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POLLEN-SEDIMENTARY ENVIRONMENT RELATIONS
AND LATE HOLOCENE
PALYNOSTRATIGRAPHY OF THE RUBY RANGE,
YUKON TERRITORY, CANADA.

by
Ian D. Campbell

A thesis submitted to the School of Graduate
Studies in partial fulfillment of the requirements
for the degree of M.Sc. in Geology

UNIVERSITY OF OTTAWA
OTTAWA, CANADA, 1987

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ABSTRACT.

A 2,43 meter section from the Ruby Range, Yukon Territory, was analysed to develop a palynostratigraphy of the region. Surface moss polsters were collected to develop an understanding of the relations between pollen spectrum, vegetation, altitude, and distance from pollen source areas. Several experiments were conducted to further elucidate the relations of pollen spectra to sedimentary environments. These experiments were supplemented by two pollen diagrams from adjacent sites with differing sedimentology.

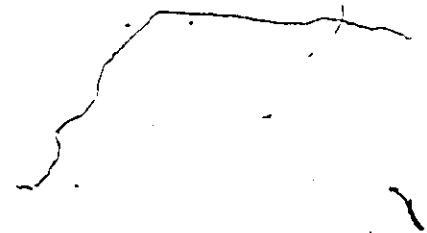
The experiments indicate that pollen grains are highly resistant to most forms of mechanical degradation, with the exception of repeated wet-dry cycles.

The experiments also indicate, confirmed by the pollen diagrams from adjacent sites, that selective pollen transport in runoff can strongly affect pollen spectra. The most easily transported pollen taxa are those with saccate grains.

The palynostratigraphy of the Ruby Range over the last 4500 years shows short duration low amplitude fluctuations between two climatic states. One is the present cold semi-arid environment, and the other is a warmer and drier climate. These fluctuations can be correlated with previous work in the Grizzly Creek Basin (Y.T.) and north of the Malaspina Glacier (Alaska). Due to difficulties with the radiometric dating of the section, absolute dates for these fluctuations cannot be

given with certainty.

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RÉSUMÉ.

Une coupe de 2,43 metres fût analysée pour développer une palynostratigraphie de la Chaîne Ruby, Territoire du Yukon. Des coussinets de mousses furent analysés pour déterminer les relations entre le spectre pollinique, la végétation actuelle, l'altitude, et la distance des régions sources de pollens. Plusieurs expériences illustrent les relations entre les spectres polliniques et les environnements sédimentaires. Deux diagrammes polliniques de coupes adjacentes avec des régimes sédimentaires différents s'ajoutent à ces expériences.

Les expériences indiquent que les grains de pollen sont très résistants à la plupart des formes de destruction mécanique à l'exception des alternances de conditions de sécheresse et d'humidité.

Les expériences indiquent aussi, confirmé par les diagrammes polliniques de sites adjacents, que le transport sélectif de pollens par ruissellement peut avoir un effet important sur le développement des spectres polliniques. Les pollens biaillés sont les plus facilement transportés.

La palynostratigraphie des derniers 4500 ans dans la Chaîne Ruby met en évidence sept oscillations climatiques de courte durée et de faible amplitude. Deux états climatiques sont apparents: l'un est semblable au climat froid et semi-aride qui domine actuellement, et l'autre légèrement plus chaud et plus sec. Ces oscillations sont corrélables avec des

oscillations dans d'autres diagrammes polliniques dans le Bassin du Grizzly Creek (T.Y.) et au nord du Glacier Malaspina (Alaska). Des difficultés avec les datations radiométriques réduisent la certitude des dates de ces fluctuations.

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NOTE

The toponyms 'Shaky Hand Creek', 'Kettle Camp', 'Bonanza Pup', and 'Alaskite Rock Glacier' are not official. They are used only for convenience.

CHAPTER 1. INTRODUCTION.

1.1 BACKGROUND AND OBJECTIVES.

Palynology is the study of resistant-walled organic micro-fossils in general and the pollen and spores of terrestrial plants in particular. It has several uses in paleoclimatology, geothermometry, and biostratigraphy. In all of these it has applications of interest to the petroleum industry (R. D. Woods, 1955). In Quaternary geology, palynology is used largely as a tool for the reconstruction of paleoclimates and to derive paleoecological information.

When interpreting a pollen and spore assemblage in paleoclimatic terms it is first necessary to determine the vegetational landscape represented by the palynomorphs (the term 'pollen' is hereafter used to include both pollen and spores except where otherwise indicated). The interpretation is rarely a straightforward process because it must take into account a number of different processes. Differences in pollen productivity and dispersiveness have been documented by several authors, including Davis (1965). The sedimentary and post-sedimentary environments can have a major effect in determining the final pollen spectrum, as noted by Havinga (1984), and Catto (1985). Climatic change also affects different species in different ways, and different species may

have different response rates to a climatic change (several examples of this can be found in Ritchie, 1984). Many other factors may exert an influence on the pollen spectrum of a given sample.

