian blanket AEv- aeolian veneer
Ap- floodplain At- alluvial terrace Au- alluvial sediments undivided Ca- colluvial apron

Plate 4. Quaternary deposits along Black Fox Creek.

Plate 5. Sorted circles, polygons and stripes on frost-shattered bedrock.

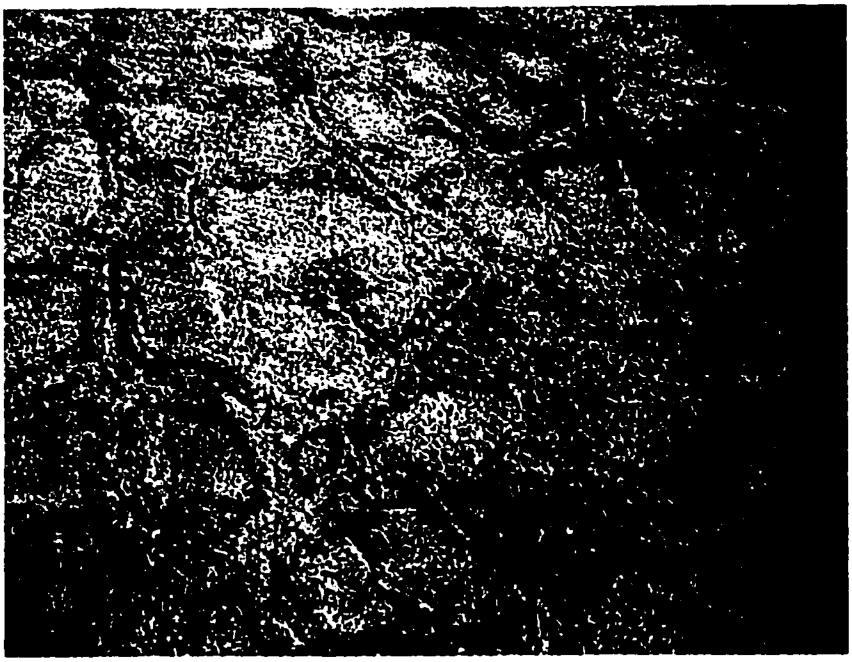


Plate 6. Low-centred ice-wedge polygons on glaciolacustrine deposits.

Brown and Kupsch (1974) suggest this is because the soil adjacent to the ice wedges is turned up by the growth of ice.

Earth hummocks (eh) are non-sorted nets that have circular shapes and form in most types of sediment and vegetation. Earth hummocks are usually cored with mineral sediment and have vegetated surfaces. They are the most common type of periglacial feature in the study area. Hummocks have formed on aeolian blankets and veneers in the study area with thin grass vegetation on the surface and moss in the spaces between hummocks. Hummocks on floodplains and terraces of Black Fox Creek are formed almost entirely by vegetation and are properly termed turf hummocks. Earth hummocks can also be found in the sediment contained by ice-wedge polygons on the glaciolacustrine plain east of Black Fox Creek (Plate 7).

sl- *Solifluction deposits* Solifluction lobes (sl) are found infrequently in the study area on, and at the base of, slopes. They have also been identified in buried deposits at the Dog Creek archaeological site.

td, tl, bd- *Thermokarsting* Thermokarst is evident in the study area as thermokarst depressions (td), thaw lakes (tl) and beaded drainage (bd). Thermokarst depressions are surface lows resulting from the melting of ground ice. On the glaciolacustrine plain in the study area, many of these depressions were once filled with water and can be identified by differences in vegetation surrounding ancient lake margins. Thermokarst lakes presently occupy many of the depressions in the study area (Plate 8). The floodplain of Black Fox Creek may also contain thaw lakes, but these are difficult to distinguish from oxbow lakes. The Old Crow basin contains hundreds of thermokarst lakes oriented parallel with the shore line due to structural control by northwest/southeast trending normal faults in the area (Allenby 1989). Beaded drainage is also found on the glaciolacustrine plain where beads or pools of water have formed in streams by melting ground ice.

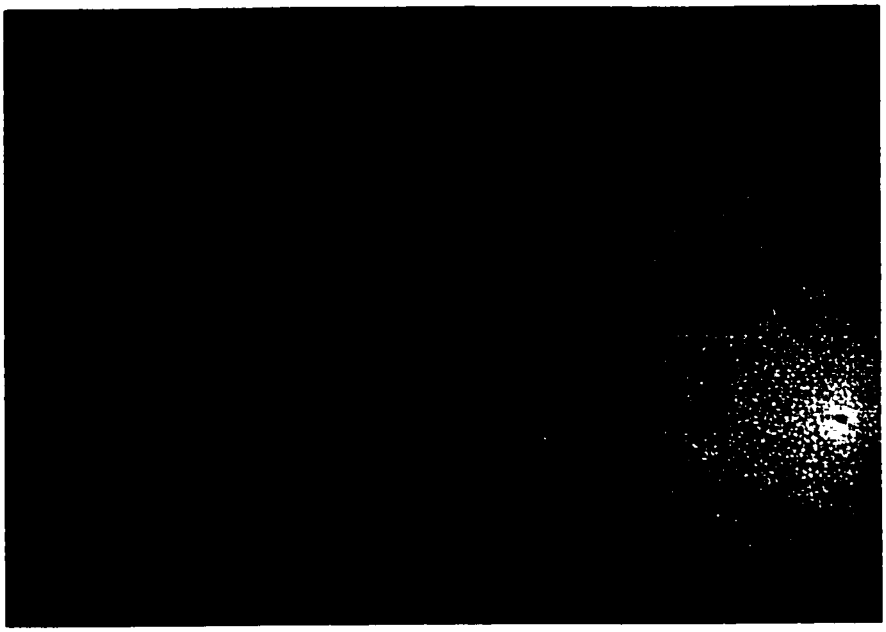


Plate 7. Earth hummocks on glaciolacustrine deposits.

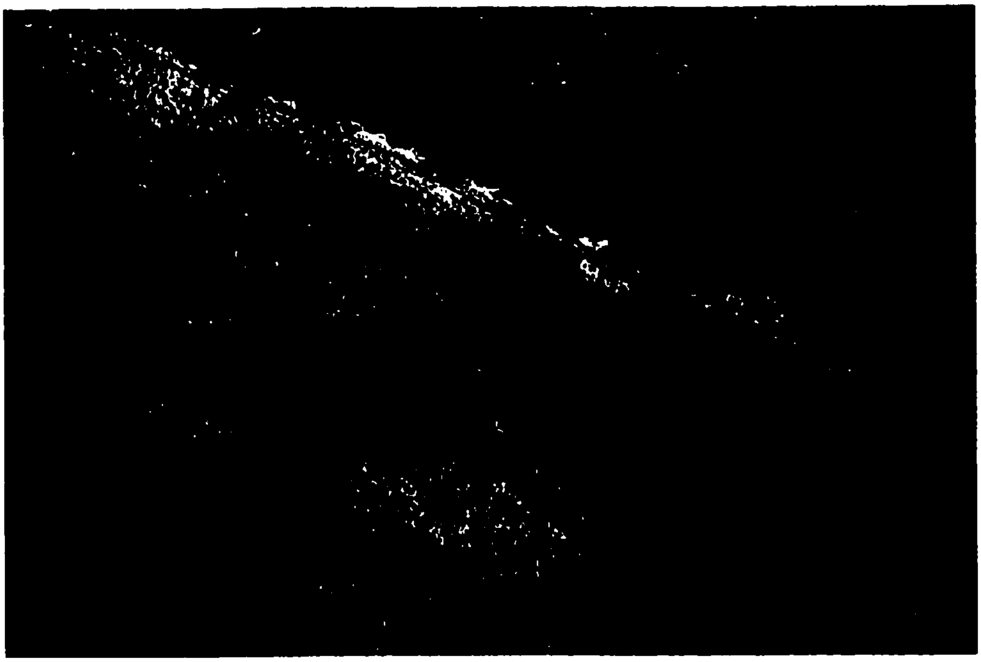
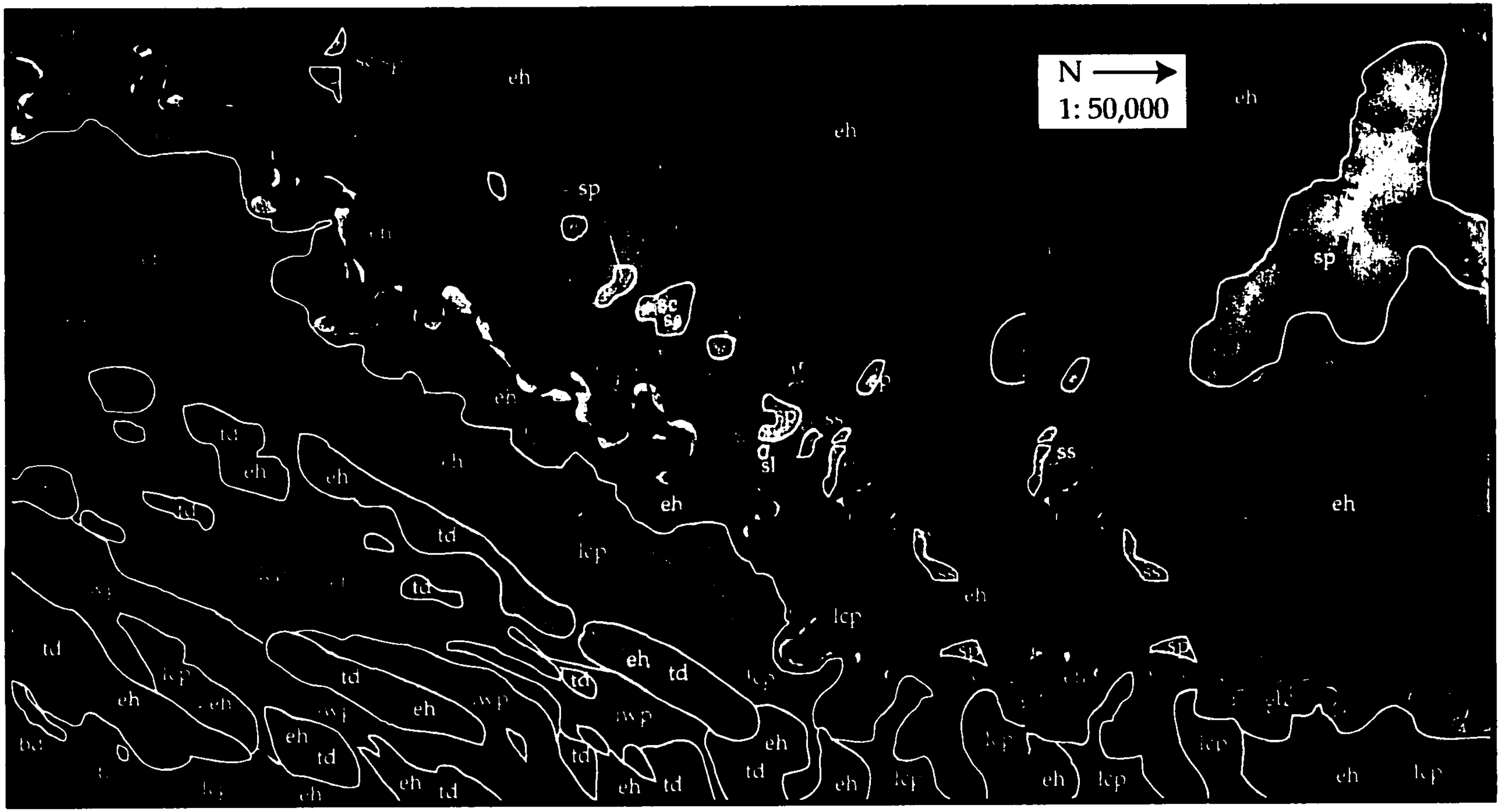


Plate 8. Thermokarst lake on floodplain of Black Fox Creek.



sc- sorted circles sp- sorted polygons ss- sorted stripes iwp- ice-wedge polygons lcp- low centered polygons
eh- earth hummocks sl- solifluction lobes tl- thermokarst lakes td- thermokarst depressions bd- beaded drainage

Plate 9. Periglacial features in the Black Fox Creek study area.

Surficial Map of the Dog Creek Site (Figure 12)

The Dog Creek archaeological site is situated on a limestone ridge[2], an outlier of the Barn Range to the northeast (Plate 10). The ridge complex on which the archaeological site is situated overlooks Black Fox Creek (Figure 11, 12). Behind the main ridge is a low area or swale that appears to be defined by the local bedrock. Another ridge (called the Mid-ridge) is located on the back side of the swale. Quaternary deposits and periglacial landforms at the site are comparable to the rest of the Black Fox Creek area.

There is a 5% slope from the northwest towards the edge of the Mid-ridge. This area is covered with a thin aeolian veneer (AEv), less than 20 cm thick. Some areas have no sediment cover, only frost-shattered limestone bedrock (R). Earth hummocks (eh) are found on the aeolian deposits. In areas with thin sediment (<20 cm), earth hummocks have diameters of <30 cm. Sorted polygons, circles and stripes occur on the exposed bedrock (sp, sc, and ss).

Sediments in the depression between the two bedrock ridges have a complex stratigraphy (Appendix IV). On the northwest side of the swale, frost shattered bedrock is covered with a thin veneer of aeolian silts (silt loam) in which there is weak soil development in the top 10-20 cm. In deposits near the edge of the Mid-ridge slope, organic-rich silt is found buried beneath aeolian sediments. Its burial is likely the result of solifluction over the edge of the ridge. In the northeast corner of the swale, shattered bedrock is capped with a thin layer (<30 cm) of black clays (9.6% sand, 32.4% silt and 58% clay) interpreted by B. Lauriol (Lauriol, B., Department of Geography, University of Ottawa, pers. comm. 1997) to be glaciolacustrine deposits. Towards the southern end of the swale, sediments consist of glaciolacustrine clays underlying aeolian silts. These clays potentially represent a high glacial lake level associated with glaciation during the Pleistocene. Earth hummocks have formed on the swale deposits.

The River-ridge has only a thin veneer of aeolian sediment. Steep slopes from this ridge to the river level are covered with colluvium and form an apron at their base (Ca). South of the River-ridge is the floodplain of Black Fox Creek.

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[2] The limestone ridge is Upper Carboniferous in age, a member of the Lisburne Group (Ortman and Norris 1980).

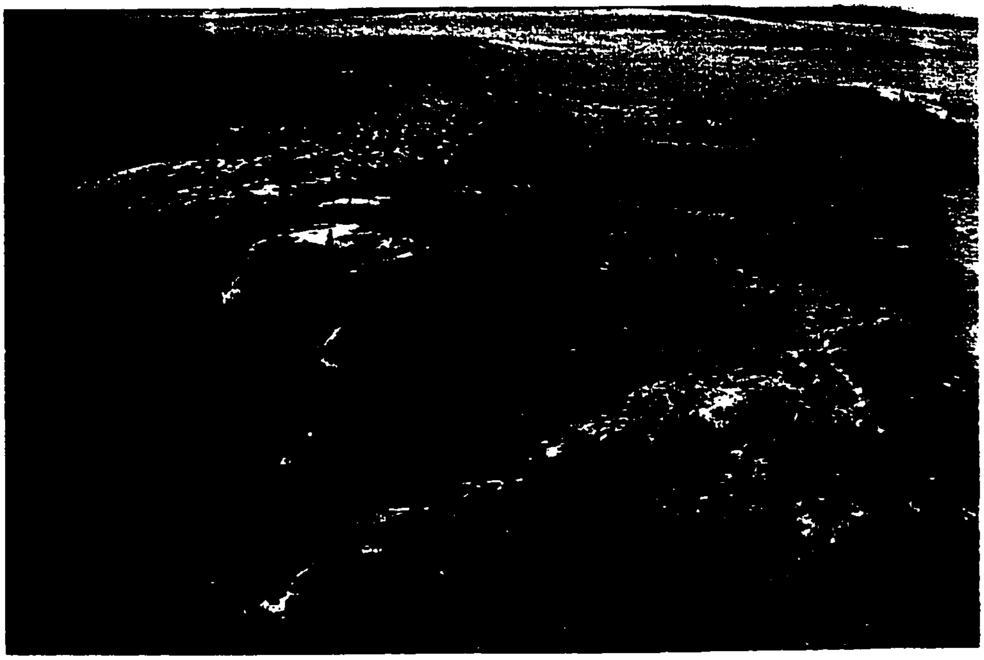
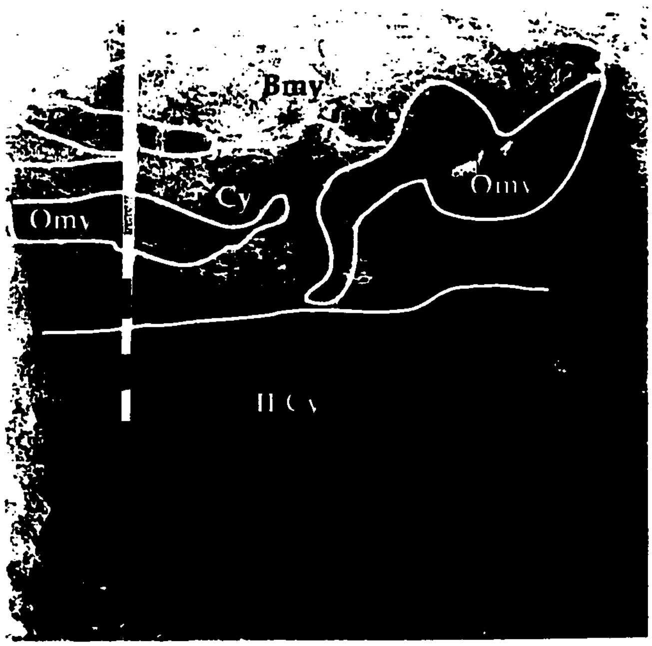


Plate 10. Dog Creek archaeological site, Mid-ridge in foreground.



Omy- Cryoturbated mesic organic horizon
Bmy- Cryoturbated B horizon
Cy- Cryoturbated C horizon, parent material
IICy- C horizon 2, parent material

Plate 11. Orthic Turbic Cryosol on Mid-ridge.

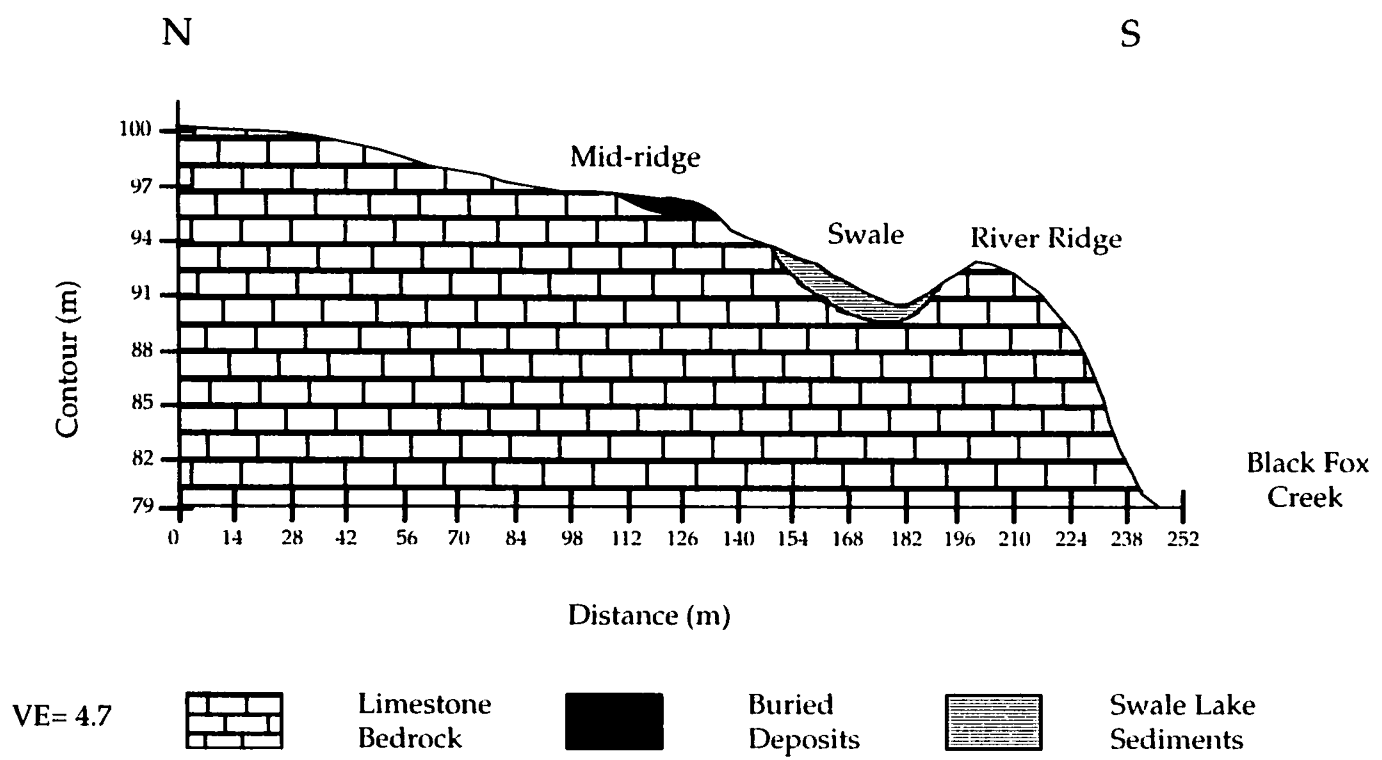


Figure 11. Profile of the limestone ridge on which the Dog Creek site is situated.

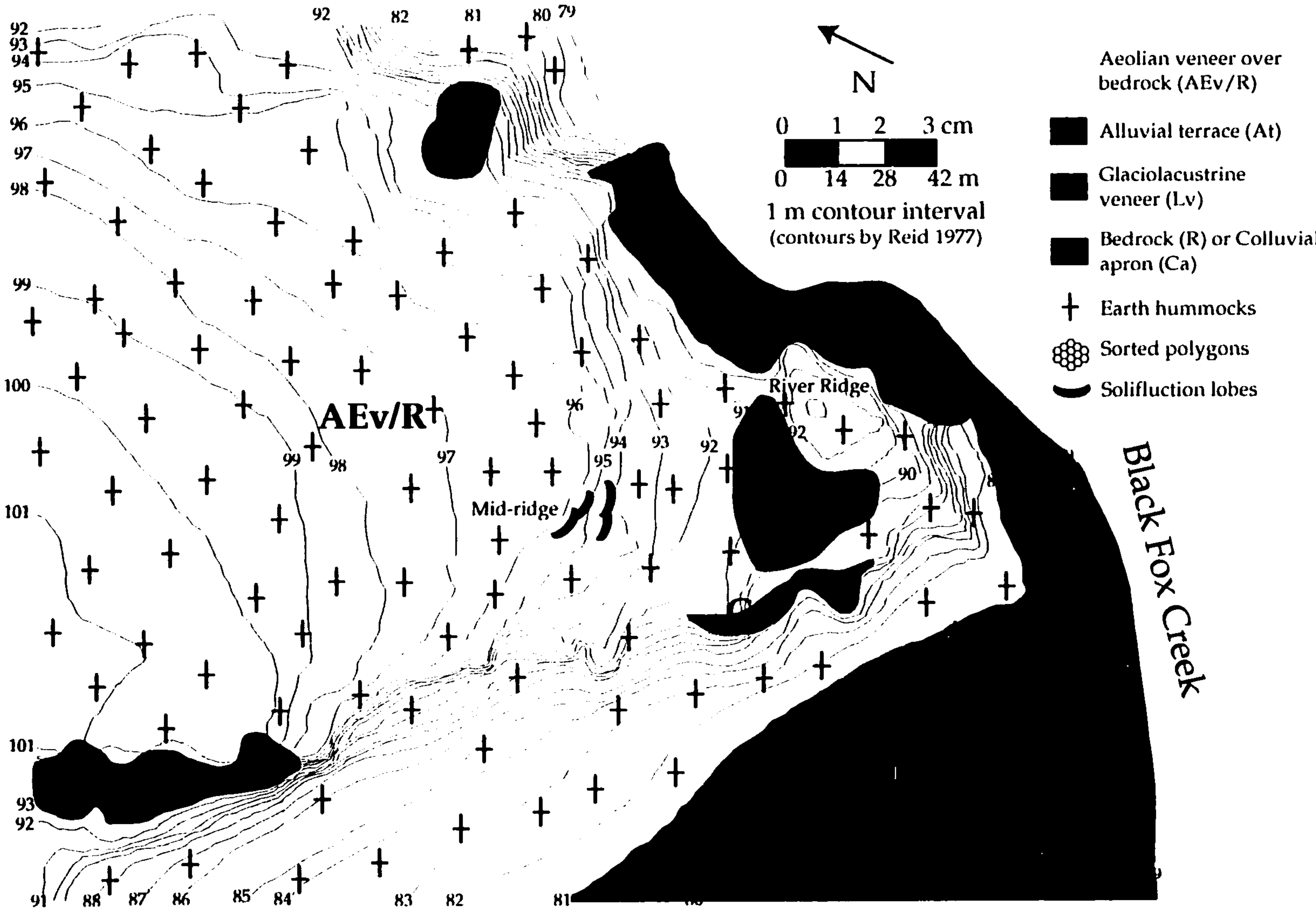


Figure 12. Contour map of the Dog Creek Site, NcVi-3 with surficial deposits and periglacial features.

Sediments closest to the creek are alluvial sands and silts (Ap). These are covered with earth hummocks and tree and shrub vegetation. Further back from the river is a poorly drained marshy area (At). Sediments consist of clay loams with a surface cover of moss. A thermokarst lake or part of an old oxbow is found in this area

Soil Development

The soils in tundra environments north of the Old Crow Basin have been characterized as Orthic and Regosolic Turbic Cryosols (Hughes et al. 1993). The soils at the Dog Creek site are designated as Orthic Turbic Cryosols based on a field pedon description as follows:

1. Site Conditions

Topography: the soil pit is located near the edge of a limestone ridge on a gentle east facing slope (5% slope). Sediments are mainly aeolian in origin.

Dominant plant community: vegetation includes sphagnum moss, shrub birch, shrub willow and various Ericales species (e.g. blueberry) (see Chapter 1 vegetation description).

Drainage class: the pedon is well drained at present.

Parent material: the parent material is a clay loam with approximately 1% clasts (greater than pebble sized) derived from frost shattered bedrock below aeolian deposits.

2. Pedon Description (Plate 11)

Horizon	*Depth (cm)*	*Description*
Bmy	varies 0-20	Very dark grayish brown (10YR 3/2, dry); clay loam; no mottles; weak, fine, granular; soft; few, fine, vertical, exped roots; clear, irregular boundary; 5-20 cm thick; weak reaction to HCl.
Omy	varies 0-40+	Black (10YR 2/1, moist); silt loam; no mottles; moderate, medium, granular; loose; few, very fine, vertical, exped roots; abrupt, irregular boundary; 5-10 cm thick; forms lenses above, within and below Bmy and Cy horizons.

Cy	varies 20-70	Dark brown (10YR 3/3, dry); clay loam; no mottles; amorphous; soft; very few, micro, vertical roots; gradual, wavy boundary; 30-50 cm thick; moderately effervescent.
II Cy	70+	Yellowish brown (10YR 5/6, moist); clay matrix with 40% clasts; no mottles; amorphous; firm; no roots; strongly effervescent.

Other information: Permafrost is greater than 1.4 m deep; the active layer extends into the bedrock. Soils are associated with non-sorted polygonal ground (earth hummocks). Organic matter is mixed with mineral material in upper half of the pedon due to cryoturbation. Although the Bm is thicker than 10 cm, the soil is not Brunisolic because it has a very weak granular structure.

Quaternary Geological History

Evidence from the Black Fox Creek study area complies with the known late Quaternary history of the area. Lack of exposed sections in the shallow creek valley prevents detailed stratigraphic analysis but geomorphic relationships can be used to interpret the general sequence of events affecting the area.

The study area contains the northern most extent and the highest level of glacial lake Old Crow represented by the glaciolacustrine plain east of Black Fox Creek and glaciolacustrine veneer in the swale at the Dog Creek site. The veneer at the Dog Creek site indicates that water levels reached at least 360 m above sea level (the altitude of the clays at the site). The clays only stretch over half of the swale suggesting that water levels never extended higher than this altitude. It is not known whether the glacial lake Old Crow sediments represents the late Wisconsin flooding event or a tectonically controlled Pliocene lake (Lauriol, B., Department of Geography, University of Ottawa, pers. comm. 1997, Schweger 1989).

The glacial lake sediments are older than most of the aeolian deposits in the area. Aeolian silts and silt loams are found overlying the glaciolacustrine clays. Wind blown sediments, are probably derived from the exposed Old Crow Lake bed present at the end of the Pleistocene.

Black Fox Creek cuts into the glaciolacustrine plain demonstrating that drainage was re-established in the area sometime after the basin drained. The creek is highly sinuous and oxbows are found in the low terrace next to the floodplain. This suggests limited down-cutting but active meandering during the Holocene. Tree ring counts from black spruce show that floodplains are no older than about 270 years. Eight counts from trees on the west side of the creek from the Dog Creek site to the confluence of Black Fox and Dog Creeks range in age from 92 to 267 years old (Appendix IV).

Periglacial landforms have developed in sediment since at least the middle of the Holocene. This minimum date is based on the initiation of solifluction in the area beginning by 5,000 years B.P. (Chapter 3). The type of periglacial feature formed is closely related to both sediment type and drainage. Sorted patterned ground develops only in areas of exposed bedrock where there is a difference in grain sizes of sediment enabling sorting to occur. Sorted polygons and circles form on relatively horizontal surfaces whereas stripes form on slopes; elongated by gravity. Non-sorted patterned ground is found extensively in the map area. Earth hummocks occur where ever there is sediment or vegetation. This includes the well drained aeolian deposits and the saturated glaciolacustrine plain. Ice-wedge polygons form only on the glaciolacustrine plain where there is a consistent and substantial water supply. The low-centered ice-wedge polygons in the area are well developed and have likely been forming over a long period of time.

Understanding the microclimatic conditions (sediment type, drainage and depth to permafrost) under which particular features form is useful for interpreting relict features. Because ice-wedge polygons only form in poorly drained areas today, it is probable that ice-wedge casts in the stratigraphic record represent poorly drained conditions. This information is useful for interpreting microclimatic and climatic conditions in an area. This information will be used to reconstruct microclimatic conditions at the Dog Creek archaeological site where relict periglacial features occur.

CHAPTER 3 Geoarchaeology of the Dog Creek Site

Introduction

In order to interpret an archaeology site fully it is necessary to understand the geological processes responsible for its setting as well as alterations that have taken place since deposition of cultural material. Archaeological sites are affected by on-going natural processes often involving sedimentary processes. Processes include bioturbation, tree throws, deflation and mass wasting (Rapp and Hill 1998, Schiffer 1987, Waters 1992). Arctic sites also experience periglacial processes such as solifluction, frost creep, frost heave and cryoturbation, which commonly alter the sedimentary record. Understanding the dynamic processes that are active at archaeology sites can help interpret the age of human occupations and the relationships between cultural material and the environment in which it was deposited.

The questions addressed by geoarchaeological research at Dog Creek are: 1) what are the relationships between buried and surficial cultural material at Dog Creek, 2) is the cultural material found at the site in its original provenience and 3) is it possible to date the occupations at the site chronometrically? In order to answer these questions the periglacial processes that have been active at Dog Creek since human occupation must be fully understood.

Background

The surficial geology of the northeast Old Crow Basin region (Chapter 2 Plate 1) has previously been discussed. Thin vegetation cover over sediments and bedrock allows for visible identification of archaeological assemblages along ridge areas. During the 1978 excavations at Dog Creek, most archaeological material on the Mid-ridge and River-ridge was found on the surface or near surface (<10 cm below surface) above bedrock (Figure 11, 12). One excavation unit on the Mid-ridge, however, had sediment up to 1.5 m deep with artifacts found buried at depth as well as near the surface. The Mid-ridge contains a low area that spans a 10 m x 5 m area and reaches 1.5 m thick. The stratigraphy is largely disturbed by frost processes that are typical in northern sites (c. f., Schweger 1985).

Periglacial Processes

Periglacial processes unique to, or magnified in permafrost regions have long been recognized by geologists, soil scientists and archaeologists. These agents include cryoturbation, frost heave, solifluction and frost creep (Table 1) (Mackay et al. 1961, Schweger 1985, Waters 1998, Wood and Johnson 1978). These processes are briefly defined in order to evaluate whether they have affected archaeological and sedimentary units at the Dog Creek site. Other common processes that often alter the sedimentary record at archaeology sites, including bioturbation and deflation, will also be considered.

Cryoturbation

Cryoturbation is used to describe irregularities and involutions in soil horizons and sediment layers due to freezing and thawing pressures (French 1996, Schweger 1985, Van Vliet-Lanoe 1988, Washburn 1980, Wood and Johnson 1978, Zoltai et al. 1978). Involutions are stratigraphic layers and bands that have been contorted by cryostatic pressures or loading. Schweger (1985), for example, interprets the involuted palaeosols at the Onion Portage site in Alaska to be the result of extremely active cryoturbation occurring during a colder climate when the active layer was thinner and the sediments were saturated due to poor drainage. Cryoturbation is often used to describe the mechanism of churning of organic matter in soils and the development of earth hummocks (Canadian System of Soil Classification 1987).

Cryoturbation causes the formation of earth hummocks, raised areas of sediment or buried organic matter (Ritchie 1984). They are often underlain by segregated ice and occur in fine grained parent materials. Earth hummocks are associated with frost cracks which occur in the active layer or permafrost due to thermal contraction of the ground at freezing temperatures. Frost cracks can be closely linked to desiccation cracks in dry sediments but can also occur in saturated deposits (Harry and Gozdzik 1988, Washburn 1980).

Table 1. Frost processes and their results in the stratigraphic record.

Process	Result
Cryoturbation	-involutions -organic material mixed in mineral soil -frost hummock development
Frost Heave	-vertical alignment and movement of clasts and artifacts in active layer of sedimentary profile -frost cracks
Solifluction	-downslope movement of artifacts and sediments -overturning of sedimentary units -doubling of sedimentary units

Frost heave

Frost heave is the upward displacement of sediments and clasts vertically due to the expansion of water during freezing and growth of ice lenses (Johnson et al. 1977, Linell and Tedrow 1981). Frost heave requires sediments to be frost susceptible, ground temperatures to fall below 0°C during parts of the year and a sufficient source of water (Anderson et al. 1984). Silts, which are commonly found in aeolian and glaciolacustrine deposits, are extremely frost susceptible due to limited drainage and often experience frost heave (Murton and French 1994).

Frost heave may have a greater effect on artifacts and clasts within a deposit than on the sediment itself. Cycles of frost heave and thaw act to displace objects up through the sediment profile and align them vertically (Benedict 1970, 1976, Mackay 1984, Washburn 1980). This occurs by mechanisms of frost pull and frost push (Brink 1977, Mackay 1984). Frost pull occurs when sediments stick to and uplift objects during freezing. Frost push, on the other hand, acts when water within the soil collects at the base of clasts and artifacts during the thaw season. During the next freeze cycle, the water expands upon freezing, pushing the object upward. Frost pull and push work to displace artifacts from their original provenience and cultural strata.

Solifluction

Solifluction is defined as the downslope movement of saturated sediments under the influence of gravity (Gamper 1983). Solifluction can take place anywhere there is a restriction to drainage such as bedrock or permafrost. Sites in the arctic are extremely susceptible to solifluction due to widespread permafrost and thin active layers. Solifluction can be active on extremely low slopes (<10°) (Benedict 1970). In permafrost regions, solifluction is often associated with frost creep and called gelifluction. Frost creep includes frost heave which enhances downslope movement.

Bioturbation and deflation

Although periglacial processes account for a large amount of sediment disturbance in arctic regions, archaeological sites in these areas also experience more common taphonomic agents such as bioturbation and deflation.

Bioturbation can be defined as the disturbance of sites by the growth and activity of plants and animals. Site context can be completely destroyed through root growth and animal burrowing (Wood and Johnson 1978). In the arctic, floralturbation is limited to the upper portions of deposits because the dominant plants, shrub birch and alder, sedges and sphagnum moss, have shallow root systems. South of the tree line, however, tree throws can be an important agent of displacement for sediments and archaeological material (Hughes et al. 1983, Waters 1992). Uplifting of artifacts clinging to roots by tree throw can create mixed or inverted stratigraphy (Plate 12) (Schiffer 1987). The most important animals that cause bioturbation in northern sites are caribou, grizzly bears and ground squirrels (French et al. 1983). Caribou dig the ground with their hoofs, disturbing artifacts, and sites located under caribou trails are extensively trampled. Grizzlies dig for ground squirrels which also destroy site context by burrowing through sediment and moving cultural material. Krotovinas are infilled by surface material and are recognizable in sites by shape, sediment type and color contrast with the surrounding sediments.

Wind erosion (deflation) disrupts archaeological sites in all climatic zones. Deflation is important in the arctic in tundra environments where protective vegetation is lacking (Washburn 1980). It is particularly destructive in shallow buried archaeological sites and surface assemblages (Cooke 1970, Washburn 1980, Waters 1992).

The primary role of wind in arctic environments is to remove silt and sand from the site matrix resulting in a condensed stratigraphy (Butzer 1971: 192, Schiffer 1987: 239). As fine grained materials are moved by wind, artifacts remain behind. Artifacts from separate stratigraphic layers can be concentrated across one horizon making dating and interpretation difficult. In terms of artifact movement, younger artifacts are displaced downward as the matrix around them erodes and are incorporated with older deposits. Because this process is generally restricted to the top few centimetres of the ground, deeply buried sites will not be affected (Waters 1992). Wind deflation has been documented in arctic situations (Washburn 1980) but the literature on the subject is not extensive.

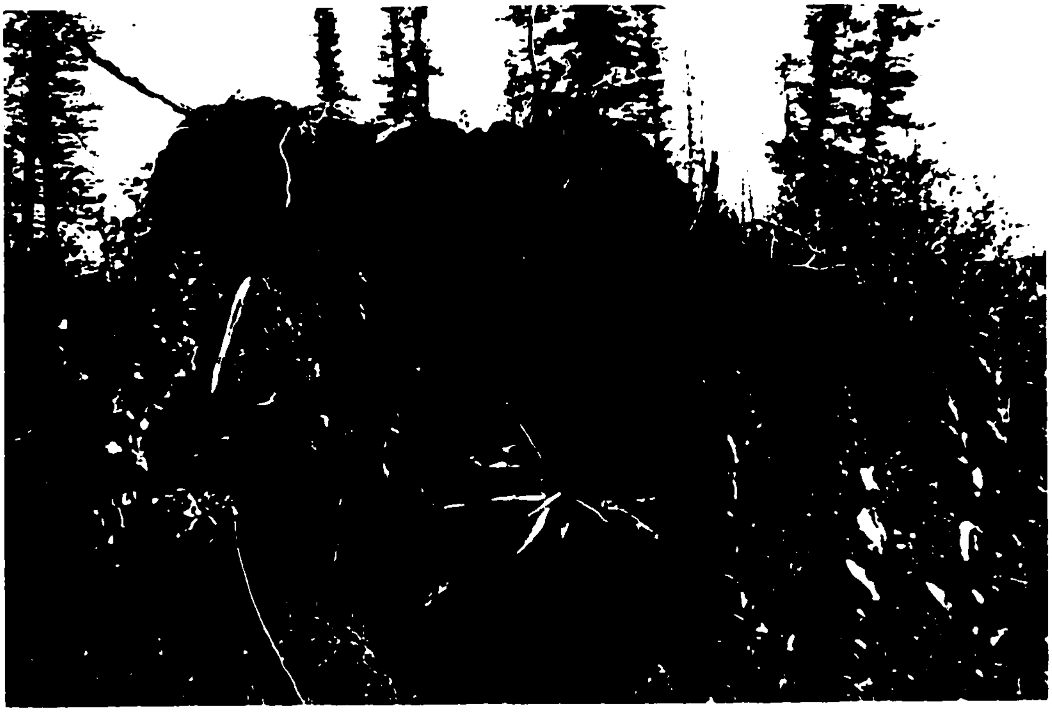


Plate 12. Tree throw along the Porcupine River near Old Crow.

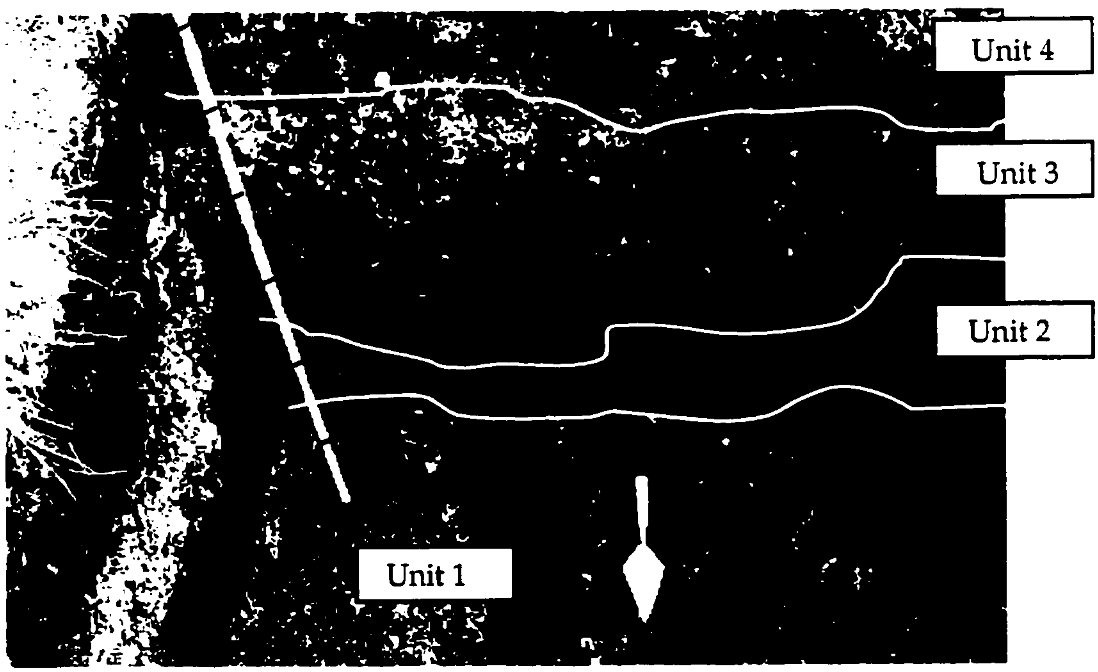


Plate 13. N1E7, south wall. General Mid-ridge stratigraphy.
Metre stick shows 10 cm intervals.

Site Stratigraphy

Excavation at Dog Creek during the 1997 and 1998 field seasons investigated the cultural material in surficial context on the Mid-ridge and River-ridge as well as in buried context on the Mid-ridge. Figure 13 displays excavation units and surface collections investigated on the Mid-ridge at Dog Creek since discovery of the site in 1976. Those units denoted by a star contain deeply buried deposits (>15 cm). Detailed descriptions of all depositional units from the Mid-ridge are given in Appendix IV. Although variation occurs throughout the stratigraphy in the deposits on the Mid-ridge, there are four main sedimentary units (Figure 14, Plate 13). These units directly overly limestone bedrock.

Unit 1. This unit overlies limestone bedrock everywhere at Dog Creek including the Mid-ridge, River-ridge and swale. The depth of its lower contact with solid, unfractured bedrock was not determined. The unit is fairly cohesive. Freshly exposed, it is dark yellowish brown (10YR 4/4, moist). It contains >40% clasts larger than 4 mm and has a matrix[3] of, on average, 30% sand, 28% silt and 41% clay. The unit is poorly sorted (Figure 15). Clasts are 100% limestone and angular (Plate 14). Loss on ignition shows that the matrix contains an average of 3% organic material and 34% calcium carbonate[4]. The unit is massive. Artifacts were not discovered in this sedimentary unit although they are found in the overlying units.

Unit 1 has been interpreted as a weathered limestone regolith that formed in place by fragmentation of underlying bedrock due to freezing and thawing cycles. Frost break up of the bedrock results in an unsorted mixture of clasts from pebble to boulder size. The finer matrix was likely formed by dissolution of limestone by rain water percolating down through the sedimentary profile, as well as settling of fine particles from overlying units. Physical and chemical weathering have been the main mechanisms for producing this deposit.

Unit 2. The second unit overlies the bedrock diamict (Unit 1) in areas of the Mid-ridge lobe deposit (Plate 15, 16). It ranges in thickness from 2 to 50 cm. This unit is cohesive and black in color (10YR 2/1, moist). Very few clasts are

[3] The matrix of the sediment refers to all grains under 1 mm in diameter, 0 ø.
[4] All values for sand, silt and clay percentages as well as organic and $CaCO_3$ content from each sedimentary unit are found in Appendix II and III respectively.

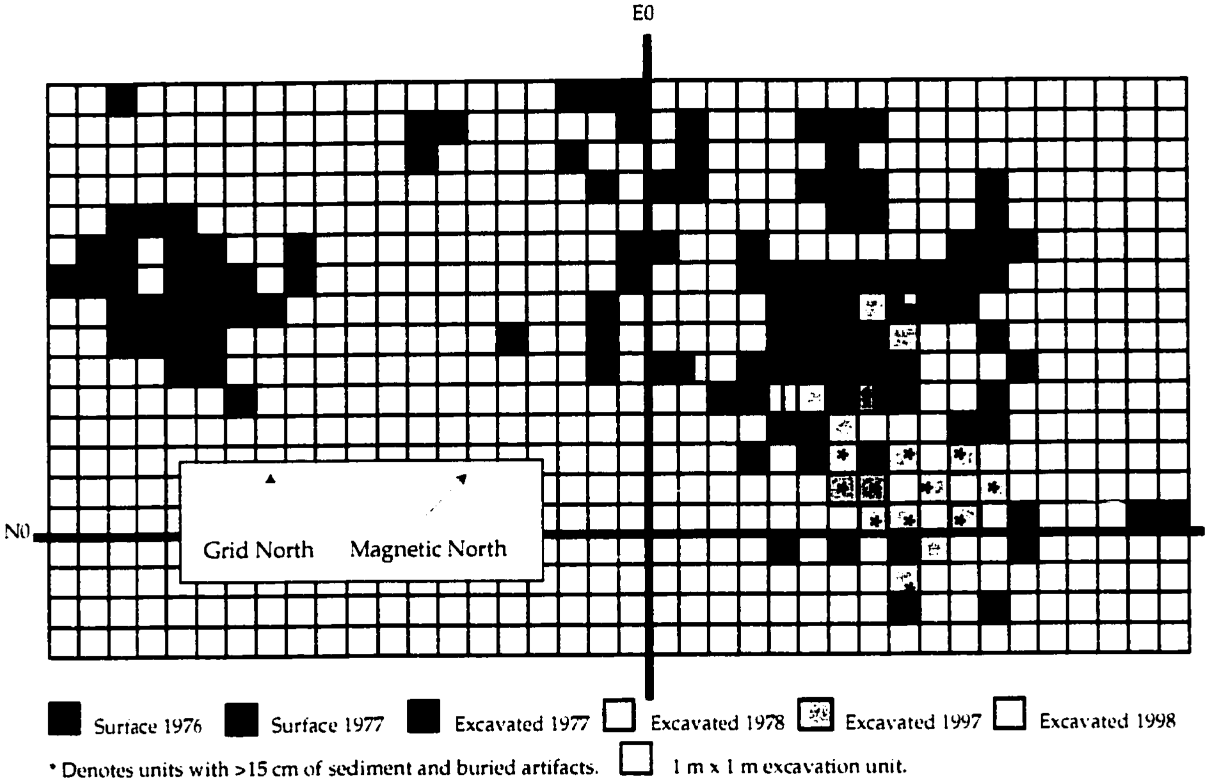


Figure 13. Excavation and surface collection units on the Mid-ridge at the Dog Creek site 1976-1978 and 1997-1998.

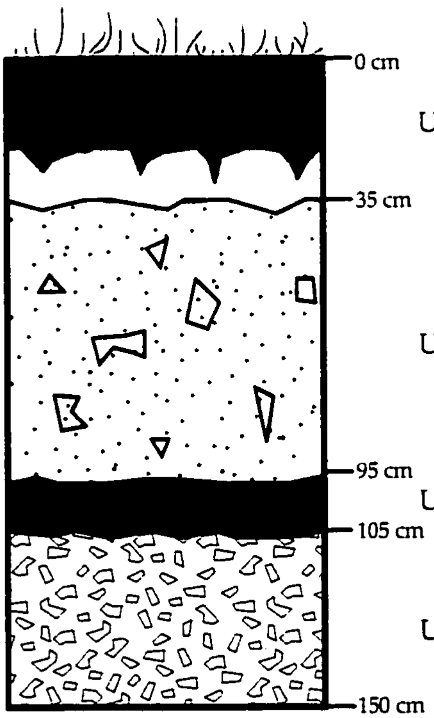


Figure 14. General stratigraphy of Mid-ridge buried deposits.

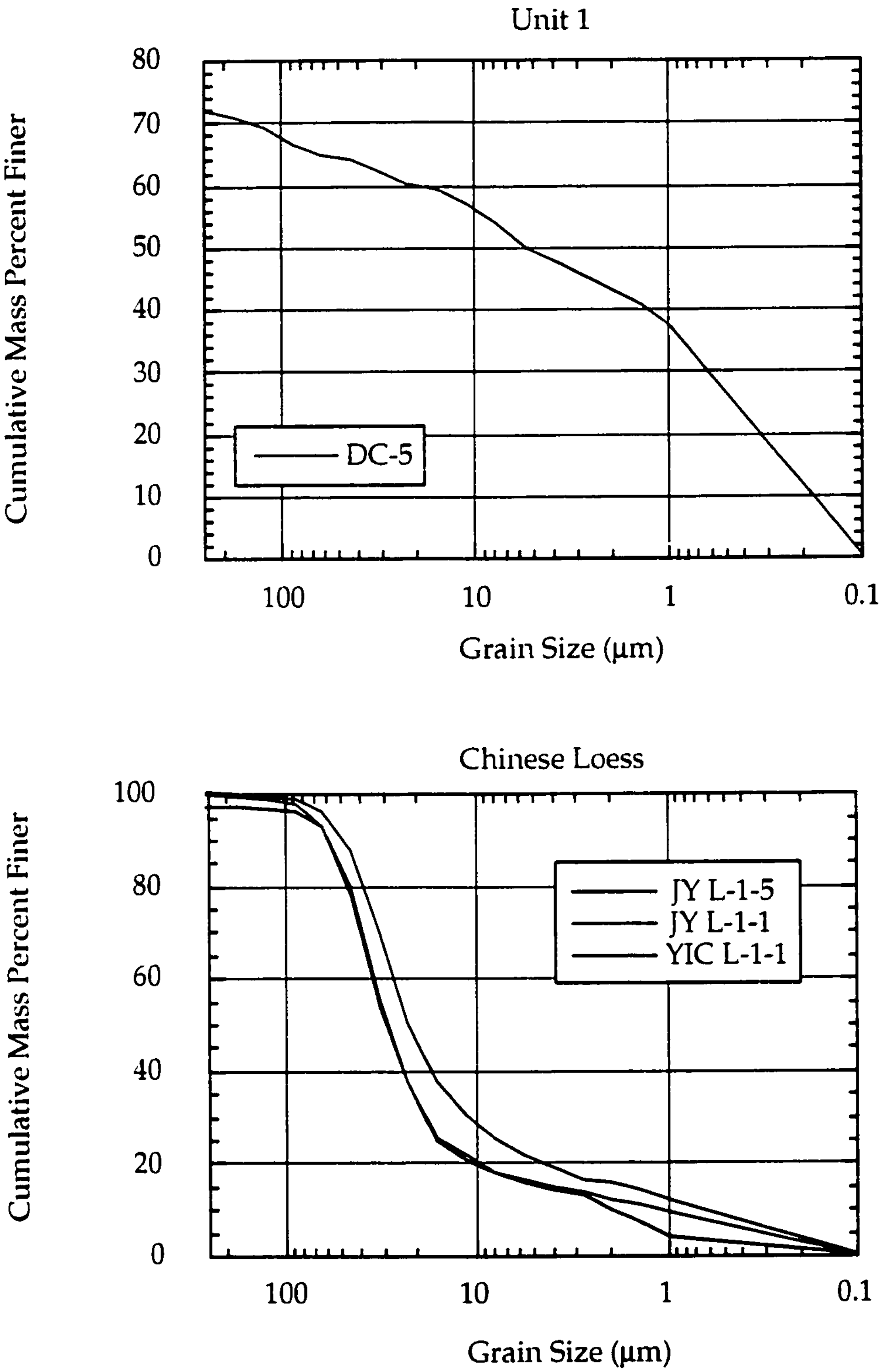


Figure 15. Grain size analysis of poorly-sorted Unit 1 sediments (< 250 µm) compared to well-sorted loess deposits near JiYuang and Yichuan, east central Loess Plateau, China (courtesy of Dean Rokosh 1999, unpublished data).

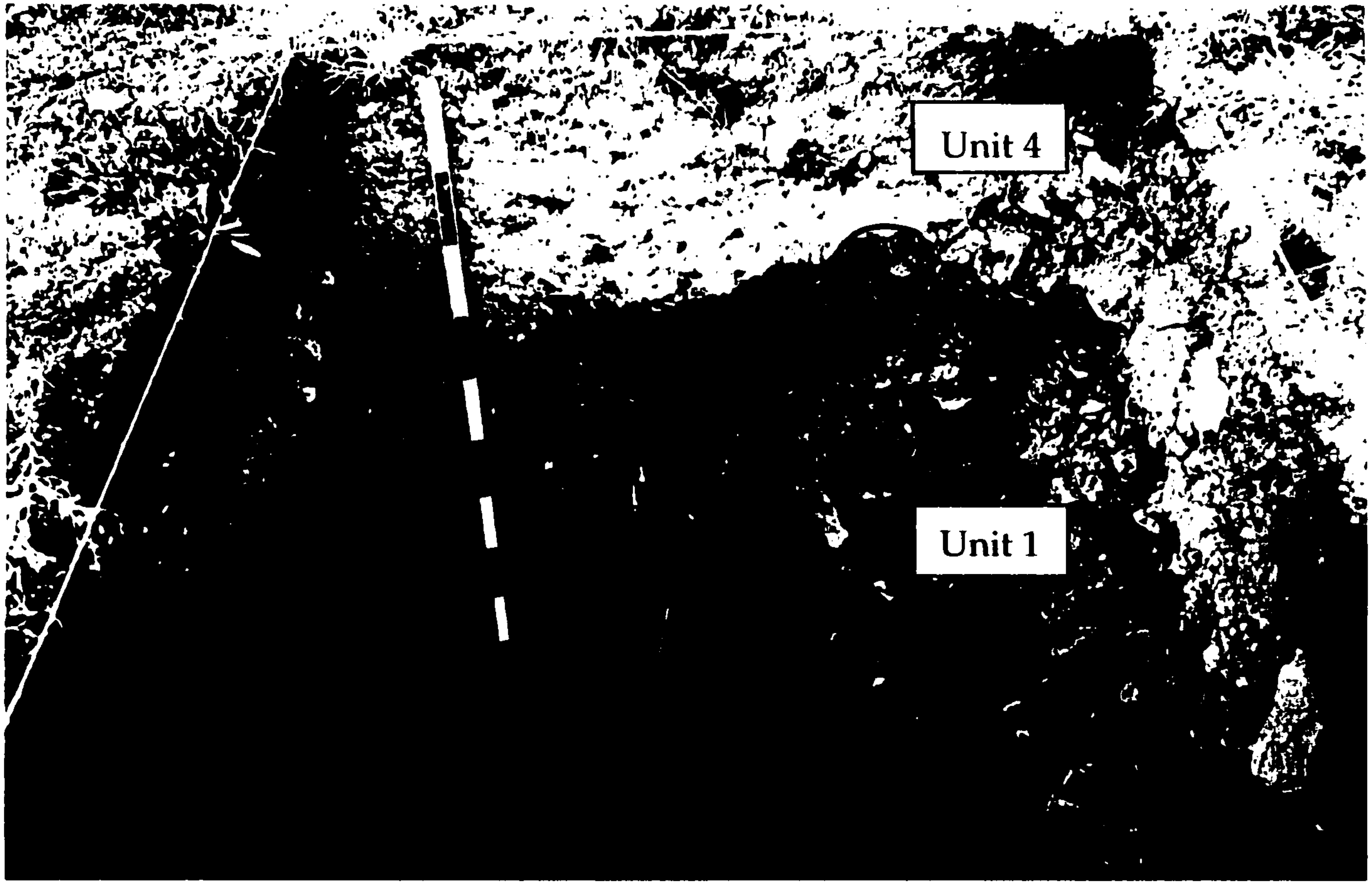


Plate 14. Unit 1 angular limestone clasts, N2E8, north wall.

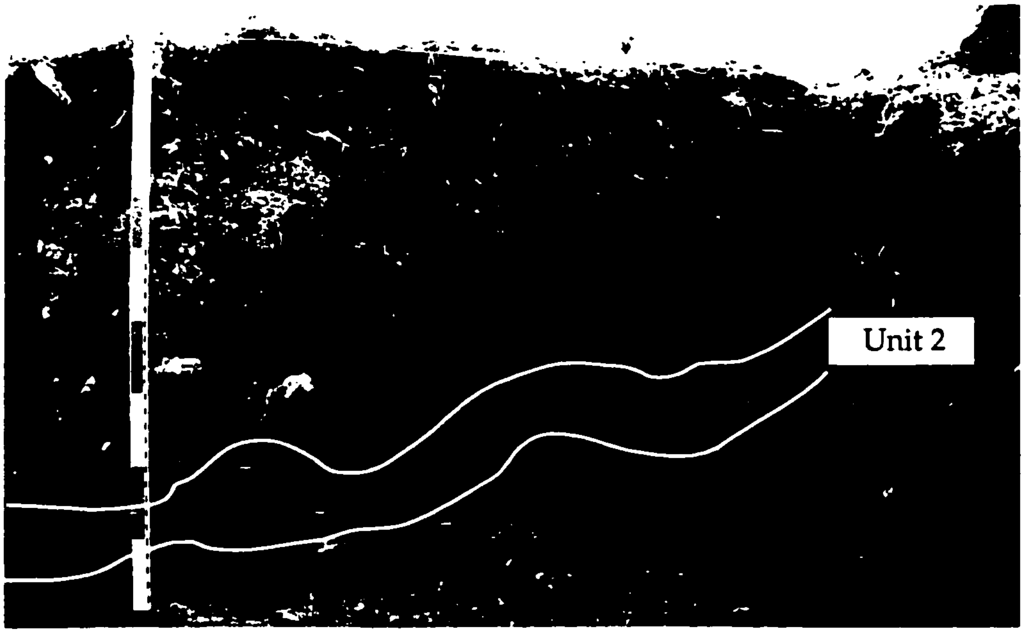


Plate 15. N0E7 South wall, Unit 2 buried organic layer.

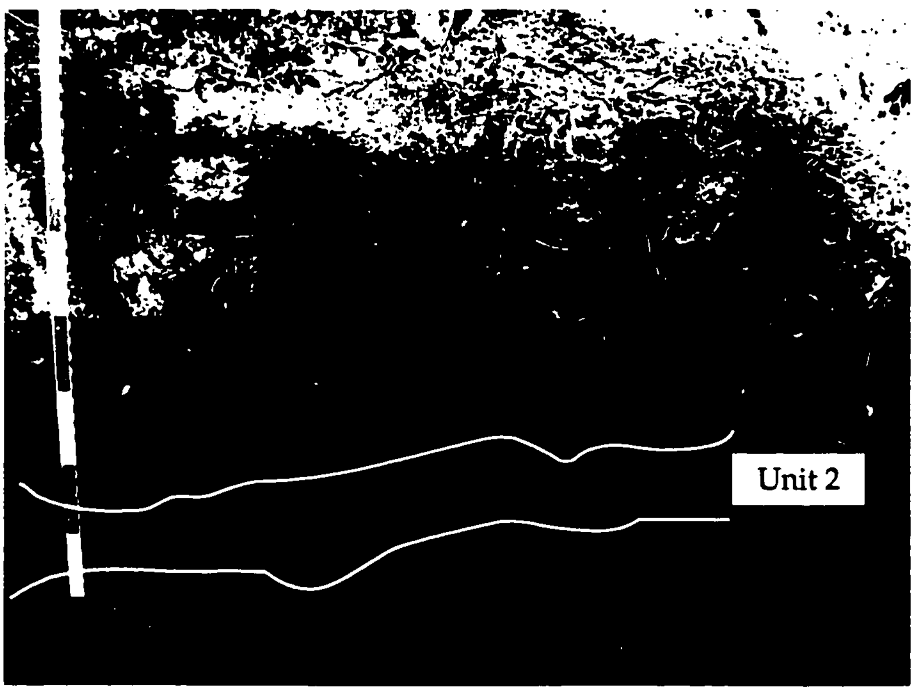


Plate 16. Unit 2 buried organic matter in S0E9, south wall.

found within the unit. The matrix is a well sorted silt with 15% sand, 63% silt and 22% clay size particles (Figure 16). The average grain size of the deposit is 8.7ø. Loss on ignition demonstrates a high content of organic carbon in the deposit averaging about 46%. $CaCO_3$ content averages 13%. The unit itself is massive with mottling of different colored decomposed organic matter. Unit 2 forms an angular unconformity with underlying Unit 1. It is sharp and dips from 5-25° to the north, usually lying on an angle with respect to other deposits and, in a few excavation units, approaching vertical. Stone artifacts, including many flakes and one projectile point, occur in the matrix. Root-etched moose bone is also present. Root-etching suggests that the bone was originally on or near the surface. Microscopic analysis has revealed charcoal, wood fragments, insect parts, pollen and other floral macrofossils in the matrix.

Unit 2 is interpreted as a buried soil based on the high percentage of organic matter in the matrix and the presence of abundant plant macrofossils and pollen. Root-etching on bone fragments suggests that this unit was once at surface as roots do not penetrate to this depth in the profile at present. The soil has a granular structure but lacks distinguishable horizons. The high organic content is likely due to vegetation decomposition after burial. The parent material of this soil is not the Unit 1 deposits found directly underneath. The Unit 1 matrix is extremely poorly sorted with a high clay percentage while Unit 2 consists of a well sorted sediment dominated by silt sized grains. The angular clasts found in Unit 1 are also absent from Unit 2.

The well sorted nature and mean grain size (8.7 ø) of the parent material of the Unit 2 soil suggests an aeolian origin. The sediment was compared to floodplain deposits from Black Fox Creek as another possible source. These sediments, however, are less well sorted than the Unit 2 deposits and have a significantly lower silt component[5]. There is also no geomorphological evidence suggesting that river levels ever reached the elevation of the site.

Unit 3. This unit directly overlies the Unit 2 buried soil. It varies in thickness from 0 - 1 m. The sediment is uncohesive and yellowish brown to dark

[5] The average grain size of the floodplain sediments near the Dog Creek site contain 20% sand, 34% silt and 46% clay (Appendix II).