This study will attempt to demonstrate certain relations between pollen spectrum and depositional environment. It will also present a palynostratigraphy of the Ruby Range, using deposits of varying sedimentology. An understanding of pollen-sediment relations is necessary to interpret these palynostratigraphic sections.

Firstly, several experiments will be presented testing some possible sources of bias in pollen diagrams. They are: 1) a test of the relative dispersiveness of several pollen taxa in air, 2) two tests of damage and differential sedimentation of pollen grains in aqueous transport, 3) a test of damage to pollen grains through wet-dry cycles, and 4) a test of damage to pollen grains through sediment compaction.

Secondly, a series of samples of modern mosses establishes the spatial distribution of pollen spectra in the Ruby Range.

Thirdly, a series of pollen diagrams of sections excavated in different parts of the Ruby Range is analysed for paleoclimatic information, sediment-climate relations, and for pollen-sedimentary regime relations.

1.2 PREVIOUS STUDIES OF POLLEN-SEDIMENTARY ENVIRONMENT RELATIONS.

Previous studies involving the relations between pollen grains and their sedimentary matrix include: 1) Hopkins (1950) who noted that saccate pollen grains tend to float longer on a lake surface than do non-saccate grains and so tend to accumulate in a ring around the lake-shore; 2) Davis (1967) who found that in lakes in Maine mixing of the sediments smoothed the pollen curves over intervals of several tens of years, 3) Davis *et al* (1971) reiterated Hopkins' conclusion that saccate grains tend to accumulate in shallow water, 4) Heyvaert (1980) who found that it was possible to distinguish the Slikke and the Schorre (two subdivisions of the tidal flats) on the basis of pollen assemblages, 5) Catto (1985) who studied the hydrodynamics of the distribution of pollen grains in a silt-sand fluvial section in the Yukon, and 6) Seret (1984) who noted that portions of the pollen diagrams of La Grande Pile peat bog (France) cannot be reliably interpreted due to the presence of frequent intraclasts.

Experimental work includes: 1) Brush and Brush (1972), confirming that pollen grains behave hydrodynamically as silt, 2) Havinga (1974) who determined that pollen infiltration into sand and silt is largely independant of the diameter of the pollen grains, 3) Holloway (1980) who determined that freeze-thaw cycles have little effect on pollen grains though

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wet-dry cycles can cause rapid taxon-dependant deterioration of the exine, and 4) Havinga's (1984) 20-year experiment in the chemical destruction of pollen grains in various soil types.

Several broad conclusions emerge from these studies. Firstly, pollen grains behave hydrodynamically as silt. Secondly, pollen grains are extremely resistant to destruction. This is in contradiction with the hypothesis forwarded by Solomon et al (1982) who suggested that the lack of upland pollen in floodplain sediments is due to the rapid destruction of pollen grains through transport in sheetwash. Thirdly, saccate grains behave hydrodynamically differently from most other pollen grains. Fourthly, although there are many sedimentological factors affecting the pollen spectra found in lake sediments which are as yet only poorly understood, gyttja is the preferred sediment for many palynologists. Fifthly, there is little known about the relations between pollen spectra and sedimentary environments other than uniform silts, peats, and gyttja.

1.3 REGIONAL SETTING.

1.3.1 BEDROCK AND QUATERNARY GEOLOGY.

The Ruby Range is a largely granitic mountain plateau (Bostock, 1952) in southwestern Yukon Territory (Figure 1). It