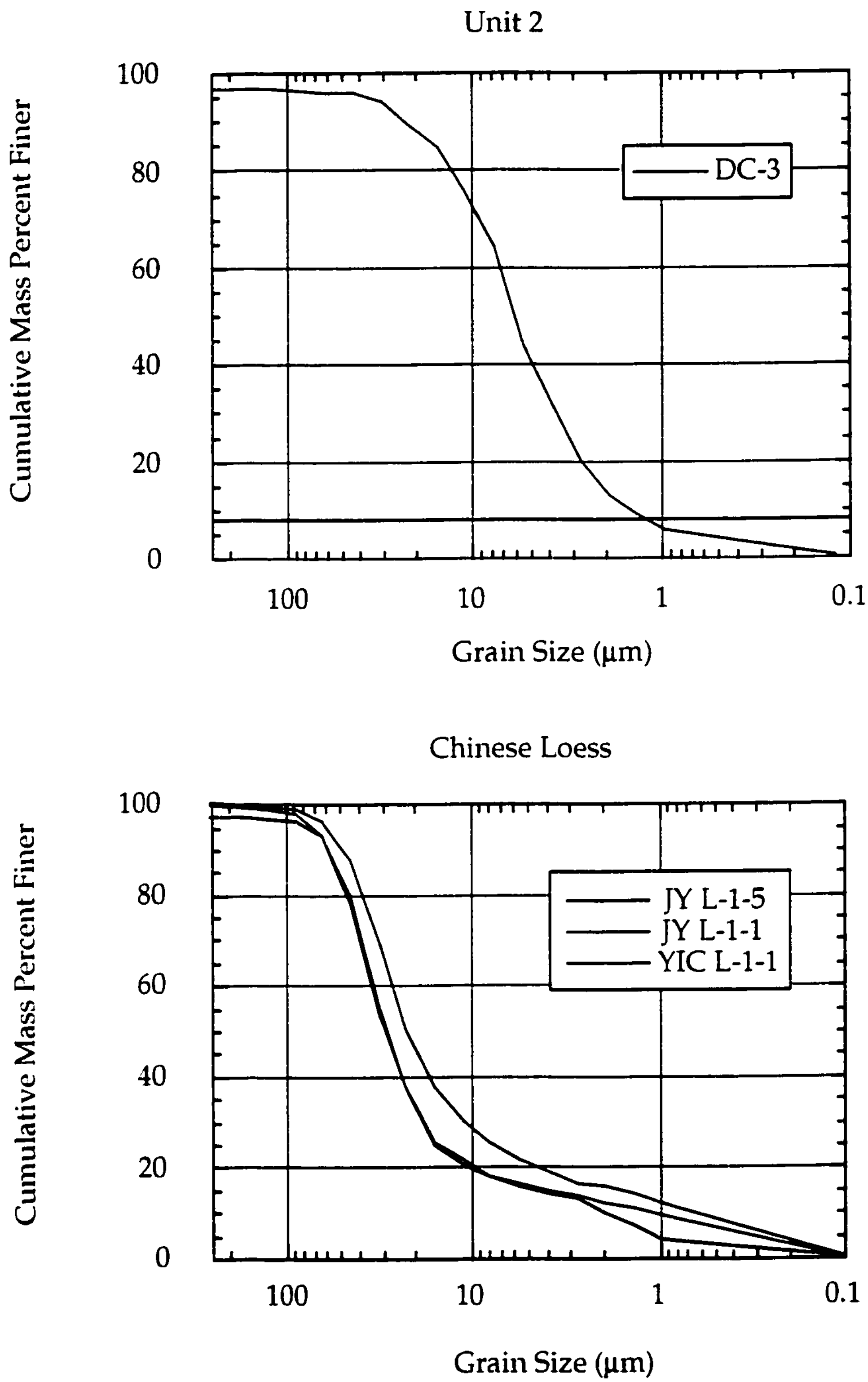


Figure 16. Grain size analysis of well-sorted Unit 2 sediments (< 250 µm) compared to well-sorted loess deposits near JiYuang and Yichuan, east central Loess Plateau, China (courtesy of Dean Rokosh 1999, unpublished data).

yellowish brown (10YR 5/6 - 4/6, moist) in color. Clasts comprise 2-30% of the material and are predominantly angular limestone (90+%). The matrix is a poorly sorted clay loam with 24% sand, 37% silt and 39% clay (Figure 17). Loss on ignition demonstrates 13% calcium carbonate, some of which could be soil carbonate. Carbonate coatings are frequent on the undersides of clasts. Organic content reaches about 8%. The unit appears to be massive. The lower contact with Unit 2 is generally sharp but has been obscured by mottles due to cryoturbation in some places. Only a few small flakes (<10) were recovered from this unit suggesting that they were not in situ and may have settled downwards from an overlying unit.

The characteristics of this unit suggest that it is a mixed deposit consisting of underlying regolith and the overlying silt deposit (see below) because it has sedimentary characteristics of both Unit 1 and Unit 4. The likely mechanisms of mixing include solifluction and frost heave.

Unit 4. This sedimentary unit caps deposits over the entire archaeological site and most of the Black Fox Creek study area. It varies in thickness at Dog Creek from 10 cm where bedrock is near the surface, up to 50 cm on the Mid-ridge. The deposit is uncohesive and has a color of very dark brown (10YR 2/2, dry). It contains a maximum of 1% clasts greater than 4 mm in diameter. Besides limestone, silicified mudstone and chert pebbles are common. The deposit is a moderately sorted silty clay loam with 19% sand, 43% silt and 38% clay sized grains (Figure 18). The unit contains approximately 22% organic matter and 6% $CaCO_3$. The unit is massive and mottled by darker colored organic rich silts. Ground squirrel burrows are frequent in the upper 20 cm. The lower contact with Unit 3 is gradational and varies in depth across the Mid-ridge. Artifacts occur in abundance in the upper 30 cm of this deposit.

This unit is interpreted to be aeolian in origin on the basis of its sorting and mean grain size. Although the unit is not as well sorted as Unit 2, it is likely that it began as a well sorted silt that was mixed with coarser grains by frost heave and cryoturbation.

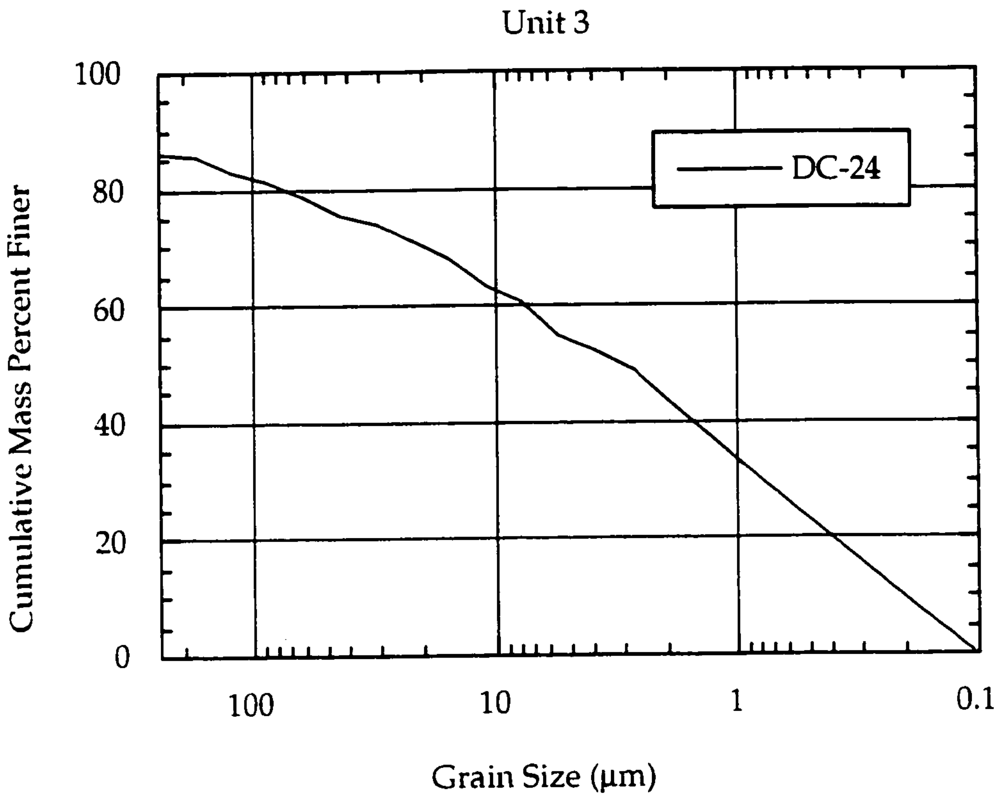


Figure 17. Grain size data for poorly-sorted Unit 3 deposits.

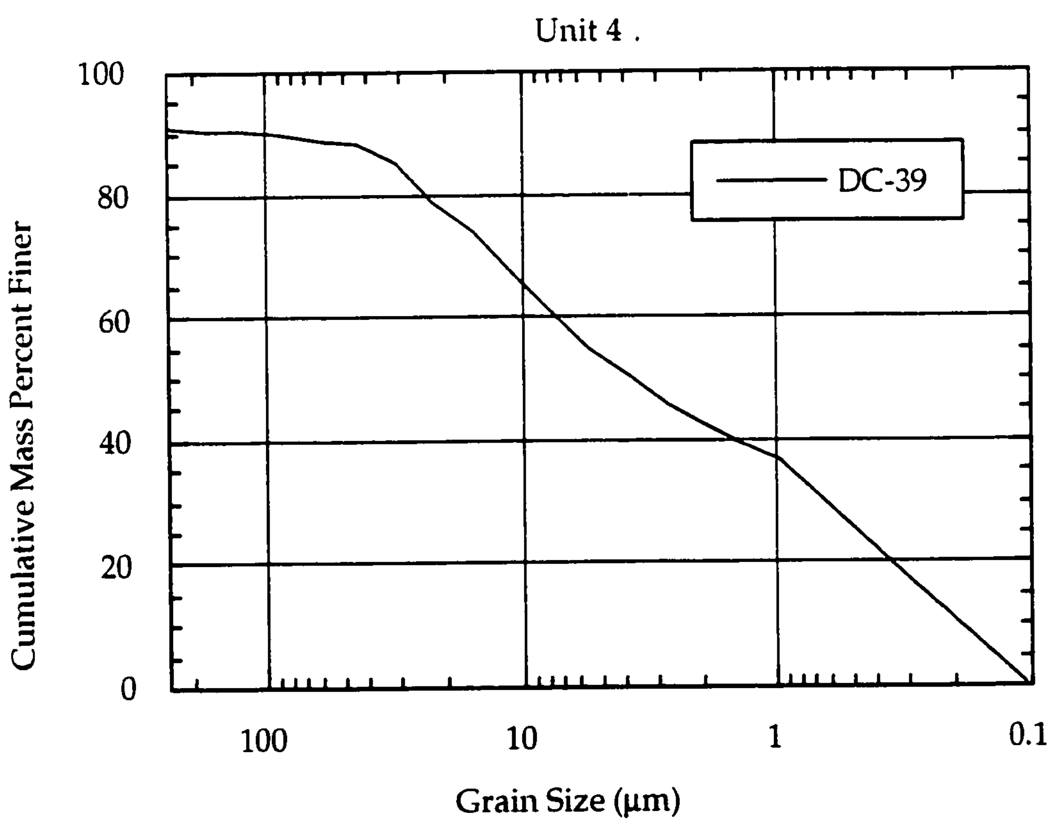


Figure 18. Grain size data for moderately-sorted Unit 4 sediments.

Mid-ridge Morphology

Although the previously described deposits are the four main sedimentary units found on the Mid-ridge, they are not always found in the same stratigraphic positions to each other. Figure 19 shows the units excavated in 1997/98 and the position of illustrated profiles (Figures 20-24). Sedimentary units 1, 3 and 4 occur across the entire Mid-ridge. Unit 2, however, is not present in all areas. Its upper surface is found anywhere from the ground surface to as deep as 100 cm and is often found at an angle to other deposits. When the deposits are mapped out in three dimensions, they show approximately three different lobes of organic rich Unit 2 (Figure 25). The strike of the lobes is 60° from magnetic north. The morphology of the deposits will be used as an aid to interpret the post-depositional activity that has occurred to transform the sediments.

Fabric Analysis

Fabric analysis was carried out on artifacts from Units 2 and 4 where clasts are a minor component, and on clasts in Unit 3 where artifacts are infrequent. Figure 26 shows stereonets portraying the three dimensional fabrics from these units. The fabric from Unit 4 shows that there is no dominant orientation of artifacts. Most of the artifacts are plunging from 0-30°. Lack of orientation suggests that these artifacts have not been moved laterally significantly from their original position. Frost heave has begun to vertically align some of the flakes. There is also a high degree of scatter in the fabric of clasts from Unit 3 although a dominant orientation of 60°/240° exists.

Unit 2 flakes appear to be more clearly oriented. There is a definite northwest trend with a best fit line of 155°/335°. This is perpendicular to the strike of the Unit 2 organic lobes and Unit 3 clasts. Orientation direction is downslope, towards the edge of the Mid-ridge. This demonstrates that artifacts have been moved by natural processes since original deposition.

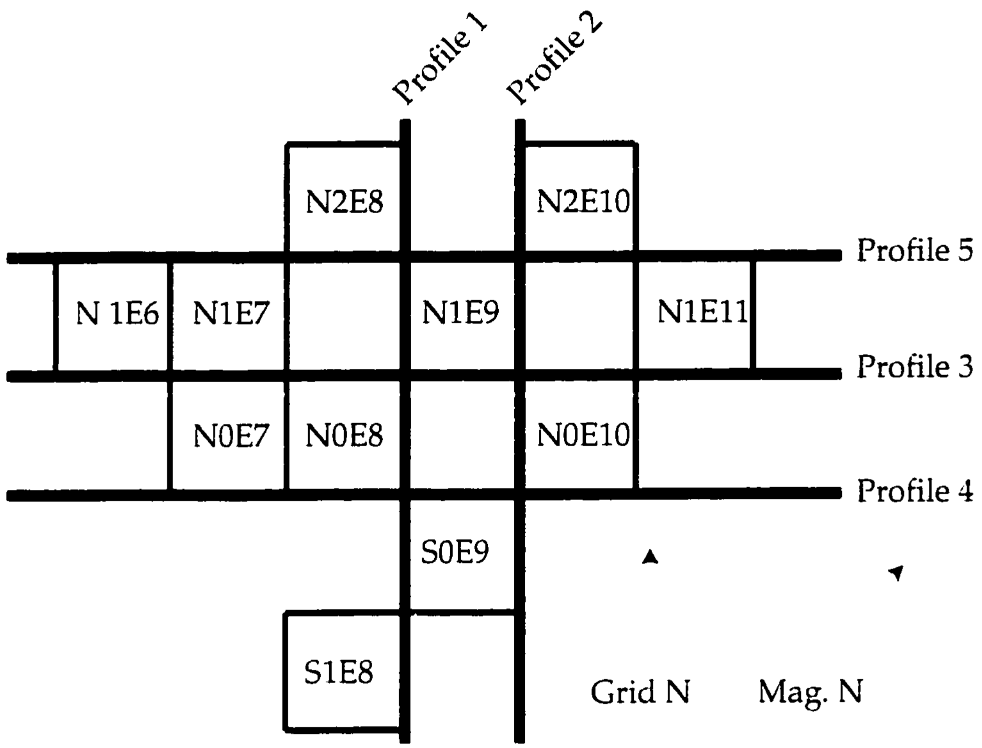


Figure 19. Excavation units on the Mid-ridge with sediments >30 cm thick.

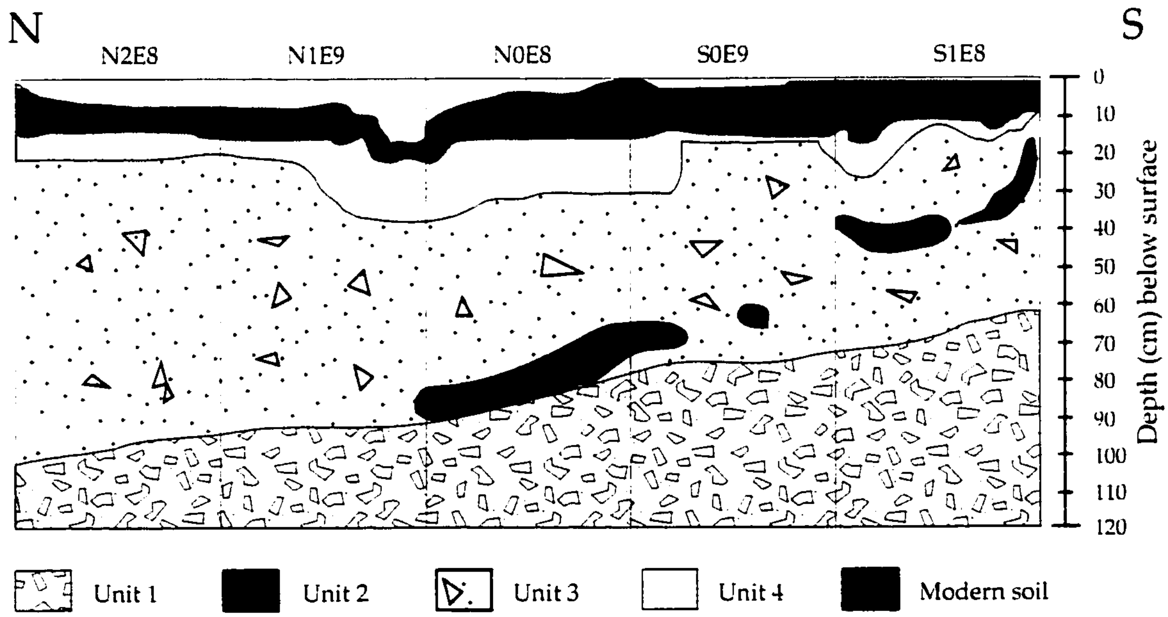


Figure 20. Profile 1, facing east.

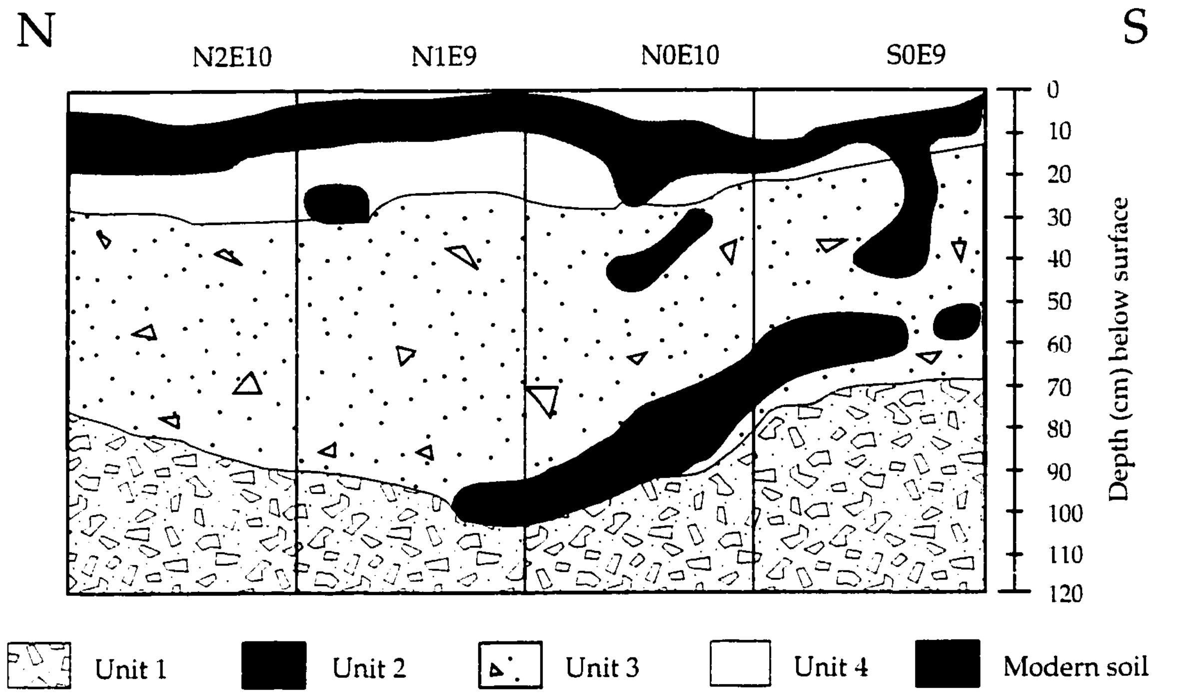


Figure 21. Profile 2, facing east.

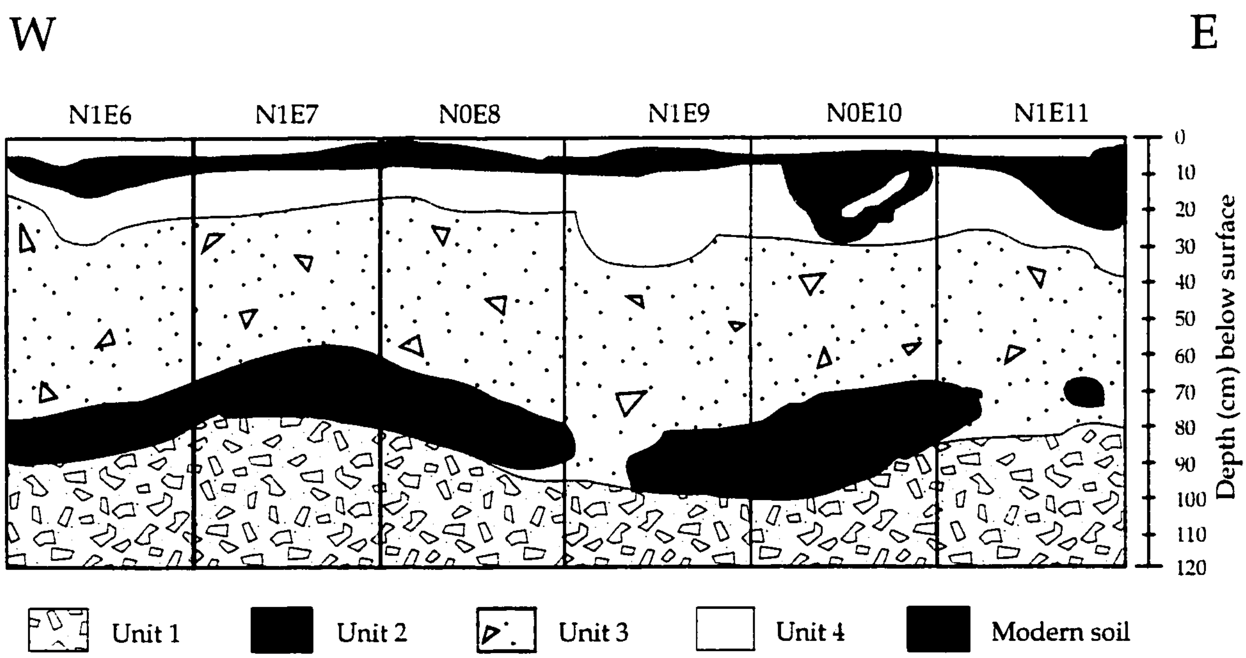


Figure 22. Profile 3, facing north.

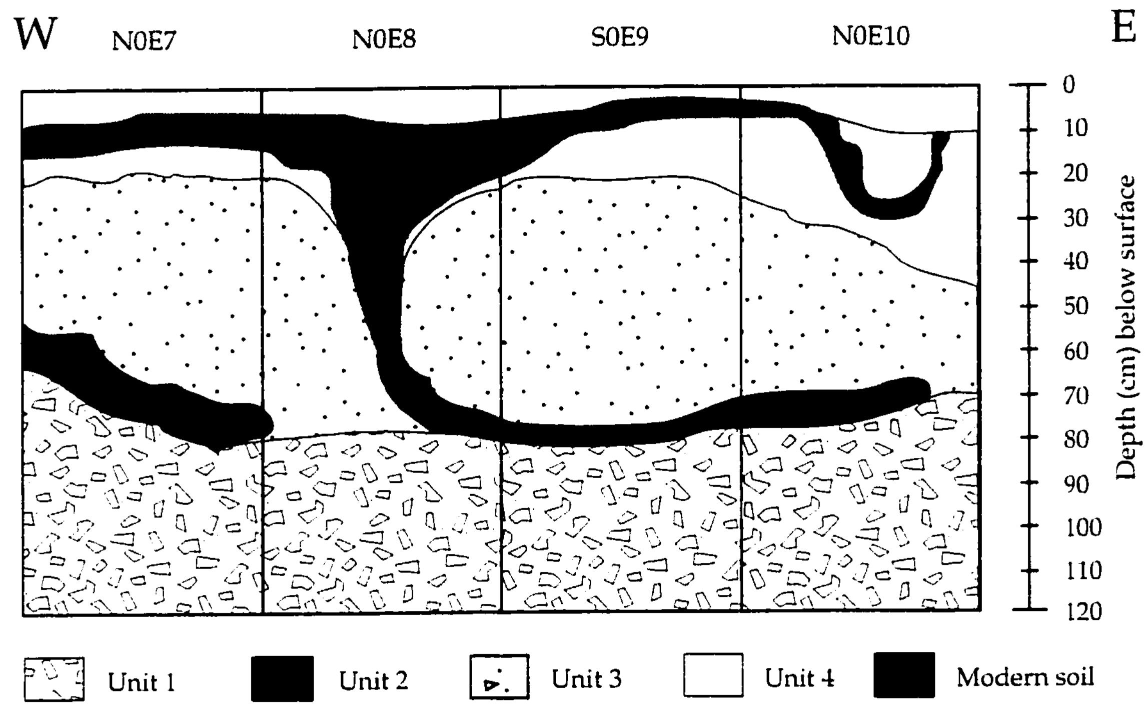


Figure 23. Profile 4, facing north.

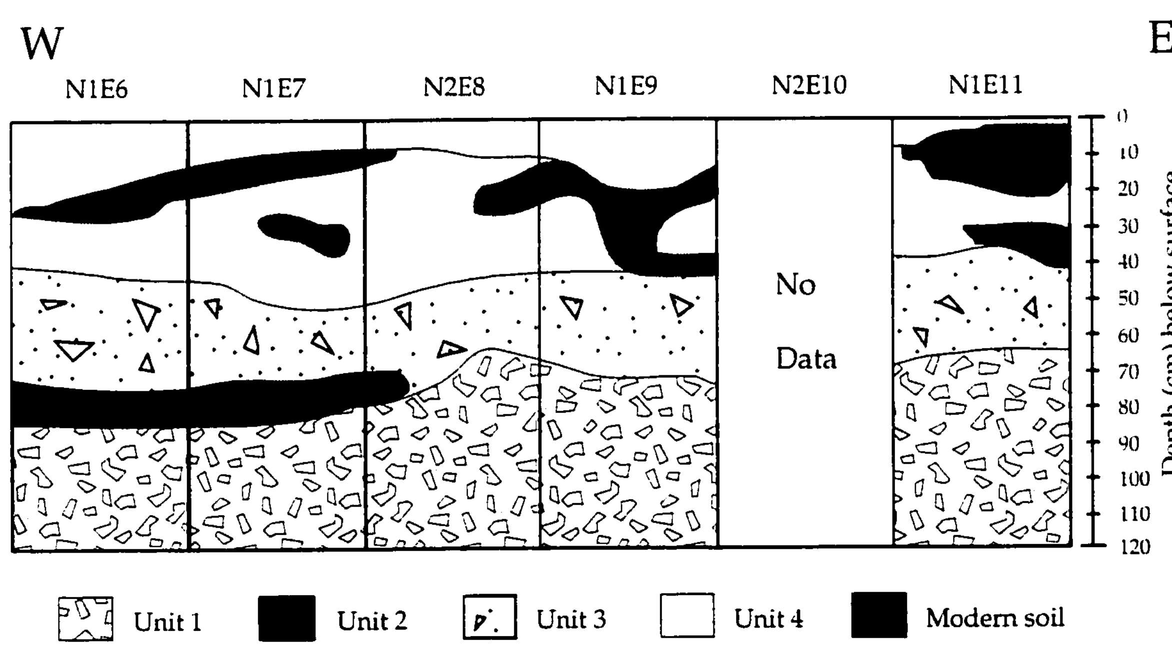


Figure 24. Profile 5, facing north.

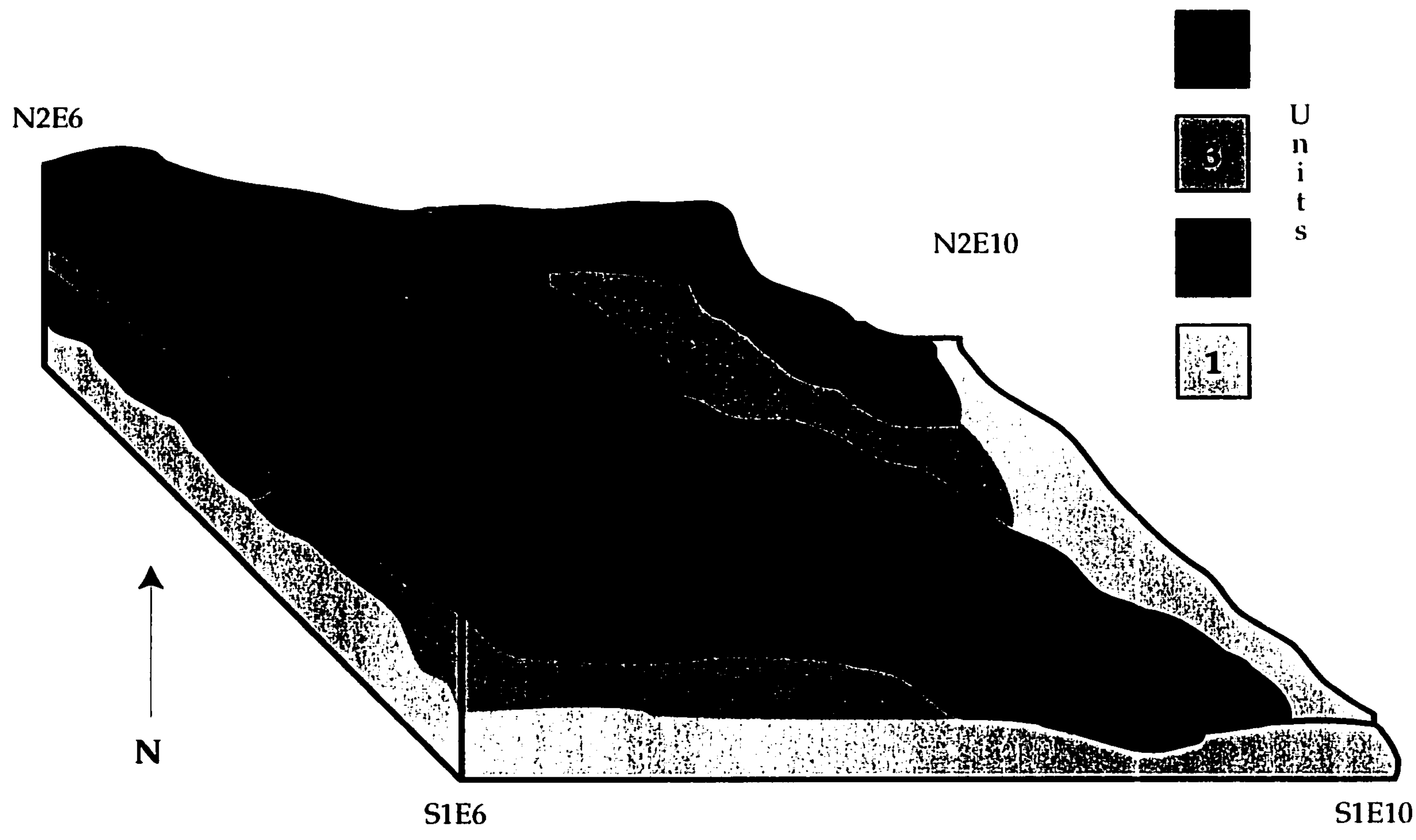


Figure 25. Three-dimensional representation of Mid-ridge buried deposits.

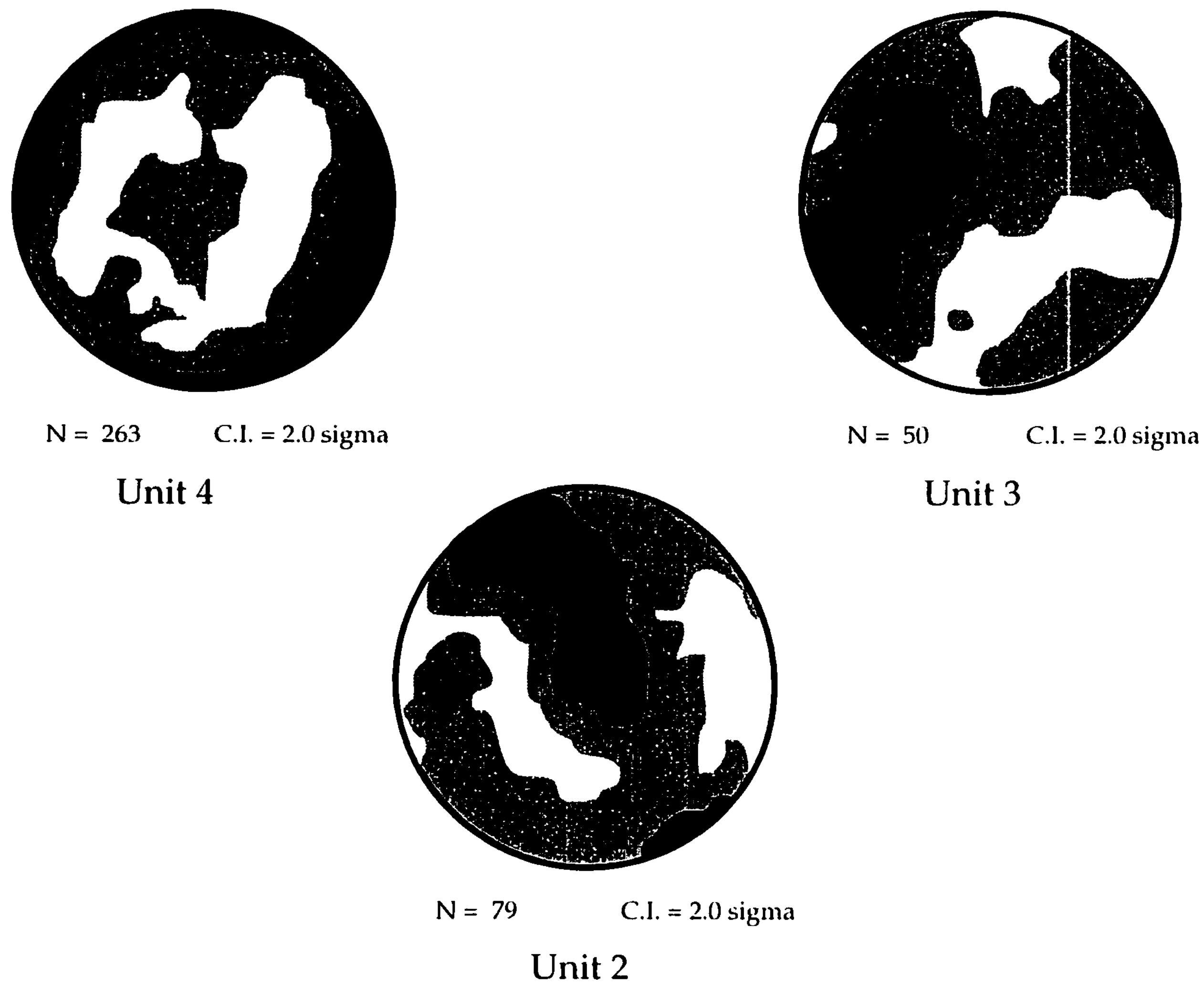


Figure 26. Fabric diagrams demonstrating the trend and plunge of clasts and artifacts within units 2, 3 and 4.