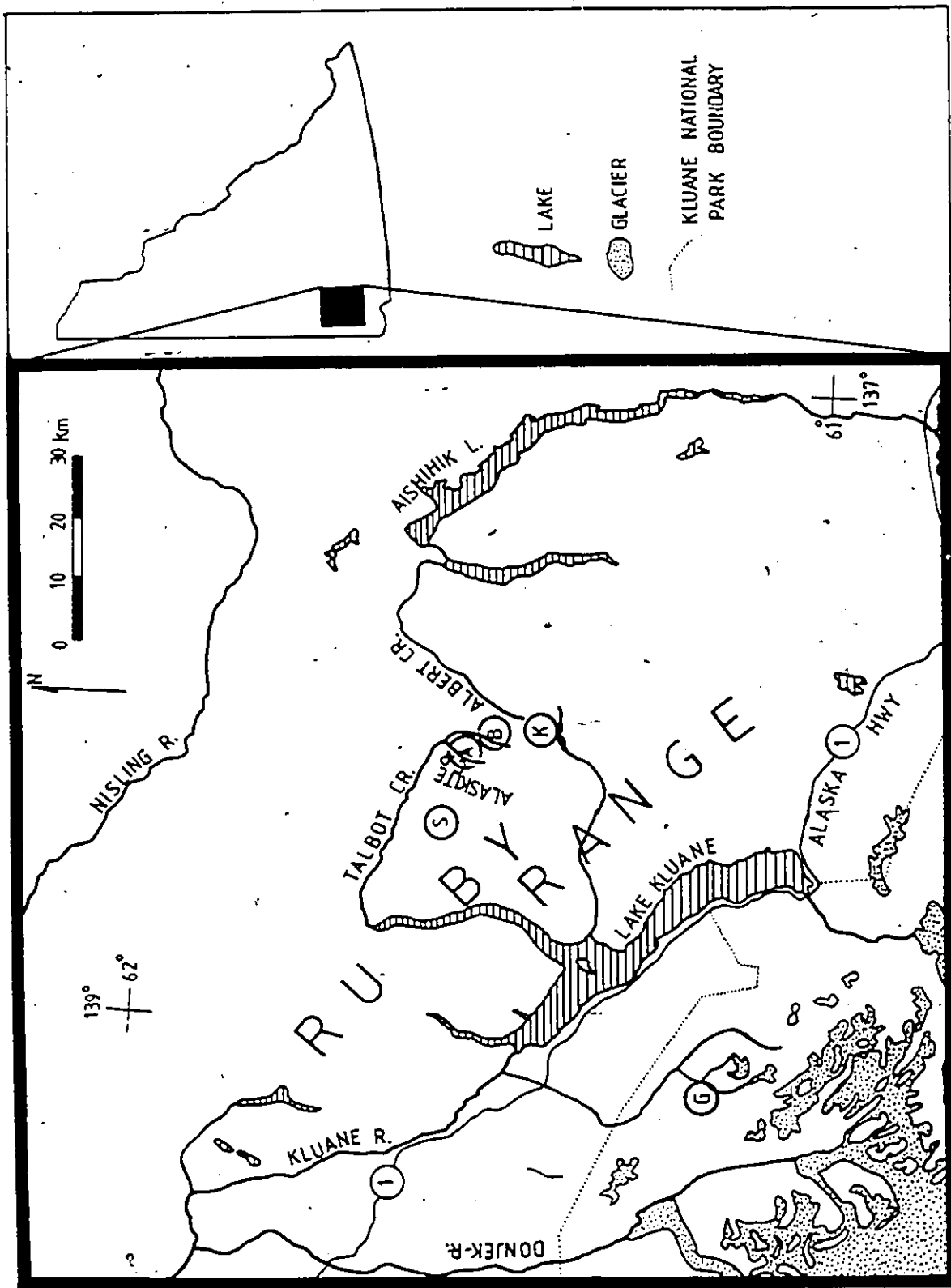


FIGURE 1. LOCATION MAP. A= Alaskite Rock Glacier; B= Bonanza Pup; G= Grizzly Creek; K= Kettle Camp; S= Shaky Hand Creek. The Alaska Highway (1) lies in the axis of the Shawk Trench which separates the Kluane Ranges and St. Elias Mountains to the west from the Ruby Range to the east.

is currently unglaciated and lies northeast of the Shakwak Trench which separates it from the currently glaciated St. Elias Mountains. The Shakwak Trench itself is a major thrust fault along which some postglacial movement has occurred (Bostock, 1952). It serves as a corridor for the Alaska Highway and is in part occupied by Lake Kluane.

The Ruby Range was largely ice-covered during the Kluane glaciation, which ended ca 9000 BP (Bostock, 1969), but lies near an area thought to have been unglaciated throughout the Pleistocene (Bostock, 1969). There is only slight evidence for small cirque glaciers in the Ruby Range during the Neoglacial period of the Holocene (Lacasse, unpublished). Mass-movement features such as mudflows and rock-glaciers are common in the deep glacial valleys and cirques (Johnson, 1984). Solifluction features and patterned ground are common on the high plateau.

The entire Ruby Range lies within the 2.5 cm isopach for the White River volcanic ash (Lerbekmo et al, 1975). This rhyodacitic volcanic ash erupted in two episodes. The eruption which blanketed the Ruby Range occurred ca. 1250 BP (Lerbekmo et al, 1975) providing a valuable stratigraphic marker for the area. This ash has been suggested as the probable cause for the migration of a group of Dene from the Yukon to the Navajo desert (McGhee, 1983).

There is very little evidence of human activity in the Range. Current activity is mostly occasional hunting and scientific research. Though the area has been heavily staked

for exploration, activity has been restricted to some exploratory drilling for molybdenum and fluorite in the northern end of the Range and placer gold deposits presently being worked on a moderately large scale in the Fourth of July and Twelfth of July Creeks. Human activity has generally had a minimal impact on the vegetation of the central part of the Range.

1.3.2 CLIMATE.

The area is on the western edge of the "Upper Yukon-Stikine Basin" climatic division of the Yukon (Wahl et al, unpublished). This area receives between 200-300 mm of precipitation annually making it one of the driest regions in Canada (ibidem). This is due to the orographic barrier formed by the St. Elias Mountains to the west. The main air-stream regions in the Yukon are the Pacific, the Arctic, and the Klondike which is present only in winter months. The Ruby Range lies well to the south of the average position of the Arctic/Pacific front in both January and July (Wendland and Bryson, 1981). It is nevertheless possible that the colder and drier Arctic air may penetrate the valleys much further south with the warmer and wetter Pacific air overriding it. If this occurs in the Ruby Range, then we would expect to see greater precipitation on the high plateau than in the low valleys. Rain over Lake Kluane can often be observed to evaporate

before reaching the valley floor. Within the Ruby Range, however, small convective storms are often channeled by the valleys.

There are no meteorological stations in the Ruby Range to permit the easy testing of this hypothesis. There are three stations further to the north at Mayo, Elsa, and Keno Hill, located within 60 km of each other and at significantly different altitudes.

STATION	PPT.	TEMP.	TEMP*	ALT.
MAYO	306.3	2.1	5.4	504
ELSA	413.0	0.3	5.6	814
KENO HILL	590.2	-1.5	8.1	1472
HAINES JCTN	157.6	3.7	7.6	599
BURWASH LDG	182.1	2.5	7.7	799
AISHIHIK	162.0	1.7	8.0	966

TABLE 1. Mean annual precipitation (mm), mean maximum daily temperature ($^{\circ}\text{C}$), mean maximum daily temperature adjusted to sea level (assumed standard lapse rate $0.65^{\circ}\text{C}/100\text{ m}$), and station altitude (m) for six stations in central Yukon Territory. Mayo, Elsa, and Keno Hill show differences suggesting a thermal inversion. Haines Junction, Burwash Landing, and Aishihik are not at sufficiently different altitudes to show this. Data from Environment Canada (1982 a and b).

It can be seen from Table 1 that the higher station receives much more precipitation. It also appears to be under the influence of a warmer air mass. Higher elevations in the Mayo area may therefore be significantly more frequently dominated by the Pacific air mass than lower elevations. This

may also hold true for the Ruby Range. The three stations at Burwash Landing, Aishihik, and Haines Junction are all below 1000 m, and show no such inversion.

1.3.3 VEGETATION

The vegetation of the Ruby Range is strongly controlled by altitude. The Range is at present populated largely by a sedge-grass-Dryas meadow on the open plateau with Betula glandulosa (dwarf birch) and Salix spp (willows) in valleys up to 1700 meters. Patchy Picea glauca (white spruce) forests with stands of Populus spp (poplars) occur in valleys below 1200 meters.

Orl6ci and Stanek (1979) note the presence of Alnus crispa along the Alaska Highway in the southern part of the Range. They also note the dominance of white spruce in the forest, with the exception of wet, poorly drained areas at low altitude which are dominated by black spruce. Hult6n (1968) shows the nearest occurrence of Pinus to be approximately 75 km to the East.

1.4 PALYNOSTRATIGRAPHY OF THE RUBY RANGE.

Very little is known with regard to the Holocene palynostratigraphy of the study area. The only previous study in the Ruby Range presenting directly useful results is that by

Campbell (1985). This paper has since been substantially revised (Campbell and Geurts, unpublished).

The above study presents two pollen diagrams from the center of the Ruby Range and is primarily concerned with the paleoclimatic interpretation of these diagrams. The revised paper shows that the climate in the last 3800 years has oscillated between two states: one similar to the present climate and the other slightly warmer and drier. These climatic periods can be correlated with the results of Bourgeois and Geurts (1983), in the Kluane Range and with the results of Heusser *et al* (1985) on the Alaska coast (see Table 2).

The warmer and drier periods show up in the pollen diagrams as a decrease in the percentage of forest pollen at sites above the tree line. Sites below the tree line do not show any such clearly defined climatic fluctuations (Beaudet, 1986; de Bastiani, work in progress; Wang, work in progress; and Geurts, unpublished).

Dewez *et al* (1984) studied the impact of the White River volcanic ash on the local vegetation. They found that the alpine herb tundra was temporarily disturbed by the deposition of the ash, and that the disturbance was more pronounced closer to the source of the ash where the deposit is thicker. Phipps (unpublished) studied the relations between modern pollen spectrum and local vegetational community in the Ruby Range and found very low rates of correlation with most of the

communities studied.

One of the difficulties in establishing a palynostratigraphy of the Ruby Range has been the lack of suitable sites. Sites below the tree line have good accumulations of material but are unsuitable due to the overabundance of spruce pollen. Sites above the tree line generally have very thin accumulations of material suitable for pollen analysis. The very few permanent lakes at high altitudes in the Ruby Range have no more than a few centimeters of sediment above a boulder base. The ephemeral lakes are also generally without a significant accumulation other than reworked volcanic ash. The present study uses soil profiles from exceptional sites above the tree-line.

Several paleovegetational and palynological studies have been carried out in the southwestern Yukon but most have been in the Kluane Ranges to the west. These include Hansen (1953), Rampton (1971), Denton (1974), Birks (1977, 1980), Bourgeois and Geurts (1983), and de Bastiani (work in progress). Palynological studies have been conducted by Dewez and Geurts (1985), Beaudet (1986), and Wang (work in progress) in the Aishihik-Sekulmun basin to the east. The paleoclimatic and paleovegetational conclusions of these studies are presented in Table 2, along with information from Heusser et al (1985), who studied sections on the Alaska coast near the Malaspina Glacier.