Radiocarbon Dating

Eight radiocarbon ages were determined from organic matter (wood, charcoal and bone) in Unit 2 (Table 2). All dates are recorded in uncalibrated radiocarbon years B.P. Samples were taken from two separate organic lobes to determine: 1) if the lobes are synchronous and 2) if there is a relationship between sample age and depth.

Three dates, C1, C2 and 98-5, were taken from an organic lobe stretching through excavation units N1E6 and N1E7 (Figure 27). C1 and C2 are two different materials (charcoal and wood), derived from the same sample. The resulting radiocarbon dates from these sub-samples overlap at two sigma (within 100 years), suggesting a reliable age estimate of 3,400 years B.P. for the sample. Bone from the same organic lobe provided a much younger age of 1,770±60 years B.P. The spread between the dates leads to three possible conclusions: 1) these dates reflect a very slow burial of organic matter through time, 2) the charcoal and wood dates pertain to the age of the buried soil on which the bone was deposited some time later. Burial of both these components may have occurred at the same time or 3) bone has absorbed younger humic acids from the overlying soil and is actually older than the radiocarbon dates suggest.

Five samples (98-1, 98-2, 98-3, 98-4, and 98-6) were taken at increasing depths along a second organic lobe (Figure 28). The oldest date, 5,290±50 years B.P. occurred in the deepest part of the lobe at 110-115 cm below surface. Dates get progressively younger with decreasing depth. A date of 2,820±60 B.P. occurred at 90-95 cm below surface, 2,590±50 years B.P. at 85-90 cm, 2,040±50 at 55-60 cm and finally 1,880±50 years B.P. at 40-45 cm below surface. These dates, although coming from samples in a single deposit (Unit 2), span more than 3,000 years of time. Because of the morphology of the unit and the order in which the dates occur, it is likely that the radiocarbon ages represent periods when different portions of the soil were buried. The deepest part of the soil was buried first, producing the oldest date. The soil was likely buried slowly over a period of a few thousand years.

Table 2. Accelerator mass spectrometer ages.

Identification	Description	Weight (mg)	Lab No.[1]	Years B.P.[2]	Unit
NcVi-3: C1	charcoal	49	TO-7121	3500 ± 60	N1E6
NcVi-3: C2	wood	163	TO-7122	3320 ± 50	N1E6
NcVi-3:98-1	charcoal	266	TO-7533	2820 ± 60	N0E10
NcVi-3:98-2	wood	36	TO-7534	5290 ± 50	N1E11
NcVi-3:98-3	charcoal	21	TO-7535	2590 ± 50	S0E9
NcVi-3:98-4	wood	43	TO-7536	1880 ± 50	S0E9
NcVi-3:98-5	bone	2400	TO-7537	1770 ± 60	N1E6
NcVi-3:98-6	wood	788	TO-7538	2040 ± 50	N0E8

[1]Isotrace Laboratory, University of Toronto.

[2]Uncalibrated radiocarbon years before present.

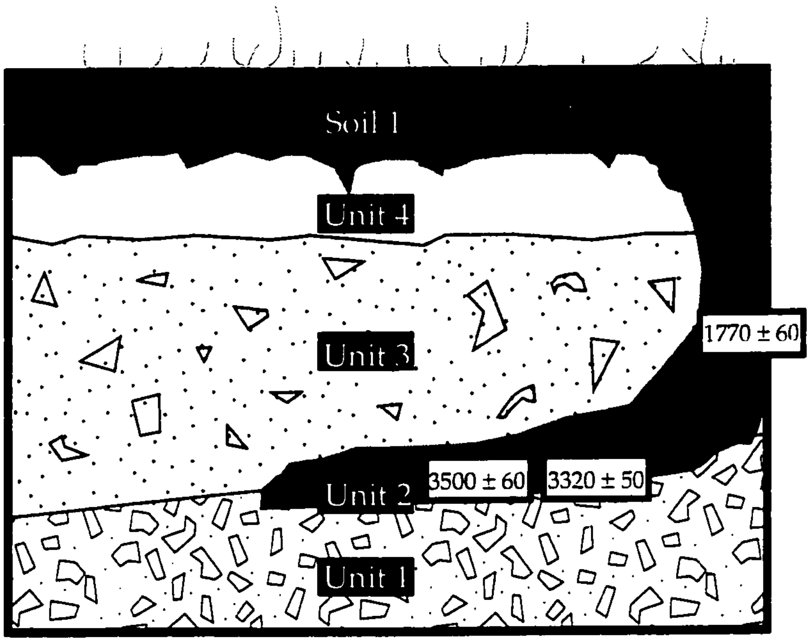


Figure 27. Radiocarbon dates (98-5, C1, C2) associated with organic lobe.

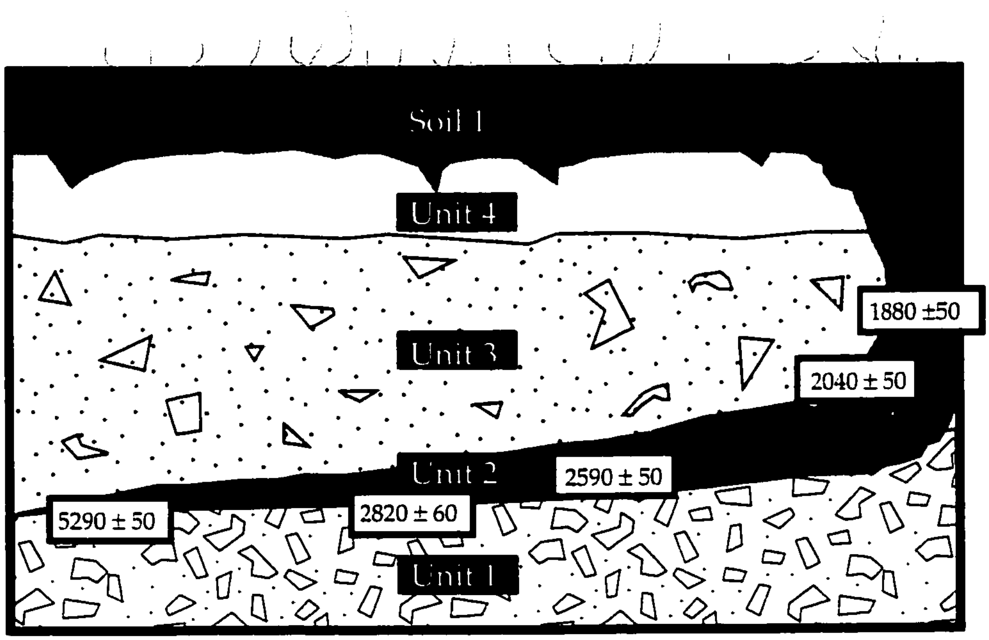


Figure 28. Radiocarbon dates (98-4, 98-6, 98-3, 98-1, 98-2) associated with organic lobe.

Comparing radiocarbon ages between the two organic lobes suggests that both were buried during the same time period (mid to late Holocene). It also demonstrates a progressive burial over a period of a few thousand years. Artifacts within and on the soil were also buried beginning at least 5,280 years before present.

Post-Depositional Site Transformation

The depositional processes responsible for creating the sedimentary units on the Mid-ridge at Dog Creek have been discussed. Secondary features including mottling in Unit 4, fabric of artifacts and clasts and the presence of a buried soil indicate that post-depositional processes have also been active. Cryoturbation, frost heave and solifluction are the three main periglacial processes acting to alter the sedimentary and archaeological record at the site.

Evidence and significance of cryoturbation

Cryoturbation is evident in the sedimentary profiles on the Mid-ridge in the form of involutions of organic matter mixed into mineral soil. An example of this is shown in Plate 17. Convoluted lenses of organic matter in mineral material and organic filled frost cracks (Plate 18) are commonly present in the upper 30 cm of the sedimentary sequences. The organic material mixed with the sediment is well decomposed and likely originates from the modern soil rather than buried surface vegetation. Together, the involutions and infilled frost cracks make up earth hummock morphology. Frost cracks (which eventually infill) mark the edges of hummocks and cryoturbated sediments occur between cracks. These earth hummocks or non-sorted polygons (Washburn 1980: 137) occur extensively over the Mid-ridge and surrounding area (Chapter 2).

Fine-grained sediments such as those on the Mid-ridge are ideal for earth hummock formation (Yershov et al. 1983, Zoltai et al. 1978). The deposits in Unit 4 are predominantly composed of silt and clay-sized grains (19% sand, 43% silt and 38% clay). Hummocks are created by the churning of sediment, soil and organic matter by frost heaving during freezing of the active layer (Linell and Tedrow 1981, Washburn 1980, Zoltai et al. 1978).

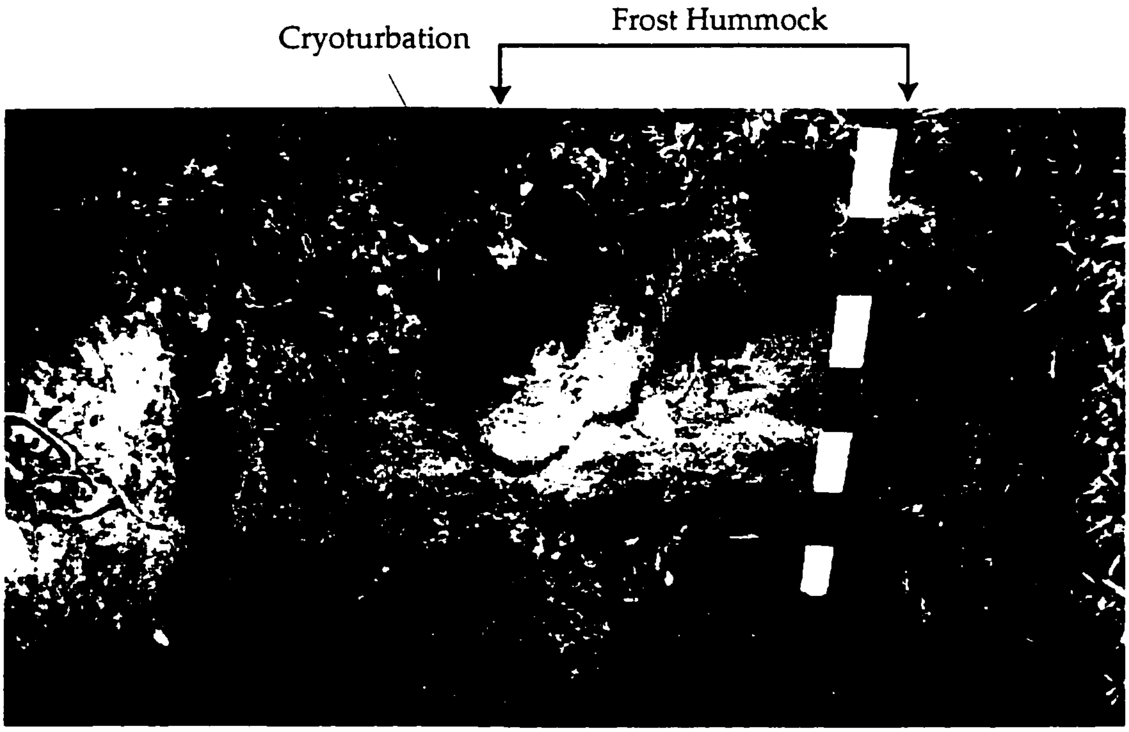


Plate 17. Cryoturbation in N0E10, south wall.

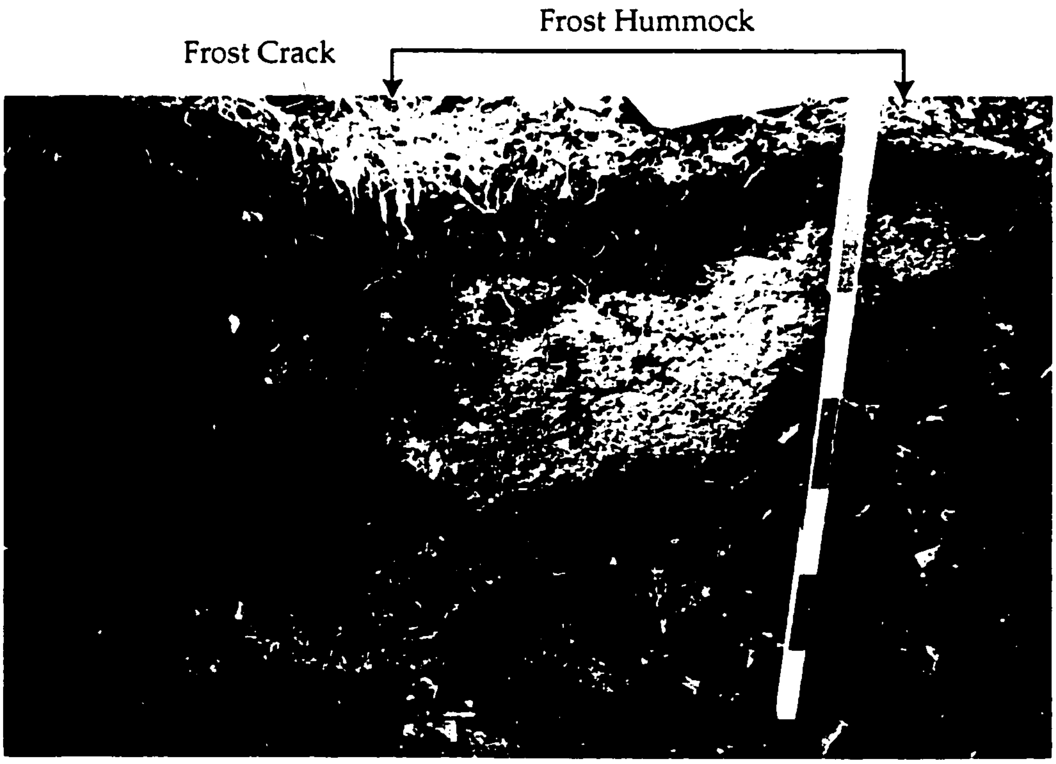


Plate 18. S2E8, east wall. Frost crack and infilled organic matter.

Cryoturbation and earth hummock development may not be active at the Dog Creek site at present. Conditions necessary for these types of periglacial activities include shallow permafrost (<1 m to surface) and adequate soil moisture. Water content of the active layer influences ice growth and the effectiveness of frost heave. The greater the soil water, the greater the freezing pressures in a deposit which leads to increased cryoturbation and earth hummock development (Murton and French 1994). Although it is evident that these processes have acted on Mid-ridge deposits, the active layer at the site presently reaches into bedrock and the sediments are dry. Conditions do not appear to by sufficient for cryoturbation and earth hummock development to be occurring today. The frost cracks and cryoturbation viewed in profiles on the Mid-ridge may provide evidence that past climatic conditions included a shallower active layer and greater soil moisture.

Evidence and significance of frost heave

Frost heave leaves a measurable effect on artifacts and clasts by aligning them vertically and uplifting them through the sedimentary profile. Although vertical displacement of artifacts is difficult to measure, vertical alignment can be documented relatively easily by recording fabric. It is assumed that artifacts, when deposited by humans, are left on a surface laying horizontally or at low angles. After burial, frost heave can begin. Table 3 illustrates the plunge of artifacts found in Unit 2, the buried soil, and Unit 4, the modern soil. Seventy percent of artifacts that were found deeply buried (Unit 2), have plunges greater than 20°, whereas greater than half of the flakes in the modern soil are dipping at very low angles (<20°). Depth of the artifacts and plunge angles are clearly associated. This likely relates to the amount of time the artifacts have been buried. The longer the exposure to frost heave underground, the more aligned the artifact will be. Those artifacts found in the modern soil are further from the freezing front and have been on the surface for a longer period of time, limiting the effectiveness of frost heave. Artifacts found within the modern soil have likely only been buried recently by aeolian silts and have not experienced as many freeze-thaw cycles as those in the Unit 2 soil. Artifact plunges demonstrate that frost heave has been active at the site. Artifacts in the buried soil have

Table 3. Plunges of artifacts in the modern and buried soils.

Unit	0-19°	20-39°	40-59°	60-90°
4	55%	25%	10%	10%
2	30%	31%	19%	20%

greater vertical alignment than those in the modern soil because of proximity to the freezing front and greater number of exposures to freeze-thaw cycles.

Evidence and significance of solifluction

Solifluction is an important transformation mechanism that has been active at the Dog Creek site. There are four lines of evidence to suggest that solifluction has taken place. These include: 1) the presence of a buried soil (Unit 2), 2) the angle of Unit 2 to adjacent deposits and the morphology of the organic lobes and 3) fabric and 4) age.

The buried soil is situated between Unit 1, the bedrock regolith, and Unit 3 where it is found in the Mid-ridge. As previously discovered, the parent material for the soil is not from Unit 1 deposits. The mineral material in the soil was interpreted as having an aeolian origin. Of the available sediments on the Mid-ridge, only Unit 4 deposits make the most likely parent material for the buried soil. Unit 2 and Unit 4 are both well sorted clay loams. Figure 29 is a plot of calcium carbonate percentages versus organic content of samples from each of the four units on the Mid-ridge. It is apparent from the graph that similar amounts of $CaCO_3$ occur in Units 2 and 4. The buried soil resembles the modern soil in all respects except for percentage of organic matter. The buried soil is inferred to have a parent material of Unit 4 deposits with increased organic carbon due to the burial and decomposition of large amounts of surface vegetation. If this interpretation is correct, the surface soil had to be buried after it formed and post-soil formation to be presently located between Unit 1 and Unit 3.

The complex morphology of the buried soil relative to other deposits also suggests that it is not in its original depositional position. It is found in sedimentary profiles sloping from the surface to greater than a metre depth (Figure 20, 21, 23). The modern and buried soil, when viewed in profile (Figure 27, 28), takes on the shape of an inclined fold. The orientation of the soil to other units is not controlled by surface topography and appears to be a secondary structure.

The presence of oriented fabric from Unit 2 artifacts also demonstrates that movement has occurred within the soil. Artifacts are oriented northwest,

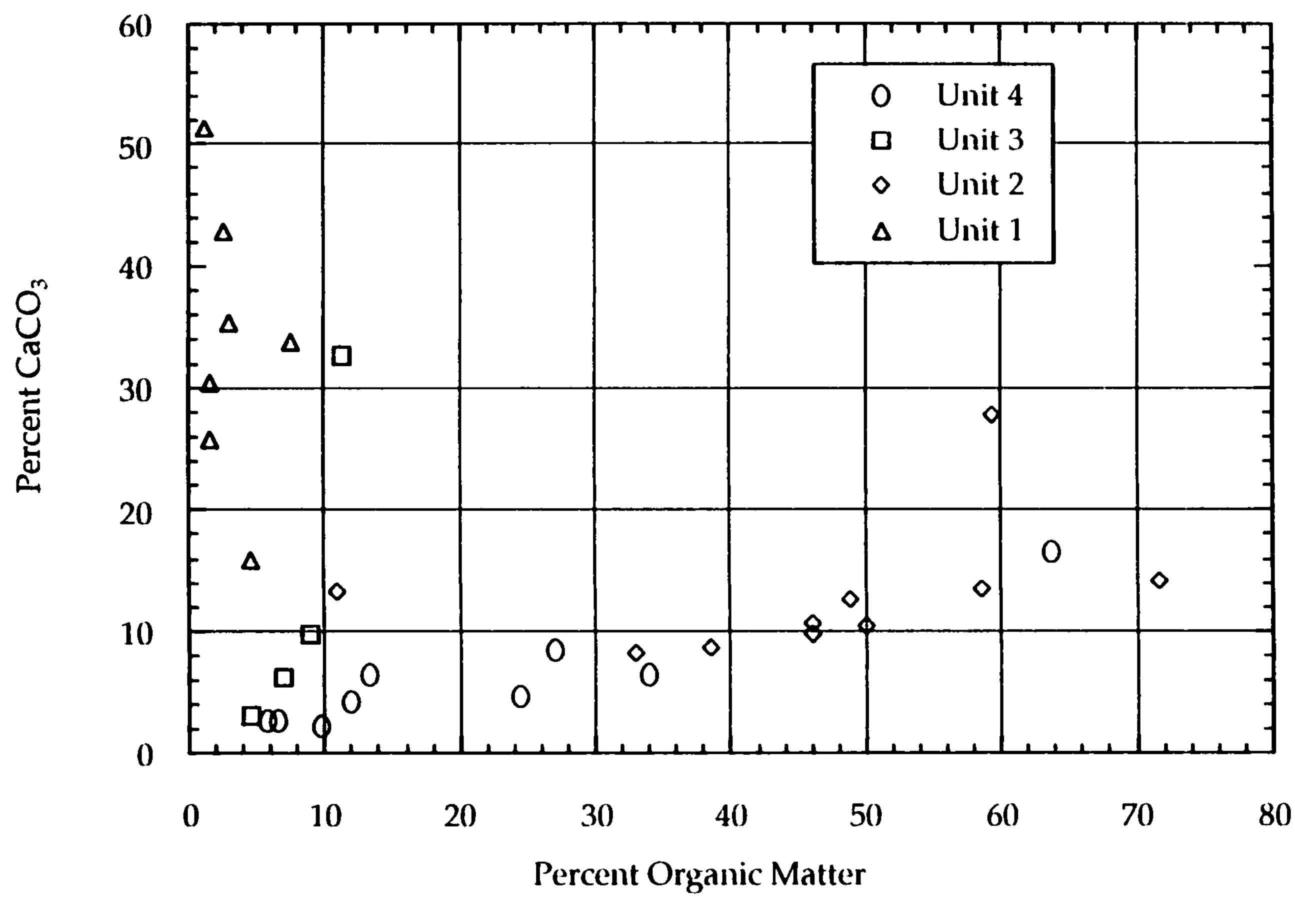


Figure 29. Percent organic matter versus percent calcium carbonate in the sedimentary units of the deep deposits.

which is upslope, away from the edge of the Mid-ridge. Gravity acting on the deposits would orient the artifacts downslope (SE). If the soil was overturned by folding, however, expected artifact orientation would be towards the northwest as seen in the stereonet diagrams. The slow burial of the Unit 2 soils as interpreted, based on radiocarbon dates, also shows that it is not in its original position. If a soil exposed at the surface was buried by sediment, all samples of that soil would demonstrate similar radiocarbon ages. All of this evidence suggests that post-depositional processes acted to move Unit 2 to its present position.

Solifluction is the periglacial process that is most likely responsible for the burial of Unit 2. Solifluction in these deposits could have taken place by two different processes. First, the surface soil may have been buried by downslope movement of the Mid-ridge sediments resulting in an overturned fold. Second, it is possible that Unit 2 sediments and organic matter are actually infilled frost cracks that have been elongated by downslope movement of the sedimentary units.

The first mechanism by which Unit 2 may have been buried is shown in Figure 30. The first profile shows the original sedimentary sequence on the Mid-ridge. Bedrock regolith was capped with aeolian silts on which the modern soil developed. During a warmer or moister time period, sediments, saturated to the base of the active layer, could be reworked by solifluction down the 5% slope above the impermeable permafrost table. The solifluction lobe, doubling over itself, would cause the surface soil to be buried. As the iobe rolled over, unfrozen portions of Unit 1 and part of the mineral deposits in Unit 4 would be mixed, creating a new deposit, Unit 3 (Profile 2). Plate 19 shows a typical solifluted surface.

The shape of the Unit 2 buried organic layer, fabric and radiocarbon dates support this hypothesis. The depth to the base of the active layer when solifluction was active can be approximated as the lower surface of the organic lobe. Because solifluction is not occurring in the Mid-ridge sediments today, this evidence suggests that the climate was moister, or that the sediments were less

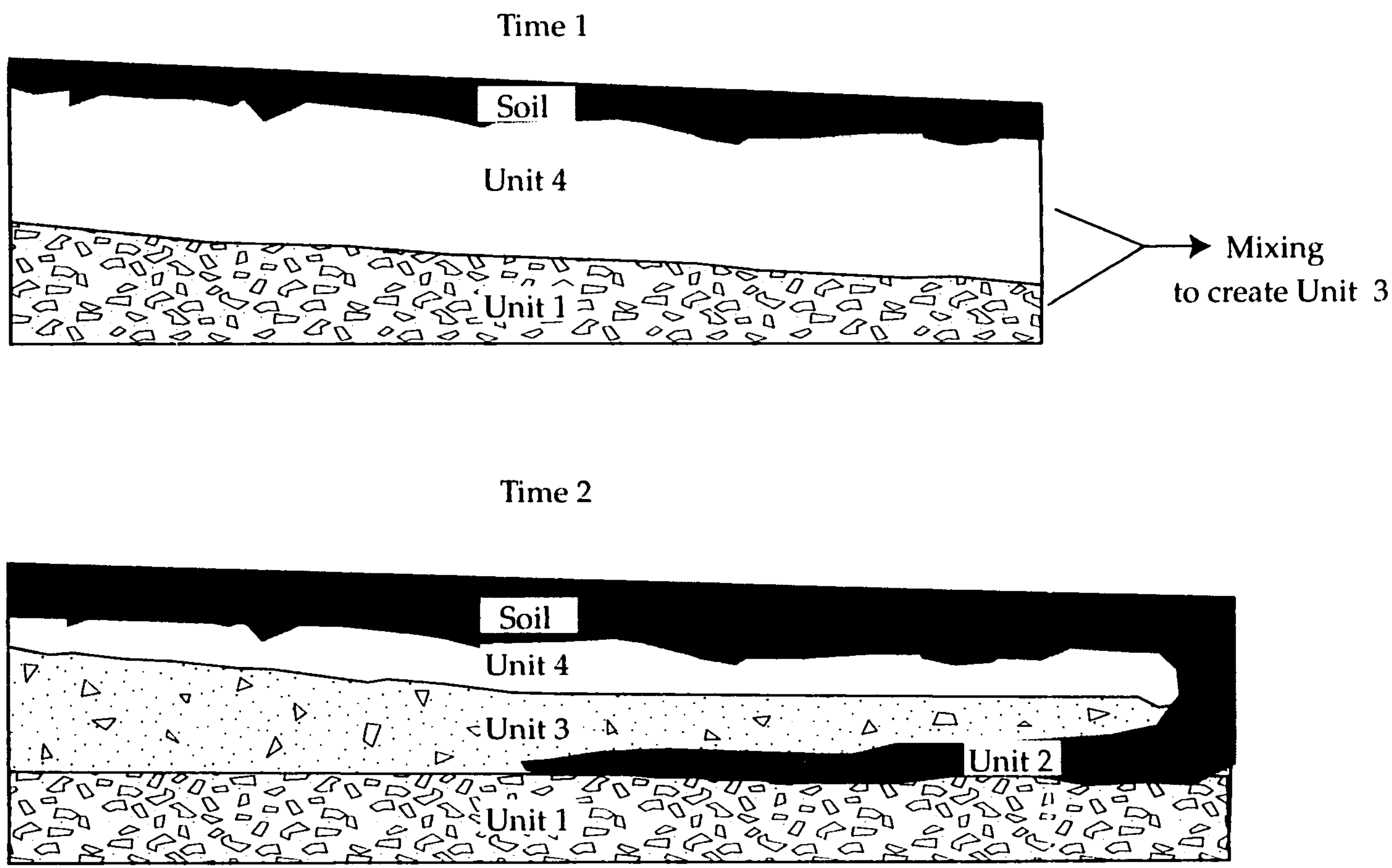


Figure 30. Mechanism of solifluction causing mixing of deposits and folding of organic rich soil.

Plate 19. Two folded solifluction lobes or soliflucted frost cracks south wall, N0E8 and N0E7.

well drained, from about 5,000-2,000 years B.P. Drainage may have been prevented by a shallower active layer than today.

An alternative explanation for the buried organic unit in the Mid-ridge deposits includes both frost cracking and solifluction. Frost cracks may have occurred in frozen sediments on the Mid-ridge[6] (Figure 31). When the active layer thawed, cracks would be infilled by surface sediment, artifacts and vegetation. Downslope movement of the saturated active layer would cause elongation in the infilled frost cracks. Because solifluction occurs fastest on the surface of a deposit (Benedict 1970), the top of the frost crack would move further downslope than the base. Plate 20 shows a possible elongated frost crack in which the upper portion of the crack has been separated from the base by faster downslope movement.

This scenario is supported by the vertical segments of organic soil seen in many of the profiles on the Mid-ridge. In this case, radiocarbon dates would reflect different periods of frost crack infilling by progressively younger vegetation rather than slow burial of one soil. Only the fabric data is not explained by this mechanism. If Unit 2 was being moved straight downslope, not overturned, artifacts would be expected to orient towards the southeast.

Both mechanisms for burial of the Unit 2 soil are reasonable and there is no outstanding evidence leading to one scenario. Whichever the case, the active layer during the mid Holocene was shallower than at present and the sediments were likely moister for solifluction to have been active.

Bioturbation and deflation

Non-periglacial processes at the Dog Creek site have also contributed to mixed and disturbed sedimentary and cultural units. These include bioturbation and deflation. Bioturbation is most evident in the deep deposits on the Mid-ridge. Arctic ground squirrels actively burrow in the upper 30+ cm of sediment. Modern burrows are hollow but older ones are commonly infilled with surface soil. It is difficult to distinguish between krotovinas and cryoturbated organic material in these deposits.

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[6] Frost cracking is occurring at present on the Mid-ridge (Plate 18).

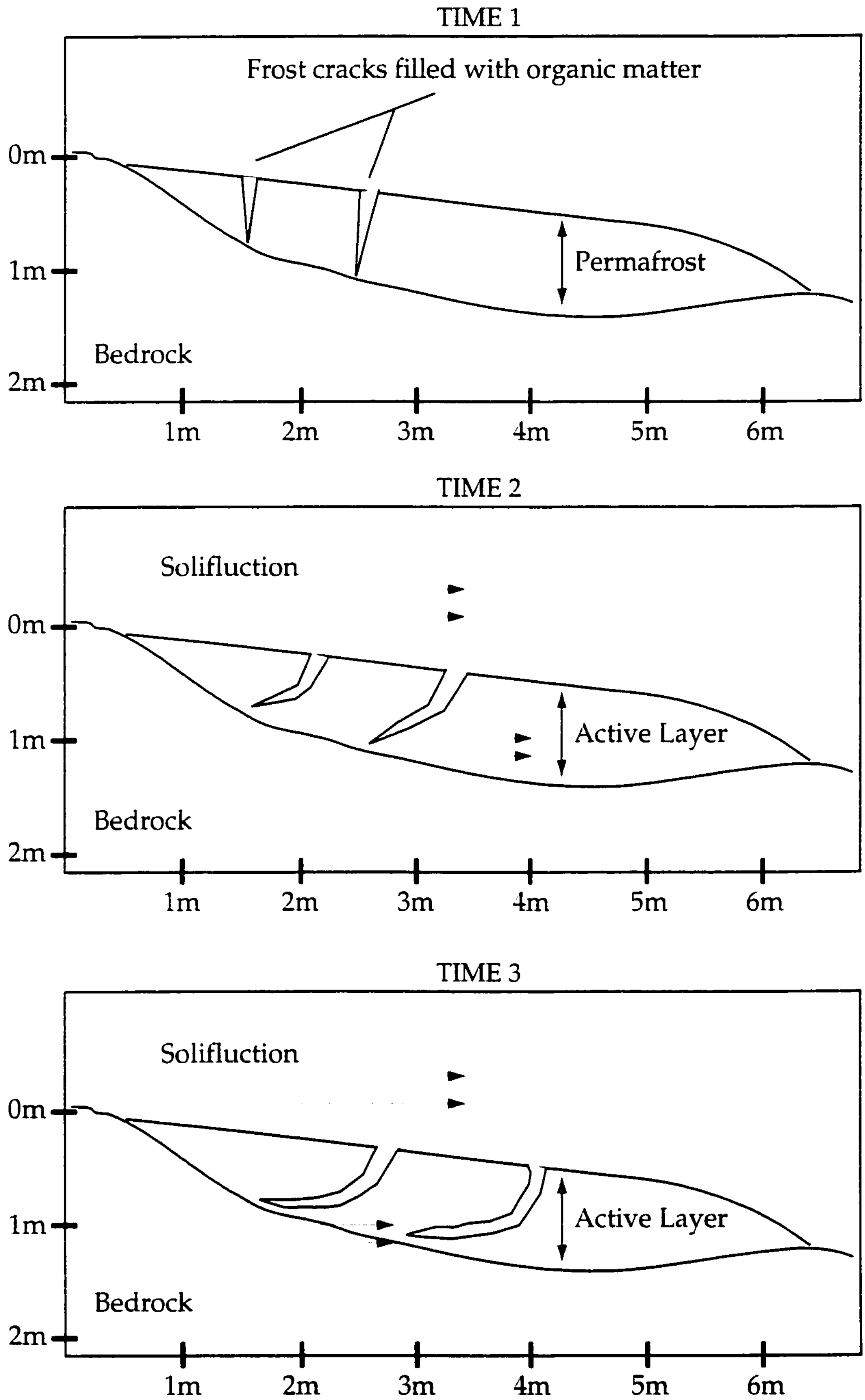

Figure 31. Dragging frost cracks by solifluction of the active layer.