YBP	VEGETATION	CLIMATE	TEMP	PPT	YBP
0					0
1400	Spruce forest	cold semi-arid	-	+	1400
1650	Spruce forest, slightly more open	slightly warmer and drier	+	-	1650
2450	as today	as today	-	+	2450
	Spruce forest, slightly more open	slightly warmer and drier	+	-	
					2600
			-	+	
					3800
			+	-	
					4500
			-	+	
5500					5500
	open spruce woodland	warm and dry (Hypsithermal)	+	-	
8500	shrub tundra	cold semi-arid			
9500- 10000	herb tundra	periglacial			9500- 10000

TABLE 2. SUMMARY OF CLIMATE AND VEGETATION IN SOUTHWESTERN YUKON AND ALASKA. Data on left summarized from Hansen (1953), Rampton (1971), Denton (1974), Birks (1977, 1980), Bourgeois and Geurts (1983), Campbell (1985), Beaudet (1986), and Wang (work in progress). Data on right summarized from Heusser et al. (1985). (+) indicates warm or wet; (-) indicates cold or dry. All dates are only approximate, as each author uses slightly different criteria in setting zone boundaries on slowly changing conditions.

CHAPTER 2. LABORATORY EXPERIMENTS.

2.1 INTRODUCTION.

The proper interpretation of a pollen diagram requires a thorough understanding of the various factors affecting the pollen spectra.

Previous work in the Ruby Range (Geurts et al, 1983; Campbell, 1985) indicates that pollen concentrations in the Ruby Range are quite low, both in the air and in most sediments. The alpine herb tundra communities seem to produce relatively little pollen, and the spruce forest is generally sparse and confined to narrow valleys. The high proportion of pollen from distant sources (up to 9% from more than 75 km distant; Chapter 3) suggests that local pollen production is quite low.

Under these conditions, processes which may elsewhere be of little importance could play a major role in determining the final composition of a pollen spectrum. Although differences in aeolian dispersiveness have been a consideration in most Quaternary pollen studies (ex. Davis, 1963), these differences acquire increased importance in a mountainous area (Markgraf, 1980; Price and Moore, 1984).

The reworking of pollen at the surface is also an important process which can significantly alter a pollen spectrum. Examples of this are the reworked Betula pollen in a

section studied by Rampton (1971) and the long-distance transport of pollen in rivers noted by Solomon et al (1982). The latter noted a lack of upland pollen in floodplain sites, and attributed this to the destruction of upland pollen in rillwash.

Differences in the preservation potentials of various pollen taxa have been noted by Holloway (1982) and by Havinga (1984). The low soil temperatures in the Ruby Range (which is underlain by discontinuous permafrost) suggest that chemical degradation of the pollen exine in the soil (the subject of Havinga's study) is probably not of significant importance at most sites. Holloway's study tested the damaging of the pollen exine through repeated freeze-thaw and wet-dry cycles. He found that although wet-dry cycles have a strong destructive effect on pollen grains, freeze-thaw cycles do not. An apparently untested possibility is the destruction of pollen grains through sediment compaction, either by cryostatic or lithostatic pressure.

This chapter presents a series of experiments designed to test the effects these factors might have on a pollen assemblage. These experiments were designed with simplicity and budget as major concerns. The results are relative only, and are intended only to indicate trends and the relative importance of the different processes in determining the final pollen spectrum. The conclusions from these experiments will be compared with and used in interpreting the surficial

palynology and palynostratigraphy of the Ruby Range.

The pollen used in these experiments was supplied by Dr. André Munaut, of the Université de Louvain, in Belgium.

2.2 AERODYNAMIC STABILITY AND DISPERSIVENESS.

2.2.1 INTRODUCTION.

Previous work (Campbell 1985, Bourgeois and Geurts 1983, Beaudet 1986) indicates that pollen transported over distances in excess of 10 km is a major component of the pollen rain of this part of the Yukon. In particular, Pinus, which is not known to grow in the Ruby Range or for 75 kilometers in any direction (Hult  n, 1968), frequently contributes more than 2% of the pollen in a modern spectrum in the Ruby Range (Chapter 3). Although it is more abundant in the Aishihik-Sekulmun basin to the east, only one individual of Alnus is known in the Ruby Range, on the southwestern slopes overlooking Lake Kluane. Alnus nevertheless contributes up to 18% of the modern pollen rain at high altitudes (Chapter 3).

The spatial distribution of Pinus, Alnus, Picea, Betula, and Salix pollen in modern samples cannot be explained without a greater understanding of the relative dispersal by wind of these taxa. This information is important to the interpretation of the spatial distribution of pollen spectra and palynostratigraphy in the study area. The following

experiment was designed to test the relative dispersiveness of various pollen taxa.

2.2.2 APPARATUS AND METHOD.

A 30 meter coil of 1/2 inch plastic pipe was extended from the basement of a building vertically up the stairwell. A 'T' was installed at each floor (approximately every 2.85 meters) connecting to an open downpointing outlet. A plastic test-tube with 2 ml of glycerinated water was positioned beneath each outlet. A cut was made at the bottom of the piping to accommodate two elbows installed as shown on Figure 2. Approximately 1 cc of mixed pollen was placed at the bottom of the vertical section of tubing. The taxa used were Pinus, Picea, Corylus, Alnus, Salix, and Zea mays.

Two tanks of compressed air were emptied in succession through the tubing to produce an upward wind. The tanks each held 2.26 cubic meters of air at a pressure of 158.2 kg/cm^2 . The tanks were emptied in 30 minutes. Limitations of the available instruments precluded the taking of windspeed measurements at the sampling ports.

2.2.3 RESULTS AND CONCLUSIONS.

The results are shown in Figure 3. Since air escapes at each sampling port, the windspeed decreases approximately

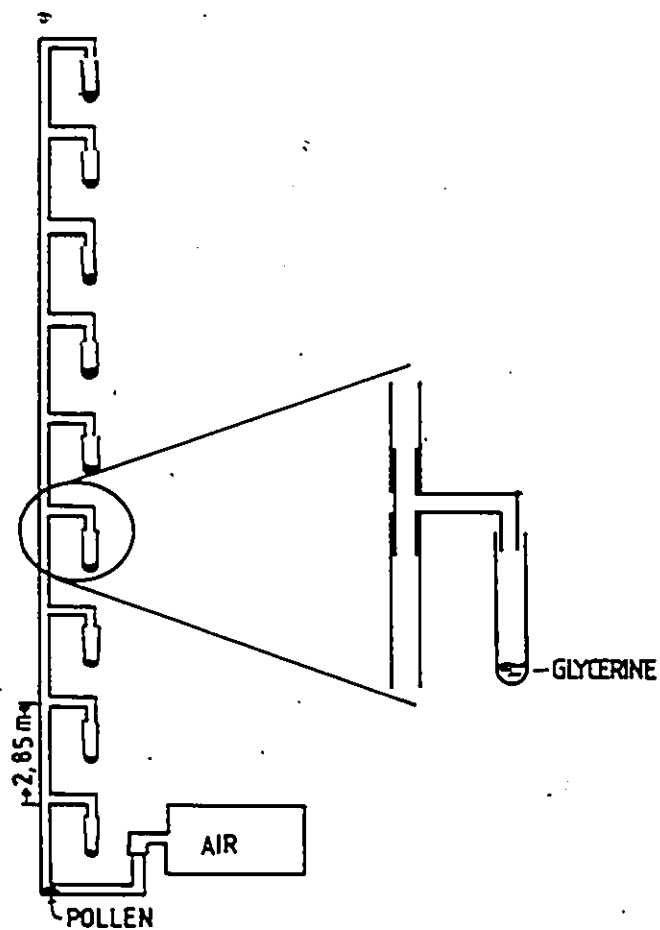


FIGURE 2. ASSEMBLY FOR POLLEN DISPERSIVENESS EXPERIMENT.
Piping is 1/2 inch plastic pipe.