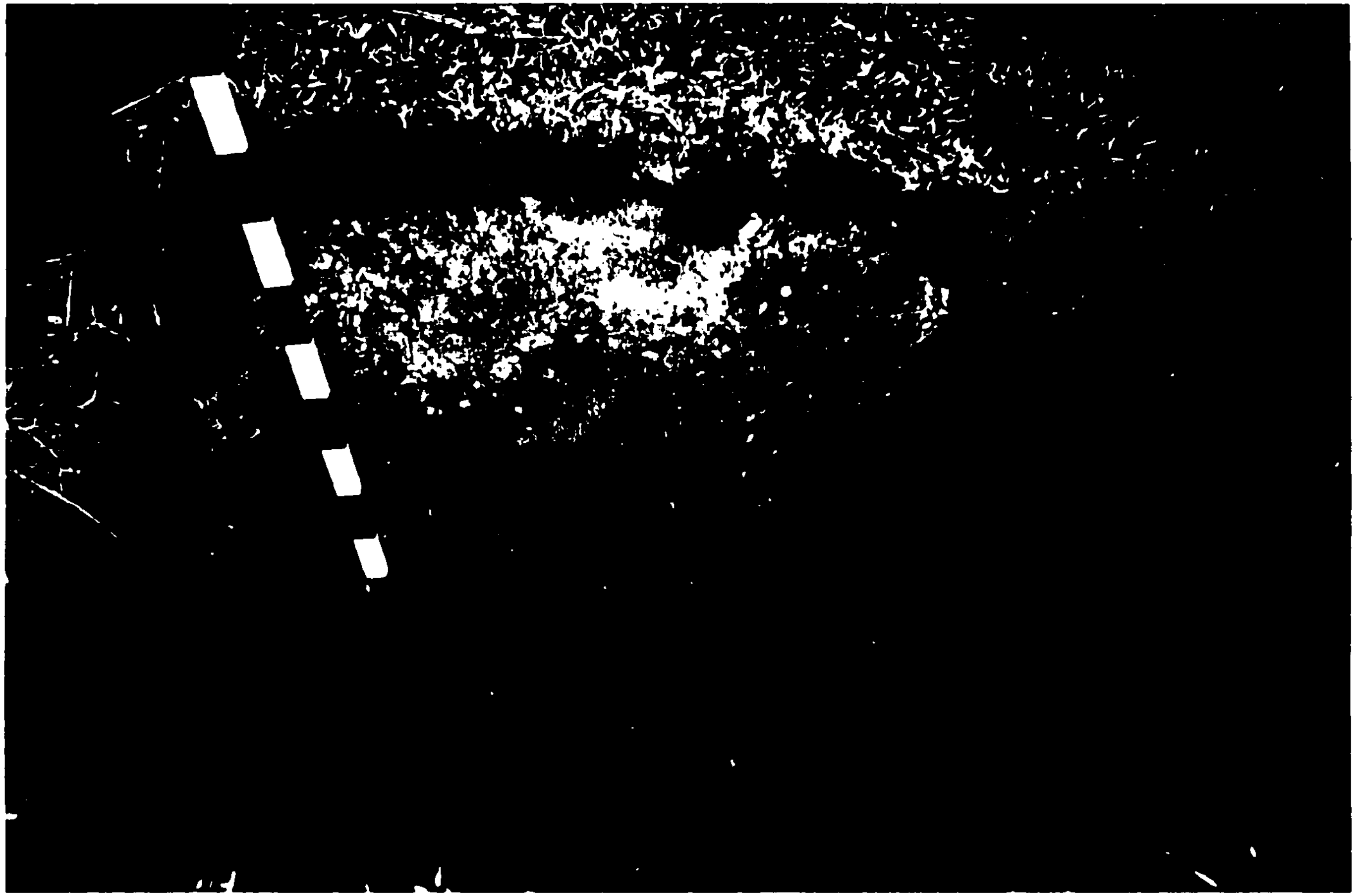

Plate 20. N1E7 south wall, solufluncted organic deposit.

Deflation has also been an active process at Dog Creek. Over much of the Mid-ridge, River-ridge and surrounding area, sediment and vegetation cover is thin. Deposition on the ridges occurs at a slower rate than wind erosion creating sediment-scoured surfaces. Artifacts from cultural occupations at the site are condensed into 10 cm of sediment everywhere at the site apart from the Mid-ridge deep deposits. Multiple possible occupations are represented one thin stratigraphic layer.

Archaeological Implications

Geoarchaeological reconstruction of the processes that formed and altered the Dog Creek site can aid in the interpretation of the archaeological record. By demonstrating that Unit 2 consists of the surface soil buried by solifluction or in frost cracks, the relationship between artifacts in Units 2 and 4 can be understood. The artifacts found buried deeply today, were once on the surface, and most likely part of the same cultural assemblage as those in and on top of Unit 4. They do not represent a discrete cultural layer. Although there may have been multiple occupations at the site, they all occurred on one surface and cannot be distinguished by geological methods. Radiocarbon dates from samples trapped in the organic lobe with artifacts provide an age estimate of when artifacts were buried as well as a minimum age for occupation at the site. The soil (and artifacts within) was buried slowly over a period of about 3,000 years based on the maximum spread of radiocarbon dates. A minimum age of occupation at Dog Creek is 5,290 years B.P., the date at which solifluction began or when soil was initially deposited into frost cracks.

Burial of the artifacts in Unit 2 resulted in displacement from their original provenience. Solifluction, frost heave and cryoturbation have all acted to rework and disturb the original cultural deposit. Although periglacial processes have transformed the sedimentary and archaeological record, it was possible to determine that all artifacts were deposited on one surface.

CHAPTER 4 Modern and Palaeo-Vegetation Records

Introduction

The modern and late Quaternary vegetation history of the northern Yukon is well known (Cinq-Mars 1979, Cwynar 1982, Cwynar and Spear 1991, 1995, Ovenden 1985, Ritchie 1982, Ritchie et al. 1983, Schweger 1982). Modern pollen rain from moss polsters and lake sediments at the Dog Creek site and mid to late Holocene pollen from the buried soil in the Mid-ridge deposits were examined to place the Dog Creek vegetation records into a regional picture for the time frame represented by the deposits. This evidence is useful for evaluating microclimatic conditions at the site during specific time periods.

Pollen Preservation

Preservation of pollen plays a key role in the ability to recognize grains and in the number of taxa found in a pollen assemblage. Preservation varied greatly between samples in this study because of the wide variety of matrices from which pollen was extracted.

Pollen was preserved better in the modern pollen samples than in the buried deposits. The same number of different taxa were recognized for both kinds of samples, however (15 modern, 15 buried taxa). The best preservation was found in pollen from modern lake sediments where all of the grains were whole and plump because of the low oxygen environment. Preservation was good in moss polsters as well, although some grains were shriveled and lacked clear ornamentation. The poorest preservation was found in the pollen of the modern soil. Concentrations were so low that counting was not possible (<10 grains of pollen per 100 grains of introduced exotic). This poor preservation was attributed to the aerobic environment of the soil.

The buried soil samples had varying degrees of pollen preservation. Although pollen was abundant, grains were normally badly degraded. Grains were most often disarticulated (especially *Picea*) or flattened and shriveled (alder and birch). It was rare, however, that pollen was deformed beyond recognition. Shriveled alder pollen resembled Tertiary alder but the elevation of the site prevents a mechanism of introducing Tertiary age pollen and similar shriveled pollen was found in the modern pollen rain samples from moss polsters. Deterioration of pollen grains likely occurred when the soil was exposed and aerobic conditions existed. Overall preservation of grains was adequate for identifying pollen from the buried soil.

Preservation could play a factor in the number of taxa found in samples from the site. The most frequent grains were *Picea, Betula* and *Alnus* but these types of grains are most often preserved in the fossil record in general (Hall 1981, Ritchie 1982). It is also possible that the large quantity of *Picea* grains found deep in the buried soil could be a factor of differential preservation of grains as they outnumber the rest of the taxa as much as 6:1. It is thought, however, that this ratio reflects the vegetation at the time more than factors of preservation because: 1) poor or differential preservation would result in low numbers of grains and 2) decreasing pollen concentrations and increasing deterioration of grains occurs with increasing depth (Hall 1981). In the deeply buried samples with high percentages of *Picea* pollen, there were substantial counts of other grains (for example, 23 grains of birch, 22 grains of alder and 5 grains of willow were counted in sample 22) and increasing pollen concentration and preservation of individual grains occurred with depth. It was not possible to determine the effects of sedimentation rate on grain concentration in this study because the pollen was extracted from a buried soil rather than a stratigraphic sequence.

Preservation factors (shriveling and tearing) have also affected the size of pollen grains. This makes it difficult to differentiate between arboreal and shrub birch at the site and to distinguish white spruce (*P. glauca*) from black spruce (*P. mariana*) in the fossil pollen record (Ives 1977, MacDonald 1987). Although arboreal birch pollen is generally larger than shrub birch, there is a large overlap in size distribution (Ives 1977). Distinguishing between the two was not attempted using samples from the site. Black spruce is dominant at the site today but either type of spruce could have been prevalent during the mid Holocene.

Preservation plays a key factor in the identification of grains and reliability of pollen assemblages at the Dog Creek site. Despite limitations due to preservation factors, a basic vegetation reconstruction based on pollen records was possible.

Modern Pollen

Modern pollen was extracted from moss polsters collected at the Dog Creek site and from shallow lake sediments in a small (20 m diameter) oxbow lake 60 m south of the site. Pollen from the lake sediments were expected to reflect local rather than regional vegetation characteristics because of the small size of the basin (Jacobson and Bradshaw 1981). The lake pollen is time-averaged due to frequent mixing in shallow water levels (<3 m). Modern pollen counts from eight samples (3 oxbow lake sediments and 5 moss polsters) are given in Appendix VI.

Results of pollen analysis show a vegetation assemblage dominated by shrubs (68%), with a strong arboreal component (26%) and lesser amounts of herb vegetation (6%) (Figure 32). The most important components of the pollen assemblage average *Picea* (25.5%)[7], *Alnus* (25.2%), *Betula* (27.5%), Ericales (7%), *Salix* (5.7%) and Graminae (2.4%).

The modern pollen components are consistent with regional records presented by MacDonald and Ritchie (1986) and Ritchie (1982). Figure 33 presents modern pollen data from 43 sites in tundra and forest tundra environments as analyzed by MacDonald and Ritchie (1986). The authors counted pollen from these sites and used discriminant analysis to determine which vegetation zones were represented by the pollen assemblages (e.g. tundra, boreal forest, grassland etc.). They found that modern pollen rain was a good reflection of regional vegetation.

When the pollen percentages from the eight samples in this study are compared to the data from MacDonald and Ritchie (1986) (Figure 33), it is clear that the assemblages are consistent with the forest tundra vegetation zone. There is a similar amount of spruce pollen, trace amounts of pine[8], slightly higher than average amounts of birch, similar percentages of alder, willow and

[7] Pollen percentages of each taxa are given in averages from the eight sites.
[8] Pine is not found in the region today. Trace percentages in the pollen records reflect pollen blown in from another location.

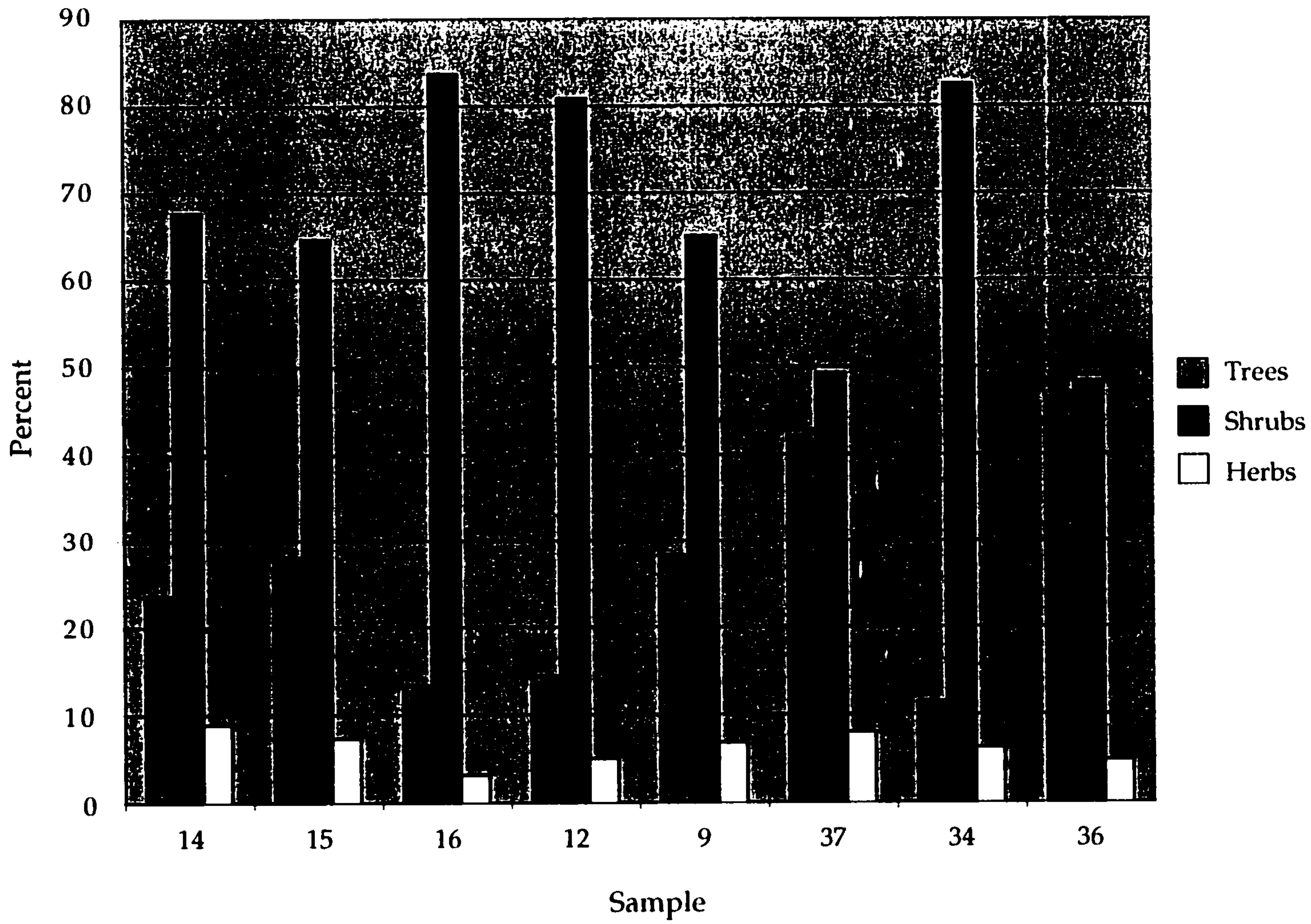

Figure 32. Modern pollen percentages.

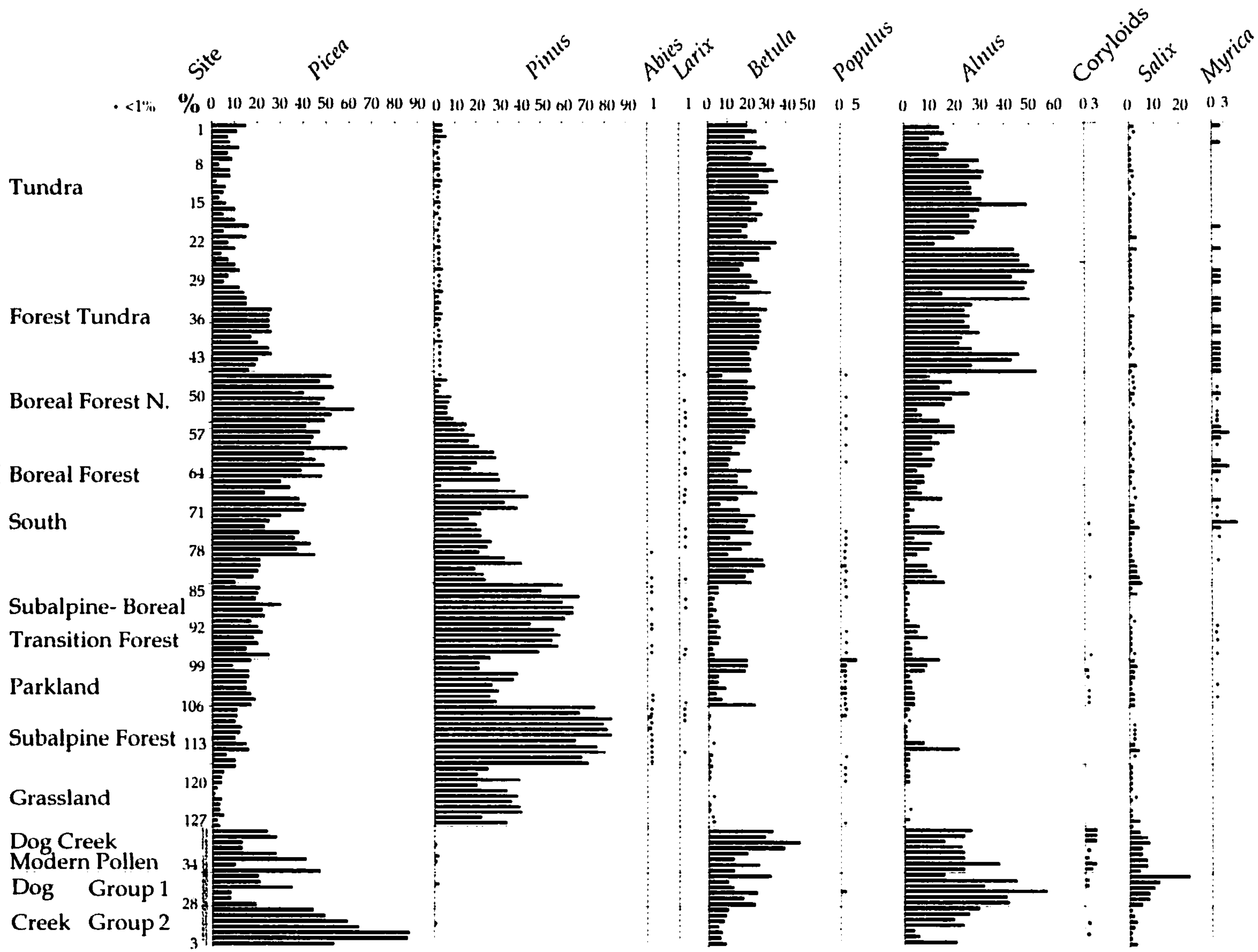

Figure 33. Modern pollen spectra from MacDonald and Ritchie (1986), sites 1-127 and Dog Creek, sites 14-3.

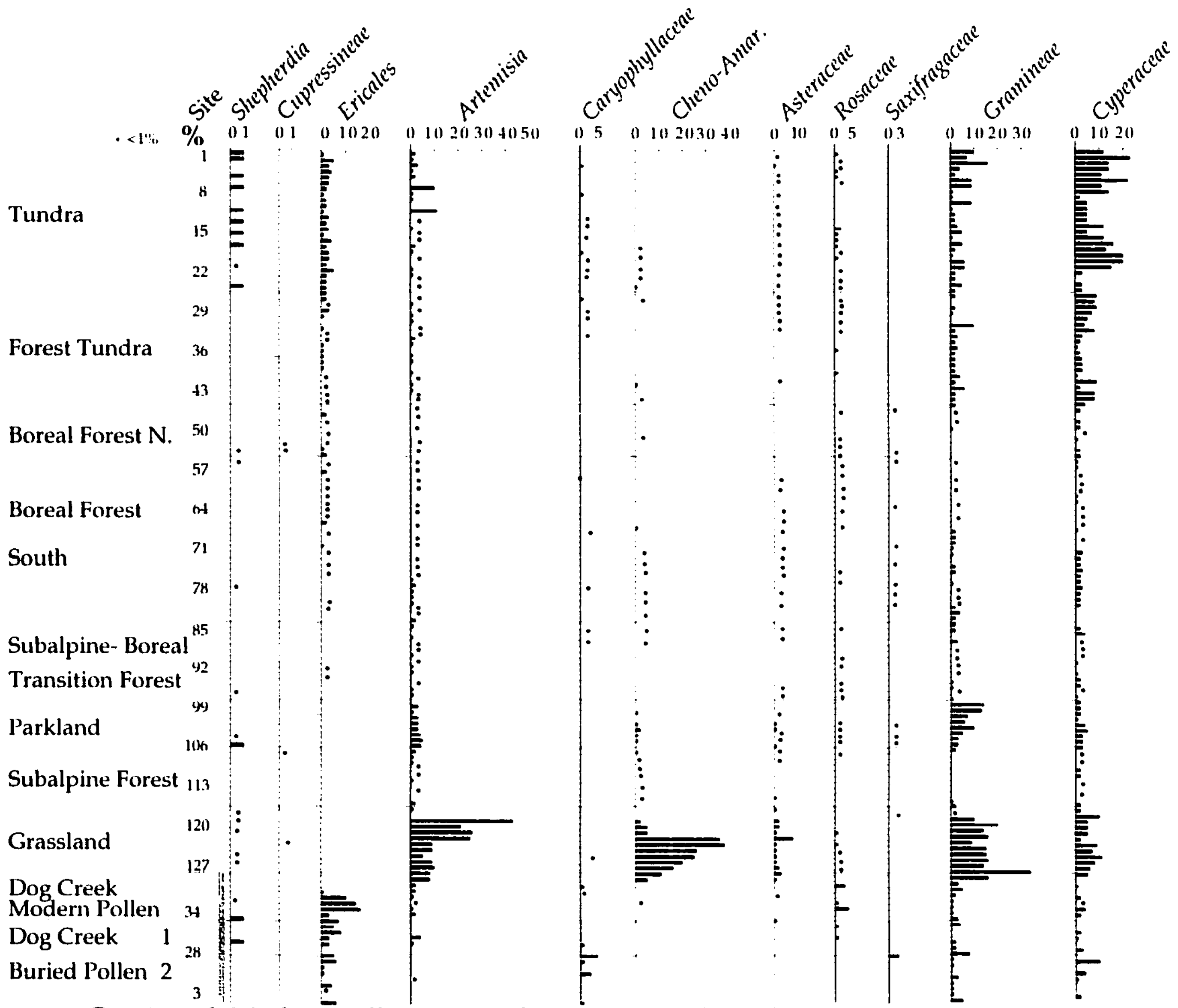

Figure 33. Continued. Modern pollen spectra from MacDonald and Ritchie (1986), sites 1-127 and Dog Creek, sites 14-3.

other shrubs and the same types and amounts of herbs, grasses and sedges. The site and study area actually contain shrub tundra vegetation on the uplands with a forest component following the river valley accounting for the forest tundra signal in the modern pollen rain. The modern pollen from samples at the site is therefore representative of the local vegetation and is comparable to regional records.

Internal variation between samples is insignificant. Pollen percentages from the oxbow lake samples (moss or sediment) are generally consistent although shrub percentages vary up to 15% (Figure 34). Lake pollen assemblages are more similar to each other than those from moss polsters. This is likely because of the mixing and averaging effect of pollen in water which doesn't occur in the other samples.

Moss polsters from around the site vary greatly in the amounts of spruce and shrub pollen they contain. The high percentage of *Alnus* in the Mid-ridge samples likely reflects the close proximity of some shrubs of this taxa to the sample site. *Picea* percentages peak in the swale and Mid-ridge sample 36. Stunted spruce trees grow in the swale today and a few lone trees can be found on the Mid-ridge. This may account for high percentages of pollen for this taxa found in the samples. The shape of the pollen curves showing percentages of taxa from each of the collection sites are all similar (Figure 34). All samples show peaks of spruce, alder, birch, heath shrubs and willow, as well as low but similar percentages of herbs. This evidence helps to conclude that pollen variation across the study site is not very significant.

Mid-ridge Pollen

Samples from the buried soil on the Mid-ridge at Dog Creek were also examined for pollen. The average assemblage is dominated by tree pollen (53%) with lesser shrub (42%) and herb (5%) components. There are, however, significant variations between the amount of tree, shrub and herb pollen in different areas of the buried soil (Figure 35). The samples from this soil can be separated into two groups with similar pollen assemblages. Group 1 samples are from parts of the buried soil that are within 1 m of the ground surface. These

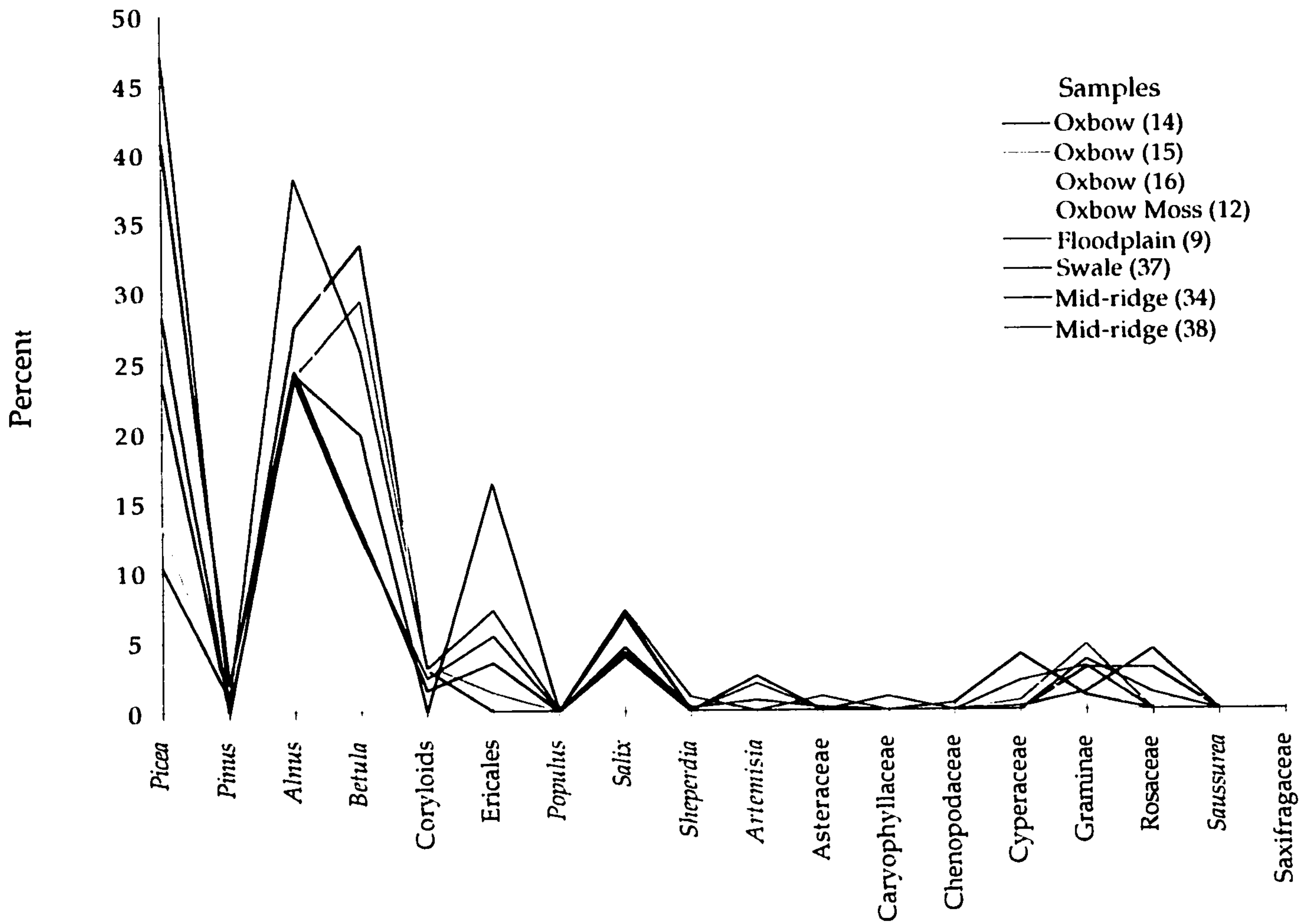

Figure 34. Pollen percent of each taxon from the modern pollen samples at Dog Creek.

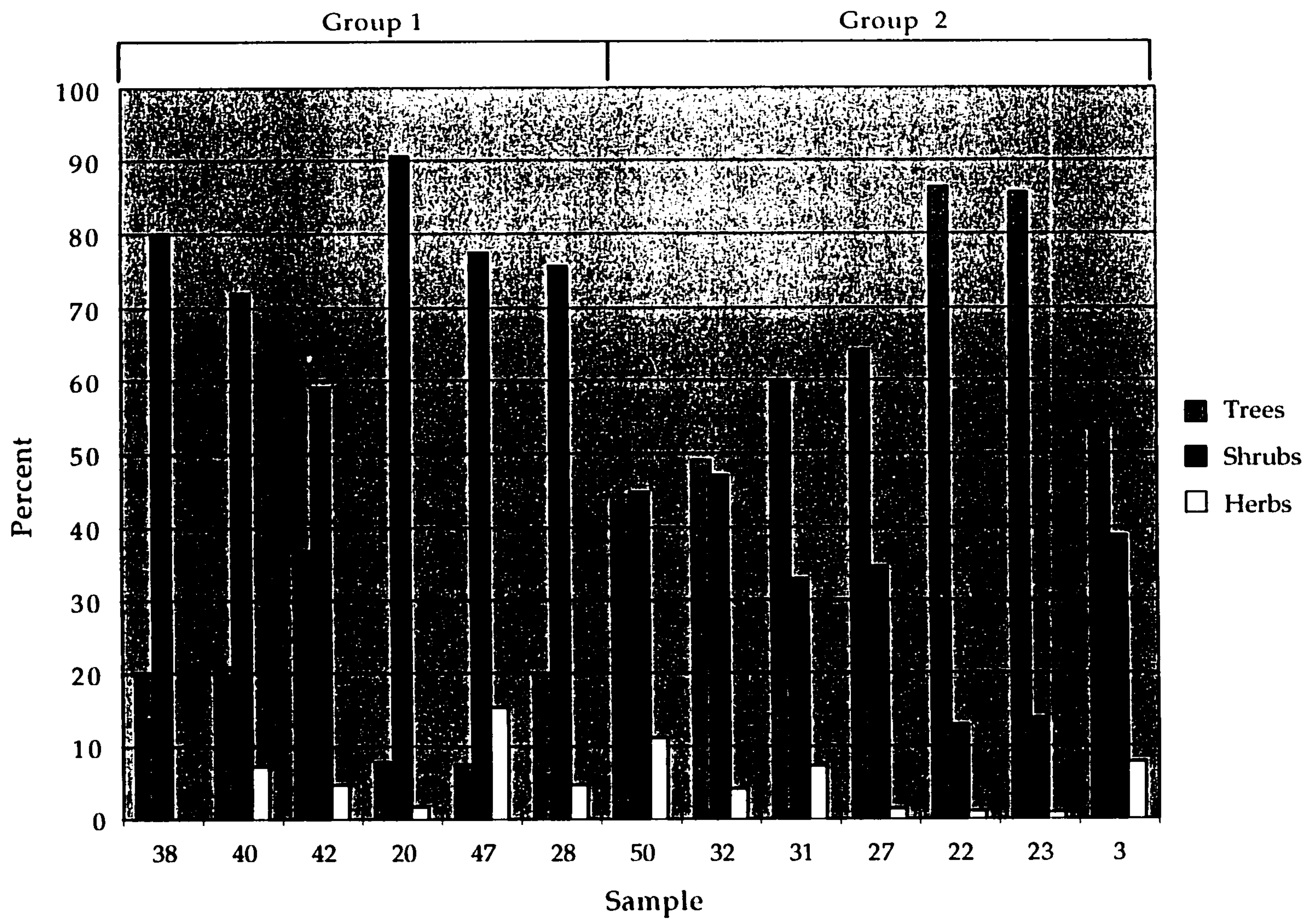

Figure 35. Pollen percentages from buried deposits on the Mid-ridge.

samples are dominated by shrub pollen (average of 19% tree, 74% shrub and 7% herb). The second group of samples were taken from the deepest locations in the buried soil (>1 m or at the termination of organic lobes). Group 2 assemblages contain substantial percentages of tree pollen (average of 66% tree, 30% shrub and 4% herb). Both groups contain similar percentages of each pollen type found (Figure 36).