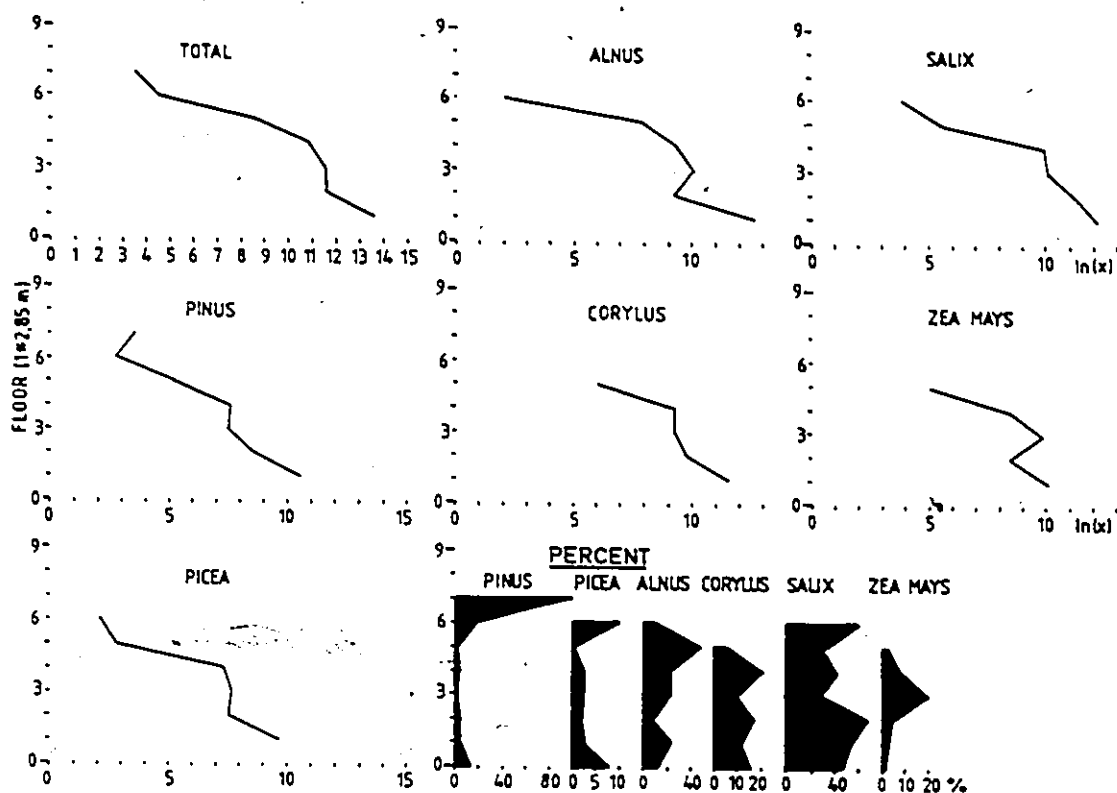


FIGURE 3. DISPERSIVENESS EXPERIMENT RESULTS. Vertical scale is graduated in floors (approx. 2,85 m), horizontal scale is natural logarithm of the number of pollen grains in 1 cc of Glycerine. The section at bottom right shows relative frequencies.

logarithmically with successive floors. It is apparent on the Figure that all taxa settle out of the airstream at an approximately logarithmic rate. Pollen was abundant in the lower samples but the upper samples were nearly or completely sterile. This is in accordance with Prentice's (1985) theoretical but hitherto untested equation for pollen dispersal:

$$Q(x) = Q_0 \left[\frac{-4V_g X^{n/2}}{nu\sqrt{\pi} Cz} \right]$$

Q = quantity of pollen airborne at X m from source
 V_g = depositional velocity (taxon dependant)
 X = distance from source (m)
 $n \approx 0.25$ $Cz \approx 0.12$
 u = windspeed

in which windspeed is a factor in the exponent.

Alnus, Picea, and Pinus appear to remain suspended in a weaker wind than Corylus, Zea mays, and Salix, but the differences over this short distance are not extreme. This experiment does provide confirmation for the suspected highly dispersive nature of the saccate grains and of Alnus (Davis, 1965). The pollen of Salix was found to be relatively non-dispersive. This may be a more important factor than actual pollen production in determining this taxon's representation in the pollen rain.

Corylus was used as a surrogate for Betula because no Betula pollen was available. The two taxa are quite similar in pollen morphology but Betula is slightly larger. We would therefore expect that Betula pollen would settle more quickly

than Corylus. Corylus is one of the rapidly settling taxa so would be expected to be generally underrepresented in the pollen rain at sites removed from the source. This may explain the underrepresentation of Corylus, found by Helm (1970). However, Betula tends to be strongly overrepresented in the pollen rain of the Ruby Range (Chapter 3). It is possible that Corylus may be a poor surrogate for Betula due not to the difference in average size but rather to a difference in pore morphology. Though both taxa have three equidistant equatorial pores, those of Betula are surrounded by a prominent protrusion of the exine.

Alnus is closer to Corylus in size and has from 4 to 6 pores shaped like those of Betula. In this experiment, Alnus was found to be less rapidly settling than Corylus. The apparent explanation for this is the protruding pores, which may act as sails by catching the wind. In this case, we would expect Betula to behave more like Alnus than like Corylus, but to settle slightly more rapidly than Alnus due to the smaller number of pores and therefore "sails". This suggests that pore morphology is an important factor in determining dispersiveness.

In the Ruby Range, the areal distribution of pollen spectra can be better understood in the light of these experimental results, and can in turn confirm and extend them. This will be the subject of Chapter 3.

2.3 DAMAGE AND DIFFERENTIAL SEDIMENTATION IN AQUEOUS TRANSPORT

2.3.1 INTRODUCTION.

Several studies involving the sedimentology of pollen grains were cited in section 1.4. None of these dealt with the condition of the pollen grains, i.e. whether they were intact, carried, or torn, etc.

Given the nature of the deposits studied in the field area, redeposition of pollen by surface runoff must be considered as a possibly significant contributor to some of the pollen spectra. This experiment was designed to test the sorting and damaging of pollen grains in transport over short distances in simulated runoff conditions.

2.3.2 APPARATUS AND METHOD.

A glass tube 1.1 m long and 2.5 cm in diameter was coated on one side of its inner surface with a mixture of fine sand, silt, and acrylic binder. This was installed with a 30° slope with the coated side down and the bottom end of the tube hanging over a plastic basin containing 2.4 litres of water. A recirculating pump was installed in the basin with tubing to carry the pumped water to the high end of the pipe. A crimp clamp and an overflow tube were included in the design (Figure 4) to regulate flow through the glass tube. A magnetic mixer