As stated in Chapter 3, the buried soil on the Mid-ridge is not representative of one time period, but was buried over a few thousand years. The soil itself likely contains pollen rain from vegetation growing over this time span (ca. 5,000 to 2,000 years B.P.). To better understand vegetation changes through time at the Dog Creek site, pollen samples were taken from the buried soil of one solifluction lobe or infilled ice wedge cast on the Mid-ridge. These samples were associated with corresponding radiocarbon dates and are presented according to position along the organic lobe from the surface (Figure 37).

Figure 38 is the pollen percentage diagram for this sequence of samples. It is apparent from the diagram that there is a change in the amount of tree pollen *(Picea)* through time. Spruce pollen percentages increase with depth along the organic lobe with increasing age. This is opposite to shrub pollen (alder and birch) which increases through time to the present. Herb pollen is found in low frequencies over the whole time period but increases slightly with time towards the present.

During the mid Holocene at Dog Creek, spruce, birch and alder dominated the pollen record. Spruce pollen is found in high proportions at 5,000 years B.P. accounting for 90% of the pollen record. Spruce pollen percentages diminish through time reaching modern values after 1,880 years B.P. In the youngest samples (< 1,880 years B. P), spruce values are lower than at present. This may be attributed to the poor pollen preservation. These samples are found at shallow depths (<50 cm) and are incorporated with the modern surface soil. Aerobic activity in this zone has left little pollen and likely caused the destruction of spruce grains.

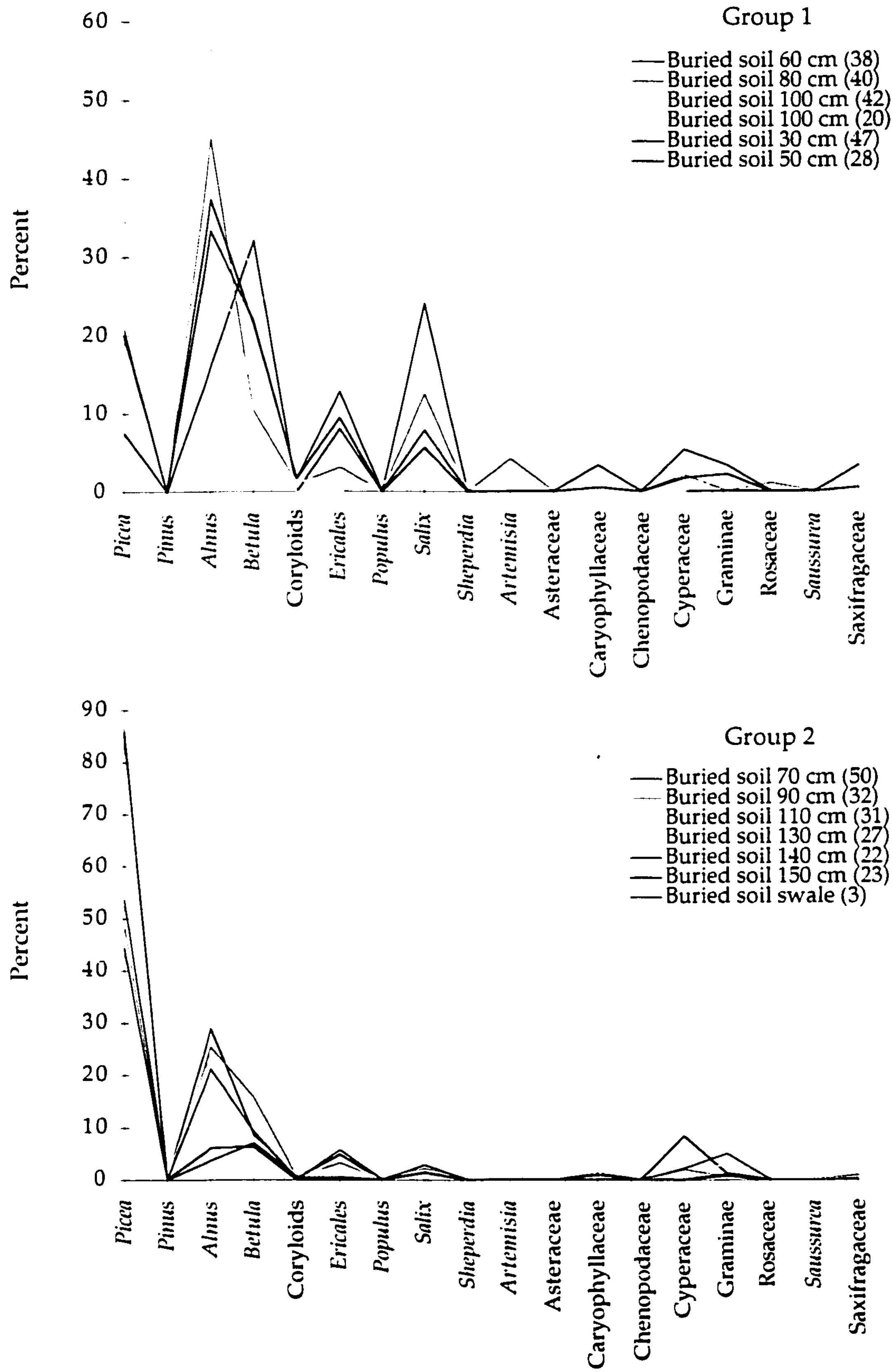

Figure 36. Pollen percent of each taxon from the buried pollen samples at Dog Creek.

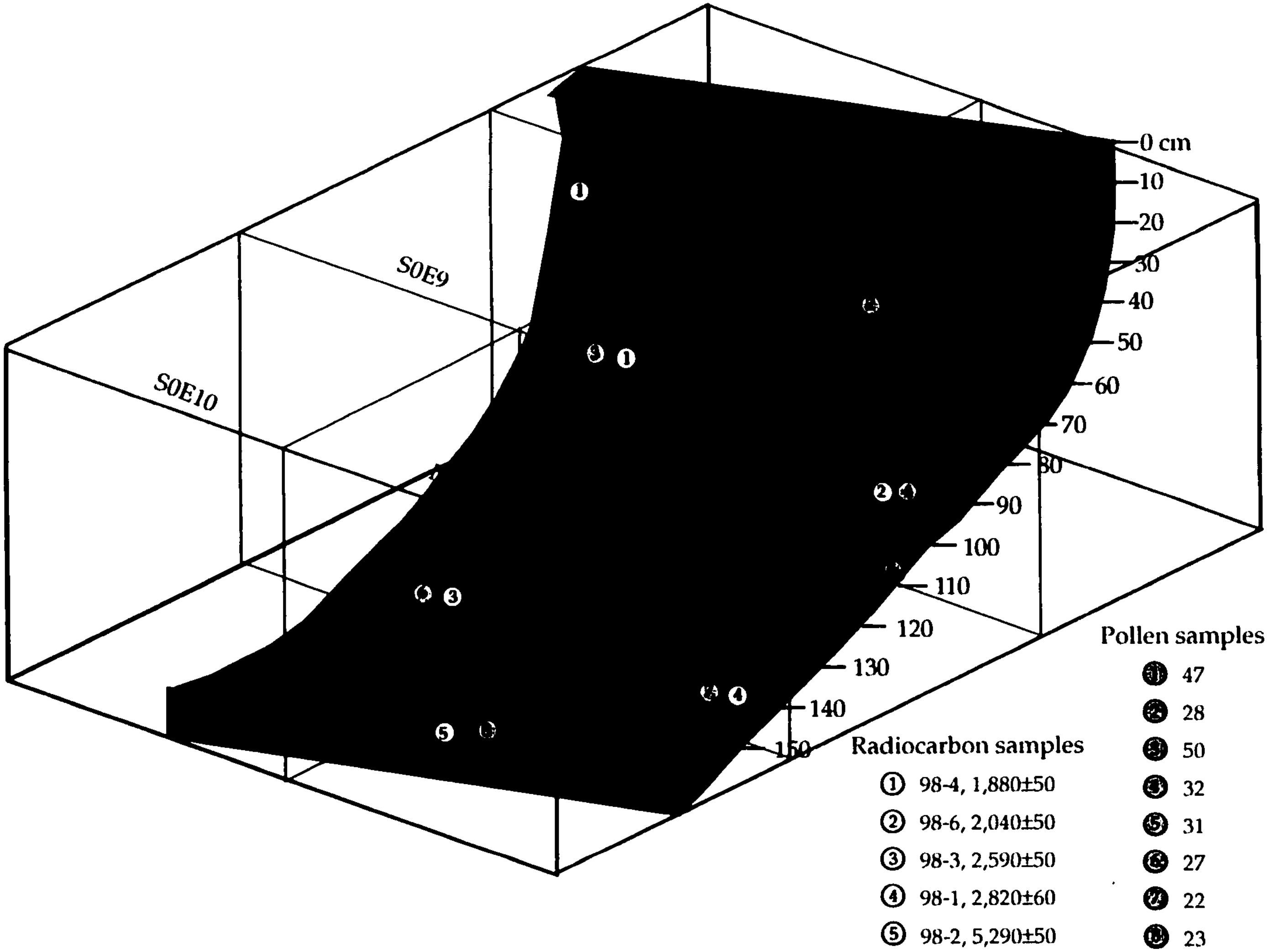

Figure 37. Organic lobe with radiocarbon and pollen sample positions.

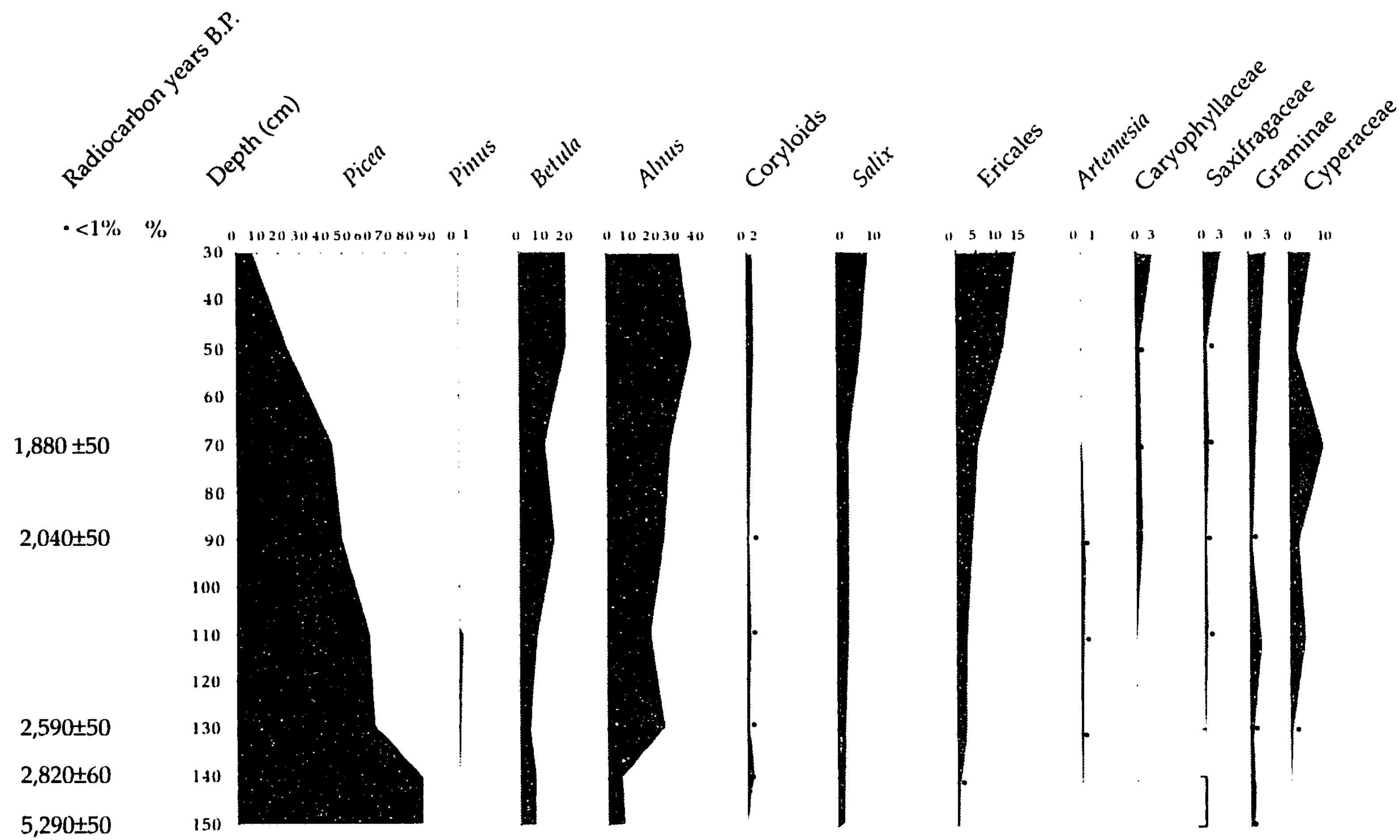

Figure 38. Pollen percentage diagram for Dog Creek solifluction lobe pollen.

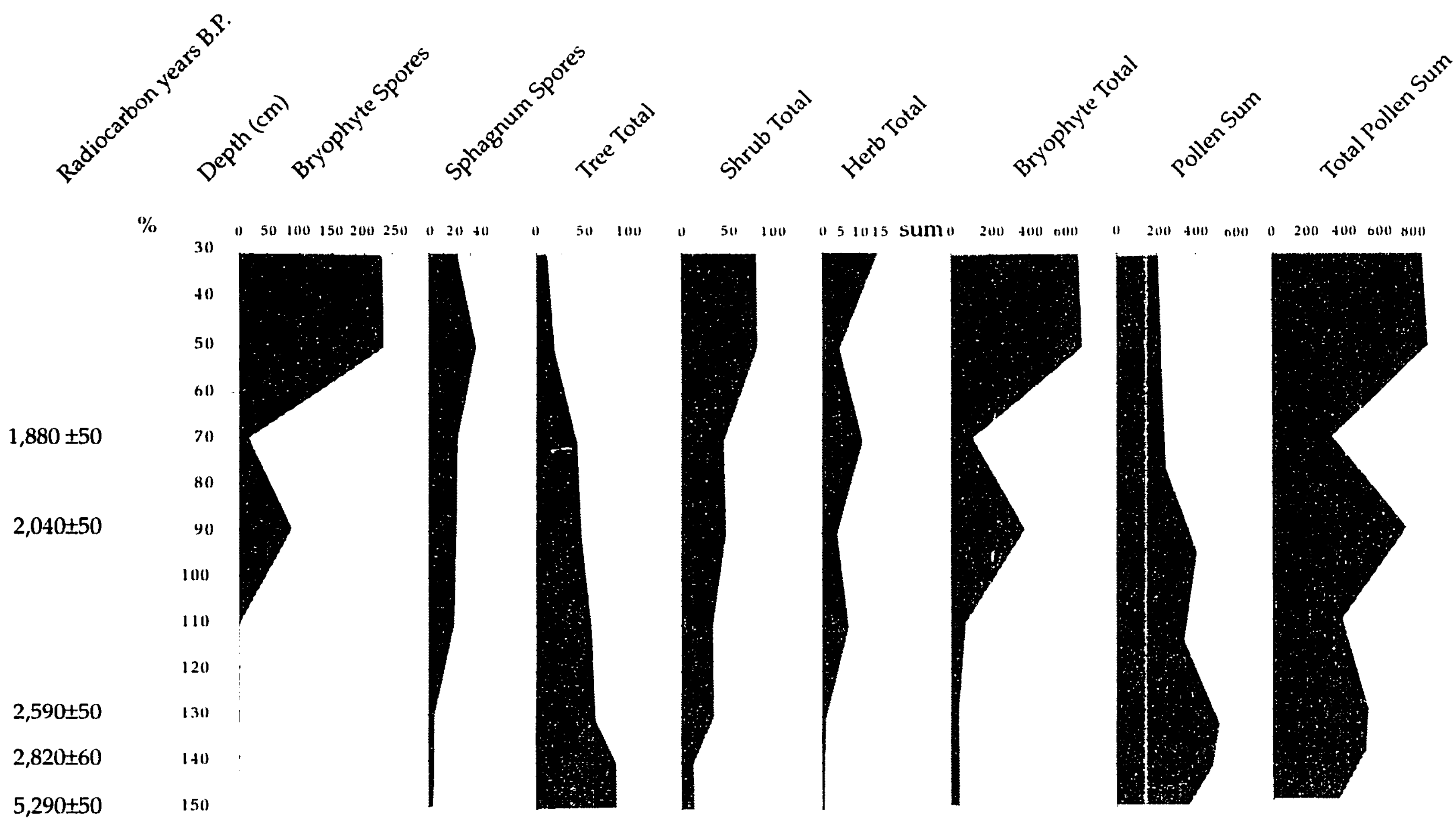

Figure 38. Continued. Pollen percentage diagram for Dog Creek solifluction lobe pollen.

Shrub taxa are found in low percentages during the spruce peak of the mid Holocene but increase through time until alder reaches modern values around 2,000 B.P. and birch after 2,000 B.P. Willow and heath shrub pollen reach modern values by around 1,880 years ago and are even slightly more frequent than at present at the end of the pollen record. By the late Holocene, shrubs account for over 70% of the vegetation. Although there is a higher percentage of shrub pollen found in later aged samples, the quantity of shrub pollen does not increase as much as spruce pollen decreases, accounting for large changes in percentage on the pollen diagram (Appendix VI).

Herb pollen is found in low percentages throughout the record. After 1,880 years B.P., pollen frequencies of most types of herbaceous taxa increase towards the present, coinciding with the increase in shrub pollen percentages.

Sphagnum moss spores are found throughout the record but were not included in the pollen percentages. Hundreds of bryophyte spores of unknown taxa were found in the samples at 30 and 50 cm depth (Figure 38). Although mosses are an important part of the vegetation assemblage in the study area, spores are not found in such high quantities in modern records. It is more likely that the large quantity of spores results from a moss polster being directly buried in the solifluction lobe than moss being dominant in the vegetation record. Spores are difficult to identify and are probably not reliable indicators of past vegetation under these circumstances.

Vegetation Reconstruction

In order to reconstruct ancient vegetation at the Dog Creek site, pollen assemblages from the buried soils (Figure 36) were compared with modern records from the site and the region (Figure 33). In the modern pollen assemblage the three major taxa (spruce, alder and birch) occur in approximately equal percentages (25-30%). Group 1 buried pollen percentages are similar to these, with slightly more alder (35%) and less birch (20%). Group 2 pollen percentages are distinctly different, containing more than double the amount of spruce (70%), significantly less birch (15%) and less alder (20%). Herb taxa composition and frequency from both the groups of buried soil are comparable to the modern pollen samples from the site.

As shown by comparison to MacDonald and Ritchie's (1986) pollen records for sites in the Yukon, the modern pollen spectrum from the Dog Creek site is representative of a forest tundra vegetation zone (Figure 32, 33). Group 1 pollen, from the upper portions of the organic deposits in the solifluction lobe, also matches the forest tundra assemblages. The group 2 pollen spectra do not compare to any of the modern pollen assemblages given by MacDonald and Ritchie. There are no modern vegetation zones with such high frequencies of spruce pollen or similar percentages of shrub taxa. The assemblage does, however, resemble the southern boreal forest vegetation zone if the *Pinus* component is disregarded. The modern northern limit of pine in the Yukon is south of Mayo and there is no evidence of more northerly extents during the Holocene (Cwynar and Spear 1991). Pollen data suggests that pine migrated north into the Yukon during the last 1,500 years, since deglaciation (Schweger et al. 1987), and is not likely to ever have been present in the study area. Lacking the pine component, the group 2 pollen assemblage does not completely resemble the southern boreal forest ecotone and therefore, does not have a modern analogue.

The pollen diagram from the buried soil of the solifluction lobe (Figure 38) can also be compared to the modern pollen vegetation zones of MacDonald and Ritchie (1986). During the mid Holocene (5,290-2,820 years B.P.) at the Dog Creek site, the pollen assemblage has no modern analogue (90% *Picea*, 5% *Alnus* and 5% *Betula*). The large percentage of spruce grains counted may be partly attributed to preservation, but it is likely that spruce trees were growing immediately over the Mid-ridge during this period, where they are not found today. Although no modern analogue exists for illustrating the vegetation represented by this pollen assemblage, the tree and shrub percentages found help to infer a spruce forest in the region similar to the boreal forest north described by MacDonald and Ritchie (1986).

Evidence from many other sites in the Yukon, Northwest Territories and Alaska (Figure 8) also suggest a dominance of spruce in the pollen assemblages recording the mid Holocene. Spruce became abundant in the records during the early Holocene but persisted in many parts of the arctic and subarctic until much later. Spruce appears in the southern Richardson Mountains at Lateral Pond and Tyrrell Lake by 9,000 years ago and persists throughout the Holocene reaching its maximum at Tyrrell Lake (40%) at 6,000 years B.P. (Ritchie 1982). At Grayday Pond, Honeymoon Pond and Monkshood Ponds in central Yukon, white spruce woodlands occur from 9,400-6,500 B.P. Green alder and black spruce began replacing the white spruce by about 6,500 B.P. resulting in conditions similar to the modern northern boreal forest (Cwynar and Spear 1991). Hail Lake and Candelabra Lake in the southern Yukon provide evidence that black spruce gained dominance over white spruce after 6,000 years ago. Green alder rose in frequency at these sites with black spruce (Cwynar and Spear 1995). Hanging Lake, located just 30 km east of the Dog Creek site contains pollen showing a high influx of spruce pollen 10,000-8,000 years ago, but only low percentages (10%) and low influx from 6,500 years B.P. to the present (Cwynar 1982). Evidence from these sites show spruce dominant in the pollen record in the early and mid Holocene. Spruce forests are found in eastern Alaska beginning 8,000-9,000 years B.P. and only spread to the west after 5,000 years ago (Lamb and Edwards 1988). Boreal vegetation, however, dominates the mid Holocene record in eastern Alaska at sites such as Tangle Lake, Healy Lake , Rebel Lake and Ped Pond (Anderson 1975, Anderson and Brubaker 1993, Edwards and Brubaker 1986, Edwards et al. 1985).

In the central Northwest Territories, although the ranges and concentrations of *Picea mariana* and *Picea glauca* (black and white spruce) were similar to today, areas in the north at 6,000 B.P. supported boreal vegetation which is not found there at present (MacDonald 1995). Zone 3 from Queen's Lake and McMaster Lake also show a dominance of black spruce in pollen records from approximately 5,000 to 3,500 years B.P. (Moser and MacDonald 1990). Spruce on the Tuktoyaktuk Peninsula actually increased between 7,000 and 5,500 years B.P. suggesting a northern extension of boreal forest vegetation (MacDonald and Ritchie 1986, Ritchie and Hare 1971). Sites throughout the northern Yukon and Mackenzie Delta show the movement of the treeline southward throughout the Holocene (Spear 1983).

All of this information suggests that the spruce treeline existed far north of its modern extent during the early Holocene and was likely still further north during the mid Holocene when *Picea* pollen is found in high frequencies at the Dog Creek site. The Dog Creek records from 5,290-2,820 B.P. suggest boreal forest vegetation in the area and an extension of the treeline north of its modern position.

The slow movement of the treeline southward during the mid- to late Holocene can be seen by spruce disappearing from areas it once inhabited and by the replacement of white spruce with black spruce at sites south of the treeline. Evidence from the Tuktoyaktuk Peninsula shows decreasing percentages of spruce pollen in Zone 4 from about 5,500-4,000 B.P. with an increase in alder in the records at approximately the same time. By 4,000 B.P., arboreal taxa were almost completely replaced by shrub heath vegetation (Ritchie and Hare 1971). At Queen's Lake and McMaster Lake, south of the treeline, an increase in pine at the expense of spruce occurs from 3,500 B.P. to the present (Ritchie and Hare 1971). Black spruce had also taken over white spruce stands at Grayday, Honeymoon and Monkshood ponds in central Yukon by 2,000 B.P. (Cwynar and Spear 1991). Percentages of spruce pollen at the Dog Creek site begin to decrease by 2,590 years B.P. with a corresponding increase in shrub components. The assemblage at this time approximates the northern boreal forest assemblages by MacDonald and Ritchie (1986).

By about 3,000 B.P., modern vegetation conditions were established in most places in the northern Yukon and Northwest Territories. Relative vegetation stability was found in eastern Alaska at approximately the same time, or slightly earlier (Anderson 1975, Anderson and Brubaker 1993). By 3,500 B.P. at McMaster lake in the Northwest Territories, a forest tundra landscape transformed into tundra with a decrease in black spruce (Moser and MacDonald 1990). Tundra was also established on the Tuktoyaktuk Peninsula during this time (MacDonald and Ritchie 1986). Modern boreal forest conditions were also met in the southern Yukon (Cwynar and Spear 1991). At Dog Creek, shrub vegetation reaches modern percentages by 2,000 years B.P. while spruce frequencies decrease to today's values. The pollen percentages at this time suggest a forest tundra environment.

The pollen records from the buried soil at Dog Creek broadly correspond to the pollen records from other sites in the Yukon and Northwest Territories for the mid to late Holocene. There is a noticeable lag in the replacement of spruce by shrub taxa which doesn't occur at the site until 2,500 years ago. This lag in the pollen records may be based on proximity of the spruce treeline today. Because the treeline is located only about 20 km south of the site and because black spruce is found on floodplains in the study area, it is likely that spruce forests remained in the area until much more recently (until 2,000 B.P.) than they did further north.

The only pollen records in the Yukon that do not seem comparable to Dog Creek are from Hanging Lake, located just 20 km to the east. At Hanging Lake pollen influxes are very low and pollen percentages suggest a shrub tundra vegetation that changes very little after 8,900 years ago. Spruce percentages, although reaching a maximum in the early Holocene, are very low throughout the rest of the record. The differences in elevation between the two sites may have been an important factor for the position of the treeline during the mid Holocene. The Dog Creek pollen data was taken from 360 m above sea level while Hanging Lake is located much higher at 500 m a.s.l. Conditions at this elevation including a fell-field with shattered bedrock is not conducive to spruce vegetation.

Climate Reconstruction

Climate simulations and ice core evidence show a decreasing trend in solar radiation causing a reduction in summer temperatures throughout the Holocene (Kutzbach et al. 1993, COHMAP Members 1988, Koerner and Fisher 1990). The warmest summers were during the early Holocene and temperatures have decreased since this time (Koerner and Fisher 1990). These records suggest that the mid Holocene, while subject to a cooling trend, was warmer than at present. Pollen records from the Yukon and Northwest Territories support a general cooling as forcasted from this evidence. The treeline was at its northern most extent from 10,000-8,000 years B.P. and has moved progressively south since this time (Ritchie et al. 1983). The disappearance of spruce forest in the northern subarctic and replacement by shrub tundra demonstrates a cooling episode during the mid Holocene. Spruce-sphagnum muskeg developing in the Mackenzie Basin between 8,000-4,000 B.P. also suggests a change to cooler conditions (MacDonald 1995, 1987).

Moister conditions in the mid Holocene have also been predicted by many researchers because of the replacement of white spruce by black spruce in boreal forest assemblages (Cwynar and Spear 1991, 1995, Moser and MacDonald 1990). Cwynar and Spear (1995) suggest that high black spruce and alder percentages from sites in the southern Yukon help to imply more mesic conditions during this time; cooler and wetter growing seasons. Muskeg development in the Northwest Territories has also been used to infer moister conditions. The replacement of arboreal vegetation by shrub vegetation in the Yukon and Northwest Territories after 3,500 B.P. and at the Dog Creek site after 2,500 years ago may suggest a return to drier conditions.

CHAPTER 5 Discussion and Conclusions

Introduction

Geoarchaeological research at Dog Creek has produced evidence of periglacial activity and vegetation change throughout the mid to late Holocene. The data have elucidated on the nature of the archaeological record in arctic regions as well as on microclimatic conditions associated with periglacial activity and spruce forest vegetation.

Transformation of the Archaeological Record

Periglacial processes including solifluction, frost cracking, frost heave and cryoturbation have clearly altered the archaeological record at Dog Creek. These processes have: 1) displaced artifacts that were originally deposited on the surface of the Mid-ridge to depths greater than 100 cm, 2) created at least two artificial cultural layers where only one previously existed, 3) vertically aligned many artifacts and presumably moved them upwards in the sedimentary profile and 4) mixed artifacts into the soil by cryoturbation. Non-periglacial processes have also been active in transforming the archaeological record. Deflation was responsible for removing sediments from ridge tops and preventing deposition. This collapsed all possible occupations at the site into one cultural level.

The majority of arctic and alpine sites, and those found proximal to Pleistocene glaciers have been subjected to the effects of periglacial processes. Although some of these processes have been mentioned in the archaeological literature, their results are rarely evaluated. Sites where periglacial activity such as cryoturbation, solifluction and frost heave have been interpreted in the stratigraphic record include Onion Portage in northwestern Alaska (Schweger 1985), Ilnuk in southwestern Alaska (Ackerman 1996) and Engigstciak in the northern Yukon (Mackay et al. 1961).

Recognizing the effects of periglacial processes is essential for accurate interpretation of archaeological sites. Indications in the sedimentary record that demonstrate these processes are:

1) Organic matter mixed and mottled with uniform mineral sediments.

2) Cross cutting relationships between different sedimentary units or soils.
3) Vertically aligned clasts and artifacts.
4) Artifacts standing on edge within a soil.
5) Vertical and V-shaped columns of sediment or soil.
6) Clusters or concentrations of rocks.
7) Ground ice.
8) Unclear, gradational or wavy boundaries between sedimentary units.
9) Artifact refits from different stratigraphic levels in a profile.
10) Frost "pot-lids" and "pot-lid" scars on artifacts.
11) The size distribution of lithics in the site profile. Large artifacts would be found high in the deposits and artifact size would decrease gradationally downwards in the sedimentary profile.

These indicators can be used by the researcher to predict the presence of periglacial activity as a transformational agent at a site. This will help to reconstruct the original position of artifacts and materials in the stratigraphy and aid in understanding limitations of interpretations.

Climatic/Microclimatic Interpretations

Reconstructed periglacial processes and vegetation from the Dog Creek site can be used to decipher microclimatic conditions on the Mid-ridge during the mid Holocene. Solifluction began in the deposits by 5,290 years B.P. The active layer was thinner than today (now 1 m deep). The site pollen record for the same time period indicates that a spruce forest with moss and shrub ground cover was located in the area. Deposits on the Mid-ridge today do not support arboreal taxa. At present, there is no solifluction occurring and the active layer extends into the bedrock.

Temperature, moisture and insulation are the most important controls on microclimate at Dog Creek. They account for the environmental differences between the mid Holocene and today. Mean annual temperatures below freezing existed in both the mid Holocene (there is evidence of an ancient active layer) and today (permafrost exists in the area). Summer soil temperatures, however, must average 9°C to maintain trees (Hom 1995, Moser and MacDonald

1990). This occurs at treeline today, but not in the study area. Warmer summer temperatures may have enabled trees to grow on the Mid-ridge deposits during the mid Holocene.

Soil moisture promotes both tree growth and periglacial processes (Dingman and Koutz 1974, Greene 1983). Spruce grows along Black Fox Creek today on saturated floodplains, but not in dry Mid-ridge deposits. Poorly drained conditions are also a requirement for solifluction and other frost processes (Burn 1988, 1990, Padilla and Villineuve 1988, Zoltai and Pettapiece 1974). Drainage in arctic sediments is often controlled by active layer thickness. Permafrost near the surface prevents water from leaving the deposits creating available soil moisture for vegetation growth and solifluction (Vance et al. 1983, Zoltai and Pettapiece 1974). Active layer thickness is dependent on insulation, as well as on temperature. Ground insulated by mosses and other vegetation protect permafrost, preventing deep active layer thaw (Nicholson 1978, Smith and Riseborough 1983).

Temperature, moisture, insulation, active layer depth, vegetation and periglacial processes are complexly interconnected. Today's climate with cool summers (<10° average summer temperatures, Nichols 1972) and low precipitation have prevented the treeline from extending to the study area. Only the floodplains in the study area, with abundant moisture, contain trees. Less vegetation on the Mid-ridge implies less insulation and therefore, a thicker active layer. Because the deposits are well drained, periglacial processes are only moderately active and solifluction is not occurring at present.

Working backwards from evidence in the deposits on the Mid-ridge can provide interpretations on microclimatic and climatic conditions during the mid Holocene. Abundant vegetation, including spruce, and solifluction suggests that the site conditions were moister than at present. Insulation by spruce, shrubs and mosses maintained a thin active layer which further promoted solifluction. Moister soil conditions may have been a result of greater precipitation in the area than today. In fact, pollen records throughout the Yukon provide evidence that the mid Holocene experienced moister conditions than at present (Cwynar and Spear 1991, 1995, Moser and MacDonald 1990). Climate models predict increased

January precipitation at 6,000 years ago (Bartlein et al. 1998, Kutzbach et al. 1998, Kutzbach et al. 1993b). Increased precipitation in the form of snow would have provided more ground insulation and a spring runoff, resulting in moister active layer soils. Climate models also demonstrate that summers experienced greater solar radiation and, therefore, warmer temperatures at this time (Bartlein et al. 1998, COHMAP 1988, Kutzbach et al. 1998, Kutzbach et al. 1993b). A moister, or warmer and moister climate may have caused the treeline to extend into the study area before 5,000 B.P. The insulating effects on the active layer by trees and snow coupled with enhanced soil moisture would have increased the activity of cryoturbation, frost heave and solifluction.

Conclusions

Geoarchaeological research at Dog Creek and in the Black Fox Creek study area was able to provide clues on palaeoenvironmental changes at the site during the mid to late Holocene and understand microclimatic conditions existing during this period.

The complex stratigraphy at Dog Creek resulted from transformation of the original deposits by periglacial activity. Originally, aeolian silts were deposited at the site on top of frost shattered limestone. An Orthic Turbic Cryosol developed on these sediments. Beginning in the mid Holocene, solifluction began to take place in the deposits. Solifluction alone, or soil-infilled frost cracks later moved by solifluction, acted to bury the surface soil under a metre of deposits. In this process, the aeolian sediments were mixed with bedrock rubble, creating a new, poorly sorted, depositional unit. Solifluction buried artifacts and vegetation that were originally on the surface from 5,290 years B.P. until at least 1,770 years ago. Frost heave has been acting during this period, aligning artifacts vertically and moving them throughout the deposits. Cryoturbation has mixed organic matter and sediment, causing distortion of unit boundaries and movement of artifacts.

Pollen from one of the solifluction lobes was used to reconstruct vegetation change in the Black Fox Creek study area from the mid Holocene to present. The records show that the treeline existed north of its modern position from about 5,300 to 2,500 years before present. At this time, a boreal forest vegetation zone was found in the study area. Percentages of spruce pollen decreased from 2,800 years B.P. to present while there was an increase in shrub taxa. Modern forest-tundra conditions were met by 2,000 years B.P.

A site chronology was the most difficult to determine from the evidence gained from this study. The artifacts typologically resemble those of the Mesa Complex at the Mesa site in Alaska dating to 10,000-11,500 years B.P. (Kunz and Reanier 1996) and the Denali Complex dating to 10,690 years B.P. at Dry Creek (Component II) (Hoffecker et al. 1996). However, there were no chronometric means of dating the cultural material at Dog Creek. The material was relatively dated to older than 5,290 years B.P. Artifacts must have been present on the surface before 5,290 B.P. to have been incorporated in soliflucted deposits. It is also possible that people occupied the site on the modern soil any time after solifluction began.

Periglacial processes at Dog Creek created multiple cultural components from the initial component. Deflation of surface sediments affected the stratigraphy on the ridges, potentially reducing multiple archaeological sequences into one composite site. Artifacts are no longer in their original provenience. Although periglacial processes can be destructive of archaeological context, they leave clues in the stratigraphic record that enable deciphering of the post-depositional transformation of cultural and natural deposits. By identifying the results of periglacial processes, original site context can be reconstructed and limitations in dating and interpretation can be understood.

Microclimatic conditions at Dog Creek allowed for periglacial activity to begin during the mid Holocene when the spruce treeline existed north of the study area. The active layer thickness was less than what is found today. Permafrost prevented drainage into the deposits and allowed solifluction to occur by saturating the active layer deposits. Moister conditions may have also allowed spruce to grow and promoted periglacial activity.

This evidence suggests that the microclimate and the stratigraphy at the Dog Creek site has changed considerably since the mid Holocene and since original occupation of the site. However, reconstruction of sedimentological and palaeoenvironmental changes was possible.

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Appendix I
Sample Information

Sample #	Unit #	Unit	Depth cm B. D.	Prepreocessed	Loss on Ignition	Sedigraph	Pollen
1	Toilet	4	5 to 30	√	√	X	√
2	Toilet	3	30-50	√	√	√ S50	X
3	Toilet	2	50-60	√	√	√ S54	√
4	Toilet	1	>60	√	√	√ Stest 1	X
5	N1E7	1	-	√	√	√ S51	X
6	C-floodplain	-	hummock 5-15	√	√	√ S52	X
7	C-floodplain	-	silt 26-32	√	√	√ S55	X
8	E-hummock	-	30-40	√	√	√ S45	X
9	E-moss	-	surface	X	X	X	√
10	E-moss	-	surface	X	X	X	X
11	oxbow moss	-	surface	X	X	X	X
12	oxbow moss	-	surface	X	X	X	√
13	oxbow moss	-	surface	X	X	X	X
14	oxbow seds	-	-	X	X	X	√
15	oxbow seds	-	-	X	X	X	√
16	oxbow seds	-	-	X	X	X	√
17	pointbar seds	-	-	√	√	√ S11	X
18	N2E8	LOI all	10 to 36	X	√	X	X
19	N2E8	1	60-80	√	√	√ S48	X
20	N2E8	2	96-110	√	√	√ S56	√
21	N1E9	LOI all	50-150	X	√	X	X
22	N1E9	2	130-150	√	√	√ S58	√
23	N1E11	2	113-120	√	√	√ S57	√
24	N1E11	3	93-114	√	√	√ S8	X
25	N1E11	4	52-77	√	√	√ S44	√

Appendix I
Sample Information

Sample #	Unit #	Unit	Depth cm B. D.	Prepreocessed	Loss on Ignition	Sedigraph	Pollen
26	N1E11	1	110-125	√	√	√ S21	X
27	S0E9	2	floor organic	√	√	√ S60	√
28	N0E8	4	48-58	√	√	√ S14	√
29	N0E8	3	60-95	√	√	√ S16	X
30	N0E8	2	89-99	√	√	√ S49	√
31	N0E8	2	106-116	√	√	X	√
32	N0E8	2	89-96	√	√	√ S53	√
33	swale moss	-	surface	X	X	X	X
34	midridge moss	-	surface	X	X	X	√
35	midridge moss	-	surface	X	X	X	X
36	midridge moss	-	surface	X	X	X	√
37	swale moss	-	surface	X	X	X	√
38	N0E7	4	39-61	√	√	√ S12	√
39	N0E7	4	61-79	√	√	√ S43	√
40	N0E7	2	81-98	√	√	√ S15	√
41	N0E7	1	83-99	√	√	√ S41	X
42	N0E7	2	84-118	√	√	X	√
43	swale clay	-	-	√	√	√ S47	X
44	fridge	4	-	√	√	√ S17	√
45	fridge	3	-	√	√	√ S61	X
46	fridge	1	-	√	√	√ S13	X
47	S1E8	4	-	√	√	√ S46	X
48	S1E8	4	-	√	√	√ S10	√
49	S0E9	4	-	√	√	√ S9	√
50	S0E9	2	-	√	√	X	√

Appendix II
Grain Size Data

Sample #	Unit	Unit	Sand %	Silt %	Clay %	Mean µm	Median µm
43	Swale Clay	Clay	9.6	32.4	58	3	0.97
6	C	Floodplain hummock	2.7	44.2	53	2.4	1.65
7	C	Floodplain silt	1	67.1	32	4.5	5.71
8	E	Hummock silt	24.5	47.1	28.5	11	9.72
25	N1E11	4	20	37.4	42.7	6.3	3.89
28	N0E8	4	26.7	28.1	45.2	7.8	2.9
38	N0E7	4	14.1	52.2	33.7	7.8	7.67
39	N0E7	4	11.3	46.4	42.4	5.2	3.78
44	Fridge	4	8.5	62.3	24.4	11	10.31
47	S1E8	4	33.6	40.8	25.7	15.6	10.61
48	S1E8	4	11.1	35	53.8	3.6	1.47
49	S0E9	4	23.2	42.9	34	9	6.62
1	Toilet	4					
2	Toilet	3	38.9	29.1	32.1	15.6	10.3
24	N1E11	3	21.2	35.4	43.4	6.8	3.16
29	N0E8	3	21.8	33.9	44.4	6.8	2.81
45	Fridge	3	13.7	48.2	38	5.9	5.54
3	Toilet	3	4	83	12.9	6.3	6.06
22	N1E9	2	6.5	75.7	17.8	7.3	7.45
23	N1E11	2	23.3	43.6	33.2	9	5.71
27	S0E9	2	13.1	62.5	24.3	7.3	6.24
30	N0E8	2	27.4	61.4	11.2	20.6	14.67
32	N0E8	2	15.2	60.1	22.4	10.3	7.23
40	N0E7	2	14.4	51.8	33.8	7.3	4.38
31	N0E8	2					

Appendix II
Grain Size Data

Sample #	Unit	Unit	Sand %	Silt %	Clay %	Mean μm	Median μm
42	N0E7	2					
50	S0E9	2					
4	Toilet	1	24.5	28.3	47.2	6.8	2.57
5	Toilet	1	35.1	21.5	43.4	10.3	5.71
19	N2E8	1	19	22.3	58.7	4.2	0.97
20	N2E8	1	41.7	25.1	33.2	16.7	14.69
26	N1E11	1	42	30.4	27.7	17.9	24.99
41	N0E7	1	19.4	37.5	43.1	5.9	3.26
46	Fridge	1	29.6	34.3	36.1	10.3	5.38
17	Sediments	Point Bar	19.7	33.9	46.4	6.3	2.73

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550° Wt.	True 1000° Wt.	% Organics	% CaCO3	% Other
1	12.4451	1.1718	0.4342	0.351	62.9458952	16.13679033	20.91731447
1	11.3424	1.6588	0.5599	0.4628	66.24668435	13.30370257	20.44961308
1	11.8045	1.6391	0.6195	0.4717	62.20486853	20.49350808	17.3016234
2	11.5899	3.0172	2.6355	2.2422	12.65080207	29.6256011	57.72359683
2	11.6023	3.8411	3.4383	2.857	10.48657937	34.39474014	55.11868049
2	12.4177	2.8025	2.5006	2.0783	10.77252453	34.24701971	54.98045576
3	11.8571	2.4258	1.0203	0.6893	57.93964878	31.01132522	11.049026
3	11.0162	1.6243	0.6365	0.4624	60.81388906	24.36014395	14.82596699
3	13.035	2.1206	0.8601	0.599	59.44072432	27.98307512	12.57620056
4	12.9526	2.4135	2.3906	1.7662	0.948829501	58.79804885	40.25312165
4	12.4459	2.3675	2.3383	1.8598	1.233368532	45.9345301	52.83210137
4	11.4255	4.4297	4.375	3.4168	1.234846604	49.16195843	49.60319496
5	12.5988	4.7056	4.6286	4.0054	1.636348181	30.09953325	68.26411857
5	13.8387	4.2558	4.1886	3.6367	1.579021571	29.47314681	68.94783162
5	11.9852	2.367	2.331	2.001	1.520912548	31.68567807	66.79340938
6	10.4083	2.1674	0.9569	0.9418	55.85032758	1.583380171	42.56629225
6	10.3219	1.7809	1.0698	1.0561	39.92924926	1.748349915	58.32240083
6	12.2511	5.1606	3.2998	3.2343	36.05782273	2.884618772	61.05755849
7	11.7627	5.1977	4.4505	4.409	14.3755892	1.814613807	83.80979699
7	12.8727	4.4334	3.8115	3.7721	14.02760861	2.01979191	83.95259948
7	11.2772	3.3336	2.869	2.8451	13.93688505	1.629415101	84.43369985
8	11.3666	7.9224	6.9648	6.9128	12.08724629	1.491742631	86.42101108
8	13.481	6.7113	5.994	5.9494	10.68794421	1.5103428	87.80171299
8	11.2566	8.6428	7.8308	7.7659	9.395103439	1.706622854	88.89827371
17	12.138	2.5856	2.3466	2.29	9.243502475	4.975106886	85.78139064

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550° Wt.	True 1000° Wt.	% Organics	% CaCO3	% Other
17	13.422	3.0359	2.743	2.6785	9.647880365	4.82858161	85.52353803
17	9.6063	3.2314	2.9242	2.8394	9.506715356	5.964203526	84.52908112
18a	11.591	2.1263	1.8908	1.8078	11.07557729	8.871578029	80.05284468
18a	10.4552	1.8078	1.6	1.5217	11.49463436	9.84370757	78.66165807
18a	11.0173	2.4711	2.2059	2.0991	10.73206264	9.822640635	79.44529672
18b	11.4271	1.4676	1.2923	1.2692	11.94467157	3.577269011	84.47805942
18b	13.482	1.3241	1.1687	1.1493	11.7362737	3.329877584	84.93384872
18b	13.6679	2.1755	1.9178	1.8887	11.84555275	3.040053488	85.11439377
18c	12.6	1.9568	1.7548	1.725	10.32297629	3.461123913	86.2158998
18c	11.3665	2.6537	2.362	2.3167	10.99219957	3.879660303	85.12814013
18c	11.3436	2.06	1.8299	1.7946	11.16990291	3.894527802	84.93556929
18d	11.8055	1.6488	1.4326	1.4084	13.11256672	3.33575934	83.55167395
18d	13.0367	2.5554	2.2234	2.1894	12.99209517	3.023899479	83.98400535
18d	12.5997	1.4293	1.249	1.2291	12.61456657	3.1642953	84.22113813
18e	11.6033	1.6191	1.3798	1.3522	14.77981595	3.874206209	81.34597784
18e	11.2778	1.4177	1.2191	1.1952	14.00860549	3.831429909	82.1599646
18e	11.2574	2.1919	1.8595	1.8268	15.16492541	3.390582683	81.44449191
18f	12.4459	2.1656	2.0162	1.7194	6.898780938	31.14820163	61.95301743
18f	10.4074	1.9106	1.7735	1.5328	7.175756307	28.63212889	64.1921148
18f	12.4184	2.9735	2.7607	2.4021	7.156549521	27.40877754	65.43467294
18g	12.8736	2.3473	2.2528	1.7475	4.0259021	48.92468329	47.04941461
18g	12.0704	4.2071	4.0502	3.1225	3.729409807	50.1154974	46.1550928
18g	11.986	2.5721	2.4721	1.9001	3.887873722	50.54235838	45.56976789
19	12.2134	3.3788	3.2755	2.756	3.057298449	34.94382083	61.99888072
19	10.8848	3.2189	3.1327	2.6038	2.677933456	37.34336123	59.97870532

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550° Wt.	True 1000° Wt.	% Organics	% CaCO3	% Other
19	12.4912	3.1932	3.0927	2.623	3.14731304	33.43041463	63.42227233
20	12.9782	2.5424	2.3647	1.9882	6.989458779	33.65645918	59.35408204
20	12.8388	2.5416	2.3405	1.9702	7.912338684	33.112642	58.97501932
20	13.18	2.3283	2.1476	1.7918	7.761027359	34.73076337	57.50820927
21a	11.8988	2.5851	2.3491	2.3323	9.129240648	1.476995791	89.39376356
21a	13.2928	2.4254	2.1983	2.1804	9.363403975	1.677324078	88.95927195
21b	10.7765	2.3919	2.2398	2.2255	6.358961495	1.358752456	92.28228605
21b	12.5807	2.0522	1.9192	1.9043	6.48084982	1.650113847	91.86903633
21c	12.2131	2.5749	2.4221	2.4068	5.934211037	1.35044962	92.71533934
21c	13.2332	2.465	2.3147	2.3032	6.097363083	1.060298728	92.84233819
21d	11.9434	2.3589	2.1859	2.1688	7.33392683	1.64753217	91.018541
21d	12.4901	2.6549	2.4683	2.4541	7.028513315	1.215591068	91.75589562
21e	12.1382	2.2234	2.0419	2.0004	8.163173518	4.242069885	87.5947566
21e	9.683	2.3044	2.1121	2.0923	8.344905398	1.952785975	89.70230863
21f	13.5813	3.1117	2.8002	2.7776	10.01060514	1.650661579	88.33873329
21f	12.2505	3.1194	2.8113	2.7893	9.876899404	1.602872347	88.52022825
21g	9.6059	2.5752	2.4327	2.4069	5.533550792	2.276963484	92.18948572
21g	10.8851	2.4429	2.2982	2.2784	5.923287896	1.842072946	92.23463916
21h	14.4985	2.2395	2.108	2.091	5.871846394	1.725222757	92.40293085
21h	13.1525	2.6161	2.4695	2.4469	5.603761324	1.963366705	92.43287197
21i	13.1973	2.8838	2.7151	2.6907	5.849920244	1.922967801	92.22711196
21i	12.8386	2.8192	2.6547	2.633	5.834988649	1.74936797	92.41564338
21j	11.9202	2.7394	2.5823	2.56	5.734832445	1.850106526	92.41506103
21j	12.3664	3.338	3.1462	3.119	5.745955662	1.851952721	92.40209162
21k	13.1808	1.9193	1.7983	1.7859	6.304381806	1.468338362	92.22727983

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550' Wt.	True 1000' Wt.	% Organics	% CaCO3	% Other
21k	13.1545	3.2724	3.0697	3.0455	6.194230534	1.680723628	92.12504584
21l	12.4558	2.1126	1.8757	1.7296	11.21367036	15.71738401	73.06894563
21l	11.6738	2.2135	1.953	1.8708	11.76869212	8.439944966	79.79136292
21m	13.4233	2.1373	1.9634	1.8338	8.136433818	13.78119378	78.08237241
21m	12.9787	2.6527	2.4504	2.2525	7.626192182	16.95528056	75.41852726
21n	13.0358	2.7291	2.5811	2.3396	5.423033234	20.11152528	74.46544149
21n	12.5984	2.2828	2.157	1.754	5.51077624	40.12217851	54.36704526
21o	10.3215	2.2992	2.1844	2.0176	4.993041058	16.48794838	78.51901057
21o	11.8577	2.6055	2.4782	2.2669	4.885818461	18.43129045	76.68289109
21p	12.07	2.4832	2.0571	1.9886	17.15931057	6.269403116	76.57128632
21p	11.7621	2.7837	2.2693	2.2119	18.47900277	4.686372291	76.83462494
21q	11.2563	1.5832	0.9458	0.8937	40.26023244	7.479098718	52.26066884
21q	13.6668	1.4852	0.868	0.821	41.5566927	7.192174914	51.25113239
21r	11.6016	1.0727	0.4336	0.3808	59.57863336	11.18672509	29.23464156
21r	11.8047	1.2284	0.4971	0.4385	59.5327255	10.84189337	29.62538113
21s	11.3656	1.5504	0.4893	0.3985	68.44040248	13.31034806	18.24924946
21s	10.4538	1.1428	0.3426	0.2802	70.02100105	12.4097114	17.56928756
21t	11.2768	1.5685	0.8456	0.7785	46.0886197	9.722664967	44.18871533
21t	11.5906	1.1789	0.6456	0.583	45.23708542	12.06826086	42.69465372
22	10.7764	1.3361	0.37	0.2867	72.30746202	14.169462	13.52307598
22	9.6826	1.3302	0.3829	0.3019	71.21485491	13.83934063	14.94580446
22	13.1537	1.0363	0.2924	0.2279	71.78423237	14.14560543	14.0701622
23	11.6727	2.3929	1.4248	1.3328	40.45718584	8.737971043	50.80484312
23	11.9197	1.5365	0.9528	0.8865	37.98893589	9.80682188	52.20424223
23	13.1528	1.7935	1.1317	1.0724	36.89991637	7.514509466	55.58557417

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550° Wt.	True 1000° Wt.	% Organics	% $CaCO_3$	% Other
24	11.9438	2.4561	2.3396	2.3008	4.743292211	3.590318724	91.66638907
24	13.1974	2.2297	2.1277	2.1085	4.574606449	1.957050887	93.46834266
24	11.8994	1.2707	1.2113	1.1897	4.674588809	3.863296537	91.46211465
25	13.2899	1.8587	1.7487	1.7226	5.918114811	3.191380095	90.89050509
25	13.5805	1.9716	1.8559	1.8321	5.86833029	2.7435032	91.38816651
25	12.4553	1.8629	1.7557	1.7372	5.754468839	2.256989347	91.98854181
26	14.4984	2.3947	2.3535	2.1012	1.720466029	23.94492383	74.33461014
26	12.5812	1.9678	1.9353	1.726	1.651590609	24.17328073	74.17512866
26	13.2348	2.9232	2.8737	2.5001	1.693349754	29.04662387	69.26002637
27	11.3653	1.4338	0.7415	0.6685	48.28427954	11.57128546	40.144435
27	12.8717	1.3754	0.6889	0.6005	49.91275265	14.60732085	35.4799265
27	11.5899	1.4095	0.7319	0.6617	48.07378503	11.3192944	40.60692057
28	10.406	1.7384	1.2456	1.2185	28.34790612	3.542965318	68.10912856
28	12.5985	1.3957	1.0656	1.0199	23.65121444	7.441687781	68.90709777
28	11.6024	1.5368	1.2058	1.1869	21.53826132	2.795064124	75.66667455
29	12.4452	2.2488	2.0468	1.9612	8.982568481	8.651078555	82.36635296
29	12.4445	2.6973	2.4592	2.3287	8.827345864	10.99584433	80.17680981
29	13.0358	2.6884	2.4483	2.3339	8.930962654	9.671179884	81.39785746
30	11.0164	3.1037	2.7384	2.5755	11.76982311	11.92857791	76.30159897
30	11.8583	2.0735	1.8503	1.75	10.76440801	10.99370849	78.24188351
30	11.7621	2.2606	2.0224	1.8524	10.53702557	17.09119864	72.3717758
31	11.9847	1.3542	0.7203	0.6603	46.80992468	10.0696822	43.12039312
31	12.9525	0.9998	0.5419	0.4986	45.79915983	9.842877666	44.3579625
31	13.839	1.6529	0.9011	0.8144	45.48369532	11.92119636	42.59510832
32	13.4813	1.0763	0.6169	0.5725	42.68326675	9.375554298	47.94117896

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550' Wt.	True 1000' Wt.	% Organics	% CaCO3	% Other
32	11.426	1.0142	0.5588	0.5161	44.90238612	9.568670336	45.52894355
32	10.3219	1.1532	0.5724	0.5192	50.36420395	10.48465929	39.15113676
38	11.8046	2.4975	2.1629	2.1088	13.3973974	4.923104923	81.67949768
38	12.2508	2.43	2.0999	2.0312	13.58436214	6.425364759	79.9902731
38	11.3433	2.2171	1.9304	1.8556	12.93130666	7.667673989	79.40101935
39	11.2573	2.6274	2.2916	2.2407	12.78069575	4.402900898	82.81640336
39	11.2773	2.0721	1.8285	1.7903	11.75618937	4.189864477	84.05394615
39	12.4178	2.2045	1.9521	1.9102	11.44930823	4.319676694	84.23101507
40-1	13.4221	1.3495	0.9075	0.8654	32.75287143	7.090168076	60.15696049
40-2	11.6726	1.1031	0.7426	0.7072	32.68062732	7.293495191	60.02587749
40-3	11.8988	1.6031	1.0692	1.0164	33.30422307	7.48549685	59.21028008
40-4	13.5798	0.6806	0.4654	0.4428	31.61915957	7.54681698	60.83402346
40-5	12.8381	0.8563	0.6021	0.5712	29.68585776	8.201246377	62.11289586
40-6	13.1794	1.1658	0.7939	0.7561	31.90084062	7.36911056	60.73004882
40-7	13.1526	0.9143	0.6063	0.5752	33.68697364	7.730703071	58.58232329
40-8	11.9191	1.1582	0.7417	0.7002	35.96097393	8.143514231	55.89551184
40-9	9.6822	1.4101	0.9538	0.9017	32.35940713	8.397212319	59.24338055
40-10	9.6058	0.8815	0.6207	0.5515	29.58593307	17.8414892	52.57257773
40-11	13.2341	1.5076	1.0267	0.9799	31.89838153	7.055162932	61.04645553
40-12	10.7768	0.9942	0.6629	0.6301	33.323275	7.498034052	59.17869095
40-13	12.9785	1.5626	1.0581	1.0001	32.2859337	8.435823744	59.27824256
40-14	13.1527	1.4284	0.9971	0.9514	30.19462336	7.271327105	62.53404954
40-15	12.6	1.0983	0.7152	0.6749	34.88118001	8.339334343	56.77948565
40-16	12.1386	1.5856	1.0357	0.9808	34.6808779	7.869117512	57.45000459
40-17	13.1975	1.2582	0.8205	0.771	34.78779208	8.941344778	56.27086314

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550° Wt.	True 1000° Wt.	% Organics	% CaCO3	% Other
40-18	12.2134	1.4117	0.938	0.8919	33.55528795	7.421741678	59.02297037
40-19	12.4249	1.2521	0.8295	0.7858	33.75129782	7.93212857	58.31657361
40-20	10.8848	0.8254	0.5224	0.4903	36.70947419	8.838689781	54.45183602
40-21	11.944	1.2974	0.8518	0.8083	34.34561431	7.620135376	58.03425032
40-22	12.4909	1.1663	0.7993	0.7604	31.4670325	7.580304459	60.95266305
40-23	14.4983	0.931	0.613	0.581	34.15682062	7.811737135	58.03144224
40-24	12.5809	1.7856	1.2305	1.1719	31.08758961	7.458659172	61.45375122
40-25	13.2894	0.9358	0.6195	0.5844	33.79995726	8.524548758	57.67549399
41	13.2324	1.5185	1.4502	1.3471	4.49785973	15.43089772	80.07124255
41	13.1951	2.4201	2.3074	2.1365	4.656832362	16.04929924	79.2938684
41	10.7748	2.7273	2.5987	2.4082	4.715286181	15.87484125	79.40987257
42	13.421	1.3398	0.5237	0.4422	60.91207643	13.82499423	25.26292934
42	11.897	1.2907	0.5208	0.443	59.64980243	13.69940202	26.65079555
42	10.8833	1.288	0.5808	0.5097	54.9068323	12.54587804	32.54728967
43	12.8366	3.1779	2.9642	2.7765	6.724566538	13.42367315	79.85176031
43	13.152	2.9019	2.7128	2.5602	6.516420276	11.95141741	81.53216231
43	14.4964	2.3879	2.2368	2.0578	6.327735667	17.03665069	76.63561364
44	12.9757	1.9446	1.334	1.2803	31.39977373	6.276121287	62.32410498
44	11.9424	1.3588	0.8851	0.8462	34.86164263	6.506409399	58.63194798
44	12.2126	1.4067	0.9049	0.8632	35.67214047	6.737238023	57.59062151
45	13.5788	3.3319	3.0896	3.0104	7.272127015	5.402322999	87.32554999
45	13.1517	2.1988	2.0478	1.975	6.867382209	7.524765575	85.60785222
45	11.6723	2.5524	2.3731	2.3092	7.024761009	5.68983203	87.28540696
46	12.4537	2.3556	2.2813	1.8364	3.15418577	42.92479044	53.92102379
46	13.1793	2.2485	2.1967	1.7581	2.303758061	44.33258536	53.36365658

Appendix III
Loss on Ignition Data

Sample	Crucible Wt.	True Dry Wt.	True 550° Wt.	True 1000° Wt.	% Organics	% CaCO3	% Other
46	11.9181	3.7	3.6096	2.9378	2.443243243	41.26535627	56.29140049
47	12.5804	1.8253	1.3925	1.2861	23.71117077	13.24813356	63.04069568
47	12.4904	3.1134	2.2425	2.1582	27.97263442	6.153751818	65.87361376
47	9.6824	1.7257	1.2197	1.1734	29.32143478	6.097657341	64.58090788
48	12.1381	4.572	4.2654	4.2168	6.706036745	2.415891195	90.87807206
48	9.6058	2.3971	2.2386	2.21	6.612156356	2.711609862	90.67623378
48	13.2889	2.3662	2.2147	2.1865	6.402670949	2.708600672	90.88872838
49	12.9519	1.6136	1.444	1.4265	10.5106594	2.464844278	87.02449633
49	13.8381	1.9782	1.7833	1.7634	9.852391063	2.286284133	87.8613248
49	10.3219	2.445	2.2315	2.2086	8.73210634	2.128648448	89.13924521
50	12.4455	1.1029	0.554	0.5041	49.76879137	10.28280813	39.9484005
50	11.8585	1.2588	0.6262	0.5692	50.25421036	10.29118641	39.45460323
50	11.7631	1.3913	0.6986	0.6353	49.78796809	10.34023118	39.87180074

Appendix IV
Stratigraphy

1) Mid-ridge Stratigraphy:

South Wall N2E8

Level 1: 20-36 cm thick; uncohesive; organic rich matrix color 10YR 2/2 dry, fresh, very dark brown; silt matrix color 7.5YR 4/4 dry, fresh, dark brown; upper contact is with ground surface, lower contact is wavy and somewhat gradational; medium silt sized matrix with 1% pebble size clasts; clasts are composed of limestone, silicified siltstone, and chert; matrix has weak reaction to HCl; massive with evident cryoturbation.

Level 2: 20-40 cm thick; uncohesive; matrix color 10YR 5/6-4/6 dry, fresh, yellowish to dark yellowish brown; lower contact wavy; coarse silt matrix; 30% clasts greater than 4 mm; clasts dominantly composed of limestone; strong reaction to HCl; massive; $CaCo_3$ collected on the underside of clasts.

Level 3: 2-10 cm thick; cohesive; matrix color 10YR 3/2 dry, fresh, very dark greyish brown; lower contact clear but wavy; clay matrix; 40% clasts greater than 4 mm; angular limestone clasts; no reaction to HCl in clay but strong reaction from pieces of limestone; massive.

Level 4: thickness unknown, lower contact covered; cohesive; 10YR 4/6 dry, fresh, dark yellowish brown; sandy clay matrix with 50% clasts greater than 4 mm; clasts composed of angular limestone, pebble to boulder size; reaction to HCl; massive.

North Wall N1E11

Level 1: 40-45 cm thick; uncohesive; color varies, in organic rich silt it is 10YR 2/2 dry, fresh, very dark brown, in clay rich silt color is 10YR 5/4 and 10YR 4/3 dry, fresh, yellowish brown and brown; upper contact is the ground surface, lower contact is clear and horizontal; medium silt matrix with 1% pebble size clasts; massive, organic matter is unevenly distributed; no reaction to HCl.

Level 2: 20-25 cm thick; cohesive; 10YR 3/3 dry, fresh, dark brown; lower contact is horizontal and gradational; matrix a clayey silt; 20 % clasts; clasts are angular limestone, pebble to cobble size; massive; weak reaction to HCl.

Level 3: Not exposed in north wall of this unit.

Level 4: thickness unknown, lower contact covered; cohesive; 10YR 5/8 wet, fresh, yellowish brown; poorly sorted silty sandy clay matrix; 40% clasts pebble to cobble sized; angular limestone clasts; massive; strong reaction to HCl.

Level 3 form south wall of N1E11: 1-10 cm thick; uncohesive; 10YR 2/1 moist, fresh, black; lower contact sharp and horizontal; fine to medium organic rich silt matrix; no reaction to HCl. The level only stretches 40 cm across the unit.

Appendix IV
Stratigraphy

South Wall N1E9

Level 1: 25-45 cm thick; uncohesive; organic matrix color 10YR 2/2 moist, fresh, very dark brown; mineral matrix color 10YR 4/3 moist, fresh, dark brown; upper contact with ground surface; lower contact sharp dipping 10° east; medium silt with 1% pebbles; massive with evident cryoturbation; no reaction to HCl.

Level 2: 32-52 cm thick; cohesive; matrix color 10YR 3/3 moist, fresh, dark brown; lower contact sharp and horizontal; silty clay matrix with 30% clasts; limestone clasts; massive; mild reaction to HCl.

Level 3: 7-20 cm thick; weekly cohesive; well color 10YR 2/1 dry, fresh, black; well sorted medium silt; no clasts; lower contact sharp and wavy; massive; no reaction to HCl.

Level 4: covered at base, thickness unknown; cohesive; 10YR 4/3 moist, fresh, brown; poorly sorted angular cobble diamicton with silty clay matrix; massive; strong reaction to HCl.

East Wall N0E8

Level 1: 10-20 cm thick; uncohesive; 10YR 3/2 dry, fresh, very dark greyish brown; upper contact ground surface; lower contact horizontal but slightly undulatory; fine to medium silt with <1% pebbles; massive; no reaction with HCl; weak soil development, cryoturbation of organic matter evident.

Level 2: 15-40 cm thick; slightly cohesive; 10YR 4/4 dry, fresh, dark yellowish brown; lower contact dipping 15° north; fine silt to pebble matrix; 25% clasts greater than 4 mm; limestone; massive reacts to HCl; carbonate coatings found on undersides of clasts.

Level 3: 35-40 cm thick; cohesive; dark organic matter 10YR 2/1 moist, fresh, black; lighter colored organic matter 5YR 3/4 moist, fresh, dark reddish brown; sharp lower contact dipping 15° north; organic rich fine silt with no clasts; massive with mottled organic matter; no reaction to HCl.

Level 4: thickness unknown, lower contact covered; very cohesive; 10YR 5/6 to 5/8 moist, fresh, yellowish brown; silty clay; 40% clasts; limestone clasts; massive; reacts strongly to HCl.

South Wall N0E7

Level 1: 2-20 cm thick; uncohesive; organic rich matrix 10YR 3/2 dry, fresh, very dark greyish brown; silt matrix 10YR 3/3 dry, fresh, dark brown; upper contact with surface; lower contact is gradational at a 20° angle; fine to medium silt with few pebbles; massive with mottling of organic matter; no reaction to HCl. Organic matter in frost cracks?

Level 2: not present in this profile, ends in south wall of N0E8.

Appendix IV
Stratigraphy

Level 3: 10-20 cm thick; slightly cohesive; 10YR 2/1 moist, fresh, black; lower contact is clear and sharp at 20° angle to level 4; organic rich silt with no clasts >4 mm; massive with mottling; no reaction to HCl

Level 4: covered to at base; cohesive; 10YR 4/4 moist, fresh, dark yellowish brown; silty clay matrix; 40% clasts; limestone clasts; massive; reacts strongly to HCl.

East Wall S1E8

Level 1: 6-34 cm thick; uncohesive; organic rich matrix color 10YR 3/2 dry, fresh, very dark greyish brown; mineral matrix color 10YR 4/3 dry, fresh dark brown; upper contact with ground surface; lower contact horizontal but undulatory with level 4, pockets of level 3 are found at the contact; fine to medium silt with few pebbles; massive with mottles of organic matter; no reaction to HCl.

Level 2: doesn't exist in this unit.

Level 3: exists in small isolated pockets. See unit S0E9 description.

Level 4: unexposed at base; cohesive; 10YR 3/3 fresh, moist, dark brown; silty clay with 40% angular limestone clasts; massive; reacts strongly to HCl.

South Wall S0E9

Level 1: 40-60 cm thick; uncohesive; 10YR 4/3 moist, fresh, dark brown; upper contact with ground surface; lower contact dips 20° east, clear and sharp; fine to medium silt with very few pebbles; massive but mottled with organic matter; no reaction to HCl.

Level 2: doesn't exist in this unit.

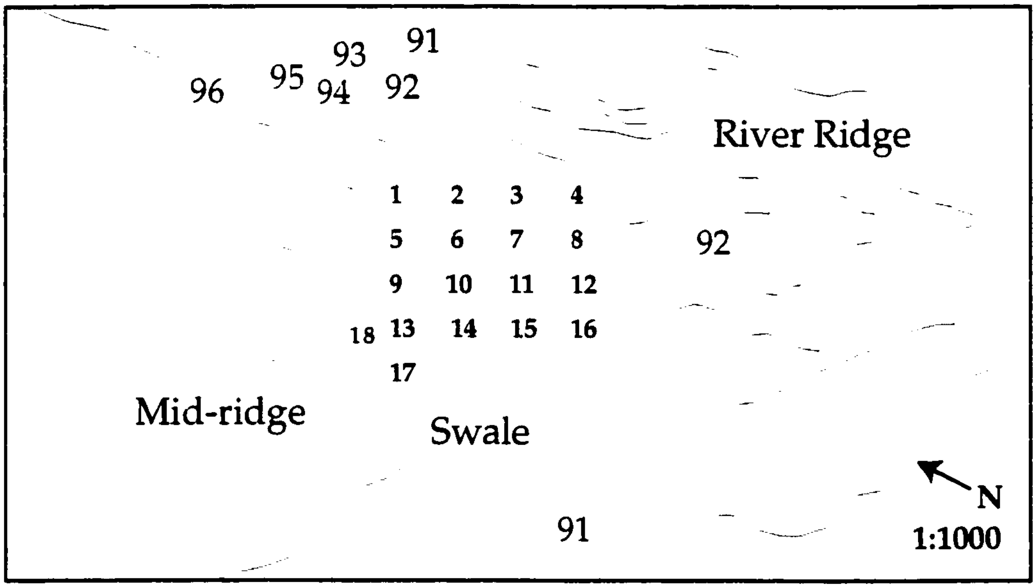
Level 3: 5-20 cm thick; uncohesive; 10YR 2/1 moist, fresh, black and 5YR 3/4 moist, fresh, dark reddish brown; sharp horizontal lower contact with level 4; silt size grains with no clasts >4 mm; massive and mottled with organic material; no reaction to HCl.

Level 4: not excavated.

Appendix IV
Stratigraphy

2) Swale Stratigraphy:

Seventeen pits were dug in the swale for examination of the surficial stratigraphy. The position of these pits are shown here:



Sediment types are based on grain size analysis and loss on ignition from samples 1, 2, 3, 4, 5, 43, 44, 45, and 46 (Appendix II, III).

1. 0-10 cm silt loam with soil development; 10-18 cm silt loam; 18+ cm shattered bedrock.
2. 0-10 cm silt loam with soil development; 10-30 cm silt loam; 30+ cm shattered bedrock.
3. 0-10 cm silt loam with soil development; 10-36 cm silt loam; 36+ cm black clay.
4. 0-15 cm silt loam with soil development; 15-30 cm black clay; 30+ cm shattered bedrock.
5. 0-10 cm silt loam with soil development; 10-24 silt loam; 24+ cm shattered bedrock.
6. 0-15 cm silt loam with soil development; 15+ cm shattered bedrock.
7. 0-10 cm silt loam with soil development; 10-20 cm silt loam; 20-28 cm clay loam; 28+ cm black clay.
8. 0-5 cm silt loam with soil development; 5-25 cm clay loam; 25+ cm black clay.
9. 0-10 cm silt loam with soil development; 10+ cm shattered bedrock.
10. 0-13 cm silt loam with soil development; 13-30 cm silt loam; 30+ cm shattered bedrock.

11. 0-10 cm silt loam with soil development; 10-24 cm silt loam; 21-24 cm silt with 45% organic matter (cryoturbated); 28+ cm black clay.
12. 0-10 cm silt loam with soil development; 10+ cm black clay.
13. 0-10 cm silt loam with soil development; 10+ cm shattered bedrock.
14. 0-6 cm silt loam with soil development; 6-20 cm silt loam; 20+ cm shattered bedrock.
15. 0-37 cm silt loam; 37+ cm black clay and colluvium from River Ridge slope.
16. 0-15 cm silt loam with soil development; 15+ cm black clay.
17. 0-9 cm silt loam with soil development; 9+ cm shattered bedrock.
18. 0-23 cm silt loam with soil development; 23- 42 cm clay loam; 42-52 cm black silt with 60% organic matter (soliflucted); 52+ cm shattered bedrock.

3) Tree ring counts:

1. *Picea mariana*, radius 14.8 cm, 92 years
2. *Picea mariana*, radius 12.9 cm, 104 years
3. *Picea mariana*, radius 17.2 cm, 267 years
4. *Picea mariana*, radius 23.4 cm, 220 years
5. *Picea mariana*, radius 7.4 cm, 173 years
6. *Picea mariana*, radius 18.6 cm, 240 years
7. *Picea mariana*, radius 5.8 cm, 103 years
8. *Picea mariana*, radius 6 cm, 190 years.

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 3557	2	83	19	12	251	21
NcVi-3: 3559	2	98	5	27	180	0
NcVi-3: 3560	2	101	40	7	5	49
NcVi-3: 3561	2	116	71	25	145	11
NcVi-3: 3562	2	111	75	70	105	80
NcVi-3: 3596	2	91	98	72	91	15
NcVi-3: 3597	2	92	38	100	183	79
NcVi-3: 3598	2	124	60	70	90	60
NcVi-3: 3599	2	125	53	70	355	32
NcVi-3: 3600	2	124	40	70	35	14
NcVi-3: 3601	2	121	47	62	310	0
NcVi-3: 3602	2	119	32	50	12	1
NcVi-3: 3603	2	120	20	45	195	30
NcVi-3: 3604	2	122	50	60	202	90
NcVi-3: 3605	2	130	43	55	332	6
NcVi-3: 3606	2	124	39	50	58	86
NcVi-3: 3607	2	122	19	50	27	40
NcVi-3: 3608	2	122	35	45	22	73
NcVi-3: 3609	2	122	27	45	358	44
NcVi-3: 3610	2	123	24	41	4	56
NcVi-3: 3611	2	123	24	42	355	31
NcVi-3: 3612	2	123	24	43	4	36
NcVi-3: 3663	2	90	50	15	333	74
NcVi-3: 3664	2	86	44	27	135	28
NcVi-3: 3665	2	92	47	60	95	39
NcVi-3: 3666	2	88	52	66	105	52
NcVi-3: 3667	2	101	45	72	10	81
NcVi-3: 3668	2	102	44	82	25	1
NcVi-3: 3669	2	95	48	15	194	23
NcVi-3: 3670	2	92	49	59	195	25
NcVi-3: 3671	2	90	56	62	158	8
NcVi-3: 3672	2	89	51	64	332	6
NcVi-3: 3673	2	93	61	70	33	50
NcVi-3: 3674	2	92	70	78	55	58
NcVi-3: 3675	2	95	65	80	135	15
NcVi-3: 3676	2	89	63	85	172	9
NcVi-3: 3677	2	109	16	27	152	89
NcVi-3: 3678	2	110	5	45	29	19
NcVi-3: 3679	2	112	17	65	300	41
NcVi-3: 3680	2	113	46	90	130	55
NcVi-3: 3681	2	112	66	66	250	1
NcVi-3: 3682	2	116	35	30	350	48
NcVi-3: 3683	2	118	70	40	132	0
NcVi-3: 3684	2	123	70	20	55	25
NcVi-3: 3685	2	121	23	20	183	42
NcVi-3: 4071	2	85	72	80	340	16

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 4074	2	92	63	42	324	26
NcVi-3: 4075	2	91	60	66	170	65
NcVi-3: 4076	2	99	70	79	296	31
NcVi-3: 4077	2	97	60	69	281	71
NcVi-3: 4078	2	98	32	73	318	6
NcVi-3: 4079	2	97	36	16	100	57
NcVi-3: 4080	2	102	45	79	116	60
NcVi-3: 4081	2	97	80	48	11	42
NcVi-3: 4082	2	116	38	17	336	42
NcVi-3: 4084	2	116	57	72	202	14
NcVi-3: 4085	2	105	50	56	344	21
NcVi-3: 4086	2	106	37	38	55	20
NcVi-3: 4114	2	77	11	82	316	33
NcVi-3: 4115	2	78	37	52	267	30
NcVi-3: 4117	2	81	35	66	248	17
NcVi-3: 4118	2	82	26	71	228	22
NcVi-3: 4119	2	81	26	73	226	25
NcVi-3: 4120	2	81	23	76	229	10
NcVi-3: 4121	2	86	26	66	229	79
NcVi-3: 4122	2	83	10	92	255	31
NcVi-3: 4126	2	79	2	92	283	31
NcVi-3: 4128	2	67	6	91	334	36
NcVi-3: 4129	2	90	24	80	346	10
NcVi-3: 4130	2	89	11	86	324	26
NcVi-3: 4131	2	90	30	60	144	50
NcVi-3: 4136	2	82	1	92	259	29
NcVi-3: 4149	2	118	51	38	329	12
NcVi-3: 4150	2	115	63	12	330	4
NcVi-3: 4196	2	89	77	47	2	71
NcVi-3: 4395	2	123	39	58	320	27
NcVi-3: 4396	2	132	11	24	285	3
NcVi-3: 4397	2	136	11	88	158	38
NcVi-3: junk2	2	87	86	60	0	90
NcVi-3: 3500	4	32	6	2	225	32
NcVi-3: 3501	4	27	91	23	287	4
NcVi-3: 3502	4	37	4	47	315	12
NcVi-3: 3503	4	37	9	34	145	0
NcVi-3: 3504	4	37	7	32	316	79
NcVi-3: 3505	4	39	23	41	305	17
NcVi-3: 3506	4	38	22	35	305	21
NcVi-3: 3507	4	39	85	32	10	36
NcVi-3: 3508	4	38	13	40	174	7
NcVi-3: 3509	4	39	22	42	195	0
NcVi-3: 3510	4	39	13	50	105	15
NcVi-3: 3511	4	41	2	50	98	1
NcVi-3: 3517	4	54	9	86	219	75

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 3518	4	57	13	92	220	42
NcVi-3: 3519	4	70	7	100	189	36
NcVi-3: 3541	4	57	90	67	135	16
NcVi-3: 3542	4	58	73	27	82	0
NcVi-3: 3543	4	54	14	66	102	54
NcVi-3: 3544	4	47	3	25	115	4
NcVi-3: 3545	4	59	30	9	90	0
NcVi-3: 3546	4	55	27	2	345	40
NcVi-3: 3547	4	59	1	54	280	37
NcVi-3: 3548	4	58	9	31	284	1
NcVi-3: 3549	4	58	29	5	179	62
NcVi-3: 3550	4	62	40	19	332	4
NcVi-3: 3551	4	67	71	12	275	9
NcVi-3: 3552	4	61	94	10	14	1
NcVi-3: 3553	4	62	92	19	140	26
NcVi-3: 3554	4	63	90	32	5	0
NcVi-3: 3555	4	61	0	21	195	0
NcVi-3: 3556	4	61	9	32	12	41
NcVi-3: 3558	4	61	96	26	219	65
NcVi-3: 3629	4	51	100	67	10	0
NcVi-3: 3630	4	52	0	62	8	0
NcVi-3: 3631	4	55	0	78	278	0
NcVi-3: 3632	4	65	80	45	101	6
NcVi-3: 3633	4	69	65	70	270	65
NcVi-3: 3634	4	69	38	77	29	2
NcVi-3: 3635	4	74	58	58	137	12
NcVi-3: 3636	4	74	54	54	114	71
NcVi-3: 3637	4	83	46	38	100	11
NcVi-3: 3638	4	83	38	55	180	21
NcVi-3: 3639	4	76	64	60	91	42
NcVi-3: 3640	4	80	50	63	37	39
NcVi-3: 3641	4	82	48	60	36	72
NcVi-3: 3642	4	77	49	80	270	2
NcVi-3: 3643	4	77	46	78	6	36
NcVi-3: 3644	4	86	46	61	21	57
NcVi-3: 3645	4	81	50	59	146	33
NcVi-3: 3646	4	80	55	63	126	3
NcVi-3: 3647	4	80	61	60	4	35
NcVi-3: 3656	4	75	66	63	115	36
NcVi-3: 3657	4	75	67	60	64	51
NcVi-3: 3658	4	80	50	60	19	59
NcVi-3: 3659	4	83	55	63	205	62
NcVi-3: 3660	4	79	50	75	155	31
NcVi-3: 3661	4	81	54	68	325	51
NcVi-3: 3662	4	84	50	80	46	0
NcVi-3: 4091	4	35	86	27	159	22

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 4092	4	38	90	42	95	21
NcVi-3: 4099	4	50	28	10	270	21
NcVi-3: 4100	4	55	29	20	18	10
NcVi-3: 4101	4	56	42	55	335	9
NcVi-3: 4102	4	54	59	16	340	2
NcVi-3: 4103	4	55	68	8	124	9
NcVi-3: 4107	4	58	71	9	241	6
NcVi-3: 4110	4	65	8	65	4	5
NcVi-3: 4111	4	68	12	77	340	22
NcVi-3: 4112	4	73	14	68	327	42
NcVi-3: 4154	4	23	37	24	115	14
NcVi-3: 4156	4	32	18	48	200	32
NcVi-3: 4157	4	29	29	37	295	65
NcVi-3: 4158	4	29	17	35	295	60
NcVi-3: 4159	4	29	22	18	102	30
NcVi-3: 4160	4	28	40	14	59	28
NcVi-3: 4161	4	36	82	23	70	26
NcVi-3: 4162	4	29	74	44	169	11
NcVi-3: 4163	4	30	38	5	107	20
NcVi-3: 4164	4	28	73	2	66	3
NcVi-3: 4165	4	34	74	49	311	12
NcVi-3: 4166	4	36	32	4	85	15
NcVi-3: 4167	4	38	86	46	251	11
NcVi-3: 4168	4	38	86	42	346	7
NcVi-3: 4169	4	46	73	41	294	9
NcVi-3: 4170	4	44	80	30	132	37
NcVi-3: 4171	4	50	77	15	151	13
NcVi-3: 4172	4	48	19	15	42	19
NcVi-3: 4173	4	39	89	32	206	130
NcVi-3: 4174	4	49	72	1	290	62
NcVi-3: 4175	4	53	76	16	279	13
NcVi-3: 4176	4	43	88	33	335	5
NcVi-3: 4179	4	71	15	57	244	57
NcVi-3: 4180	4	71	51	70	190	81
NcVi-3: 4181	4	57	91	77	6	1
NcVi-3: 4182	4	65	80	58	131	5
NcVi-3: 4183	4	47	99	30	280	9
NcVi-3: 4184	4	74	56	91	268	71
NcVi-3: 4185	4	68	86	15	86	11
NcVi-3: 4186	4	78	33	22	259	85
NcVi-3: 4187	4	77	58	86	323	36
NcVi-3: 4189	4	83	68	58	128	28
NcVi-3: 4190	4	76	56	93	321	23
NcVi-3: 4191	4	76	59	92	341	23
NcVi-3: 4192	4	90	29	93	134	34
NcVi-3: 4193	4	92	32	86	269	22

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 4194	4	90	36	89	108	32
NcVi-3: 4195	4	92	22	80	72	9
NcVi-3: 4213	4	21	53	0	240	45
NcVi-3: 4214	4	33	37	75	70	11
NcVi-3: 4215	4	34	56	10	198	51
NcVi-3: 4216	4	33	42	2	23	14
NcVi-3: 4217	4	32	24	5	207	88
NcVi-3: 4240	4	35	93	79	128	12
NcVi-3: 4241	4	34	79	83	44	23
NcVi-3: 4242	4	36	82	75	147	26
NcVi-3: 4243	4	36	80	76	169	25
NcVi-3: 4244	4	37	78	80	132	12
NcVi-3: 4245	4	38	80	67	89	33
NcVi-3: 4246	4	35	69	97	224	31
NcVi-3: 4247	4	36	65	89	345	5
NcVi-3: 4248	4	49	16	40	0	14
NcVi-3: 4249	4	49	17	38	5	32
NcVi-3: 4249	4	52	32	27	246	48
NcVi-3: 4250	4	48	18	40	315	6
NcVi-3: 4251	4	44	52	19	120	13
NcVi-3: 4252	4	44	56	25	212	22
NcVi-3: 4253	4	35	69	96	4	56
NcVi-3: 4254	4	33	86	80	244	4
NcVi-3: 4255	4	36	88	73	153	18
NcVi-3: 4256	4	37	74	83	170	13
NcVi-3: 4257	4	35	65	93	155	13
NcVi-3: 4258	4	37	58	96	155	51
NcVi-3: 4259	4	40	72	73	195	39
NcVi-3: 4260	4	41	71	73	56	12
NcVi-3: 4261	4	41	76	69	180	32
NcVi-3: 4262	4	43	76	64	322	9
NcVi-3: 4263	4	43	70	54	59	9
NcVi-3: 4264	4	37	66	85	4	3
NcVi-3: 4265	4	44	69	41	89	19
NcVi-3: 4266	4	34	71	40	242	9
NcVi-3: 4267	4	45	49	25	226	18
NcVi-3: 4268	4	51	21	54	41	8
NcVi-3: 4270	4	52	29	8	75	0
NcVi-3: 4271	4	39	95	73	28	4
NcVi-3: 4272	4	36	87	80	115	12
NcVi-3: 4273	4	36	80	83	113	20
NcVi-3: 4274	4	32	66	90	244	15
NcVi-3: 4275	4	35	82	68	210	6
NcVi-3: 4276	4	43	72	67	20	6
NcVi-3: 4278	4	53	27	59	224	12
NcVi-3: 4279	4	52	21	51	274	24

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 4280	4	47	54	52	200	70
NcVi-3: 4281	4	45	57	53	152	8
NcVi-3: 4282	4	44	52	38	50	1
NcVi-3: 4283	4	47	44	23	115	16
NcVi-3: 4284	4	36	88	85	18	40
NcVi-3: 4285	4	38	84	70	25	67
NcVi-3: 4286	4	42	83	64	100	15
NcVi-3: 4287	4	42	75	70	184	40
NcVi-3: 4288	4	44	71	72	345	27
NcVi-3: 4289	4	47	51	51	311	56
NcVi-3: 4290	4	50	46	50	290	12
NcVi-3: 4291	4	49	46	49	321	10
NcVi-3: 4292	4	54	22	56	335	90
NcVi-3: 4293	4	54	11	44	246	46
NcVi-3: 4294	4	51	40	27	92	6
NcVi-3: 4295	4	57	24	7	20	9
NcVi-3: 4296	4	39	90	64	229	32
NcVi-3: 4297	4	45	79	63	210	22
NcVi-3: 4298	4	44	74	74	120	29
NcVi-3: 4299	4	43	73	73	100	34
NcVi-3: 4300	4	46	71	75	357	21
NcVi-3: 4301	4	54	40	63	220	2
NcVi-3: 4302	4	50	53	53	90	6
NcVi-3: 4303	4	49	42	48	88	69
NcVi-3: 4304	4	51	38	26	19	15
NcVi-3: 4305	4	52	41	30	26	15
NcVi-3: 4306	4	45	52	38	300	11
NcVi-3: 4307	4	46	55	25	276	8
NcVi-3: 4308	4	45	68	29	75	15
NcVi-3: 4309	4	49	44	59	217	8
NcVi-3: 4310	4	52	32	66	54	5
NcVi-3: 4311	4	54	27	48	206	10
NcVi-3: 4312	4	49	46	21	126	15
NcVi-3: 4313	4	38	86	71	75	19
NcVi-3: 4314	4	37	78	78	190	49
NcVi-3: 4315	4	40	80	71	280	39
NcVi-3: 4316	4	42	79	74	330	30
NcVi-3: 4317	4	44	76	71	89	14
NcVi-3: 4318	4	45	75	79	297	10
NcVi-3: 4319	4	47	72	82	81	0
NcVi-3: 4320	4	47	67	80	282	25
NcVi-3: 4321	4	46	73	67	205	2
NcVi-3: 4322	4	47	58	90	267	11
NcVi-3: 4323	4	49	56	89	297	38
NcVi-3: 4324	4	52	45	94	170	0
NcVi-3: 4325	4	55	50	61	10	4

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 4326	4	47	55	63	39	36
NcVi-3: 4327	4	54	38	43	116	12
NcVi-3: 4328	4	58	16	30	0	18
NcVi-3: 4329	4	51	39	21	120	24
NcVi-3: 4330	4	49	44	27	196	74
NcVi-3: 4331	4	47	55	26	27	1
NcVi-3: 4332	4	47	62	30	270	35
NcVi-3: 4333	4	49	47	28	191	68
NcVi-3: 4334	4	40	88	71	175	11
NcVi-3: 4335	4	45	79	81	85	13
NcVi-3: 4336	4	49	73	76	65	15
NcVi-3: 4337	4	52	67	63	150	85
NcVi-3: 4338	4	53	58	62	110	14
NcVi-3: 4339	4	49	56	52	116	10
NcVi-3: 4340	4	56	45	59	264	53
NcVi-3: 4341	4	53	41	48	91	31
NcVi-3: 4342	4	60	26	34	132	18
NcVi-3: 4343	4	51	46	34	290	4
NcVi-3: 4344	4	50	44	31	43	74
NcVi-3: 4345	4	51	46	37	95	26
NcVi-3: 4346	4	54	37	25	0	90
NcVi-3: 4347	4	46	57	30	40	9
NcVi-3: 4348	4	48	66	33	110	9
NcVi-3: 4349	4	48	80	37	80	4
NcVi-3: 4350	4	41	89	67	78	29
NcVi-3: 4351	4	53	75	81	190	4
NcVi-3: 4352	4	53	58	56	297	10
NcVi-3: 4353	4	52	61	48	287	19
NcVi-3: 4354	4	50	61	42	341	5
NcVi-3: 4355	4	52	44	35	125	23
NcVi-3: 4356	4	46	59	28	310	13
NcVi-3: 4357	4	53	59	27	9	16
NcVi-3: 4358	4	44	87	67	327	67
NcVi-3: 4359	4	57	75	68	132	43
NcVi-3: 4360	4	53	64	44	145	8
NcVi-3: 4361	4	61	43	50	326	15
NcVi-3: 4362	4	60	28	53	75	22
NcVi-3: 4363	4	59	39	32	69	11
NcVi-3: 4364	4	63	4	44	99	9
NcVi-3: 4365	4	46	88	73	0	90
NcVi-3: 4366	4	54	43	17	65	81
NcVi-3: 4368	4	50	97	72	100	34
NcVi-3: 4369	4	57	76	70	148	13
NcVi-3: 4371	4	63	94	41	115	24
NcVi-3: 4372	4	54	86	24	85	16
NcVi-3: 4373	4	57	80	23	86	41

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
NcVi-3: 4374	4	59	57	21	112	3
NcVi-3: 4375	4	58	48	24	260	7
NcVi-3: 4377	4	62	24	36	178	14
NcVi-3: 4378	4	57	66	75	74	10
NcVi-3: 4379	4	60	48	69	352	1
NcVi-3: 4380	4	64	44	69	170	14
NcVi-3: 4381	4	64	28	45	156	15
NcVi-3: 4382	4	63	26	32	240	56
NcVi-3: 4383	4	65	7	25	328	14
NcVi-3: 4384	4	65	80	76	145	8
NcVi-3: 4385	4	60	71	70	121	16
NcVi-3: 4386	4	66	67	68	264	19
NcVi-3: 4387	4	69	5	69	15	21
NcVi-3: 4389	4	70	6	31	280	79
NcVi-3: 4390	4	69	59	80	309	16
NcVi-3: 4392	4	67	70	71	279	16
NcVi-3: 4393	4	65	74	70	213	36
NcVi-3: 4394	4	65	80	74	13	53
NcVi-3: junk1	4	44	61	29	351	55
NcVi-3: junk3	4	56	14	41	297	28
Clast 1	3				200	11
Clast 2	3				100	2
Clast 3	3				70	31
Clast 4	3				151	3
Clast 5	3				141	22
Clast 6	3				134	11
Clast 7	3				200	86
Clast 8	3				120	54
Clast 9	3				336	65
Clast 10	3				335	48
Clast 11	3				335	76
Clast 12	3				45	38
Clast 13	3				204	31
Clast 14	3				206	14
Clast 15	3				20	16
Clast 16	3				306	41
Clast 17	3				134	28
Clast 18	3				284	89
Clast 19	3				237	15
Clast 20	3				262	48
Clast 21	3				325	45
Clast 22	3				289	87
Clast 23	3				45	27
Clast 24	3				260	18
Clast 25	3				46	32
Clast 26	3				285	50

Appendix V
Fabric Data

Catalogue Number	Unit	Depth cm B. D.	Northing cm	Easting cm	Trend	Plunge
Clast 27	3				250	19
Clast 28	3				324	18
Clast 29	3				244	10
Clast 30	3				244	6
Clast 31	3				260	16
Clast 32	3				62	8
Clast 33	3				160	30
Clast 34	3				323	26
Clast 35	3				314	22
Clast 36	3				318	28
Clast 37	3				230	38
Clast 38	3				285	51
Clast 39	3				58	9
Clast 40	3				299	64
Clast 41	3				336	12
Clast 42	3				319	41
Clast 43	3				248	40
Clast 44	3				261	21
Clast 45	3				64	59
Clast 46	3				228	34
Clast 47	3				267	45
Clast 48	3				155	20
Clast 49	3				64	61
Clast 50	3				89	90

Appendix VI
Pollen Data

Sample Number		JE 38	JE 40	JE 42	JE 20	JE 47	JE 28	JE 50	JE 32	JE 31	JE 27	JE 22	JE 23
Depth cm		60	80	100	100	30	50	70	90	110	130	140	150
Unit		4	2	2	2	4	4	2	2	2	2	2	2
Trees	Picea	5	40	67	9	18	46	112	199	204	335	424	311
	Pinus			3						2	3		
Shrubs	Alnus	4	87	60	66	81	87	73	103	65	127	18	22
	Betula	8	20	25	29	53	50	22	64	28	24	34	23
	Corylus		2	2		4	4	1	2	3	1	2	
	Ericales	2	6	5		31	22	12	13	8	20	2	
	Populus				1								
	Salix	6	24	19	9	19	13	5	9	9	10	7	5
	Sheperdia			1									
Herbs	Artemisia		8	2					1	2	1		
	Asteraceae												
	Caryophyllaceae			1		8	1	2	5				
	Chenopodaceae												
	Cyperaceae		4	2		13	4	21	8	13	3		
	Graminae			3	2	8	5	3	2	8	3	5	3
	Rosaceae		2										
	Saussurea												
	Saxifragaceae					8	1	2	1	2			
Aquatics	Potamogeton												
Bryophytes	Bryophyte spores				1	578	570	45	292	3			
	Sphagnum	6	24	14	25	51	78	44	64	52	20	23	22
Exotic	Lycopodium	222	2	51	87	81	464	33	33	54	78	56	52
Pollen Sum	Trees/Shrubs/Herbs	25	193	190	116	243	233	253	407	344	527	492	364
Total		253	219	255	229	953	1345	375	796	453	625	571	438

Appendix VI
Pollen Data

Sample Number		JE 1	JE44	JE 3	JE 14	JE 15	JE 16	JE 12	JE 9	JE 37	JE 34	JE 36
Depth cm		10	20	50	0	0	0	0	0	0	0	0
Unit		4	4	2								
Trees	Picea	24	10	76	24	42	29	37	112	82	10	79
	Pinus							3		4	1	
Shrubs	Alnus	54	28	30	28	36	36	66	96	49	37	40
	Betula	16	19	13	34	44	104	109	79	26	25	21
	Corylus	1			3	5	6	1		3	3	4
	Ericales	25		8		2	21	38	65	7	7	9
	Populus											
	Salix	14	4	4	4	10	17	13	18	14	7	7
	Sheperdia								1		1	
Herbs	Artemisia	4			2	3	2	1	3	5		
	Asteraceae	2							1		1	
	Caryophyllaceae	1		1	1		1					
	Chenopodaceae	11								1		
	Cyperaceae	12	3	3		1		6	1	8	2	
	Graminae	3	7	7	3	7	4	3	5	2	3	6
	Rosaceae				3			2	17			2
	Saussurea	1						2				
	Saxifragaceae											
Aquatics	Potamogeton							7	7	3	1	
Bryophytes	Bryophyte spores		50	11						1		
	Sphagnum	4	47	27	3	3	6			5		11
Exotic	Lycopodium	40	33	21	113	109	80	238	163	99	71	162
Pollen Sum	Trees/Shrubs/Herbs	168	71	142	102	150	220	281	398	201	97	168
Total		212	201	201	218	262	306	526	568	309	169	341