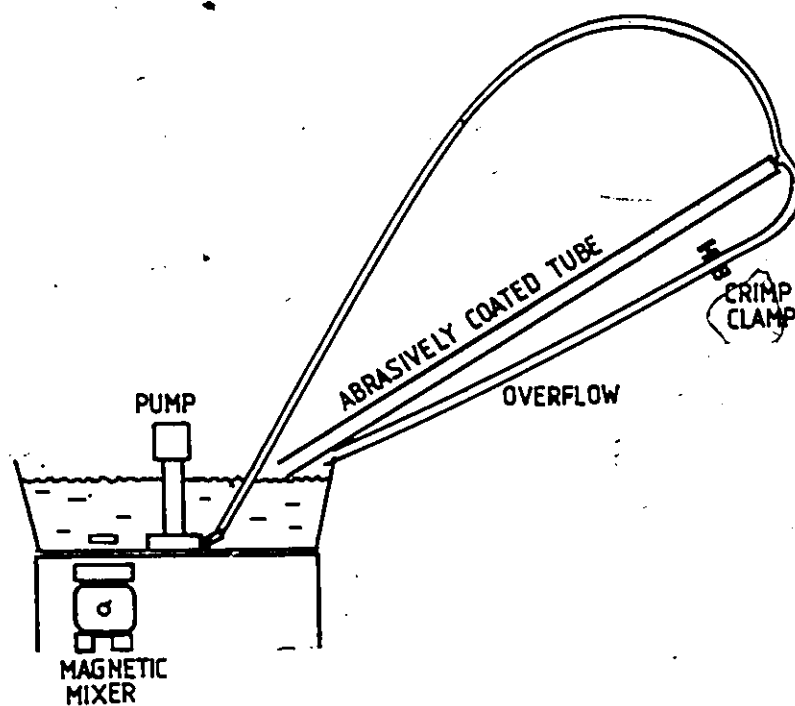


FIGURE 4. AQUEOUS TRANSPORT EXPERIMENT ASSEMBLY.

was installed in the basin. A mixture of pollen including compositae (echinulate Aster types), Corylus, Alnus, Plantago, Salix, Tilia, Gramineae (mostly Zea mays), Picea, and Pinus was added to the water.

Circulation was first established bypassing the glass tube in order to allow mixing and to establish the effect of the pump itself on the pollen. Samples were drawn with syringes from the surface and the bottom of the basin at intervals starting at 5 minutes and gradually increasing to 30 minutes.

After 45 minutes, flow through the tube was established at 7.2 litres per hour providing an average distance of transport over the abrasive surface of 33 meters for the contents of the basin. Some difficulties were encountered in maintaining thorough mixing within the basin. The pollen grains were classified according to the taxon and degree of damage on a scale from 0 (undamaged) to 3 (torn and mutilated to the point where recognition becomes difficult).

2.3.3 RESULTS AND CONCLUSIONS.

The results of this experiment are presented in Figure 5. Several taxa were insufficiently abundant in the mixture to yield statistically significant results. These are not included in the Figure.

The major effect, both in the initial 45 minute period

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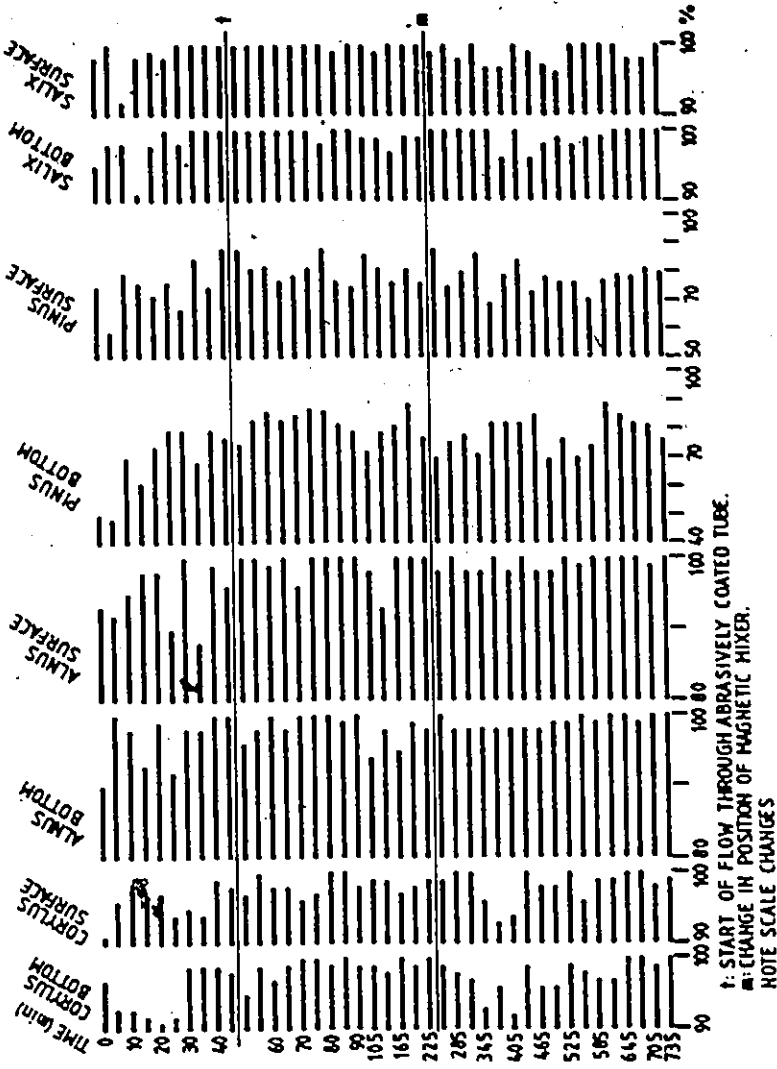
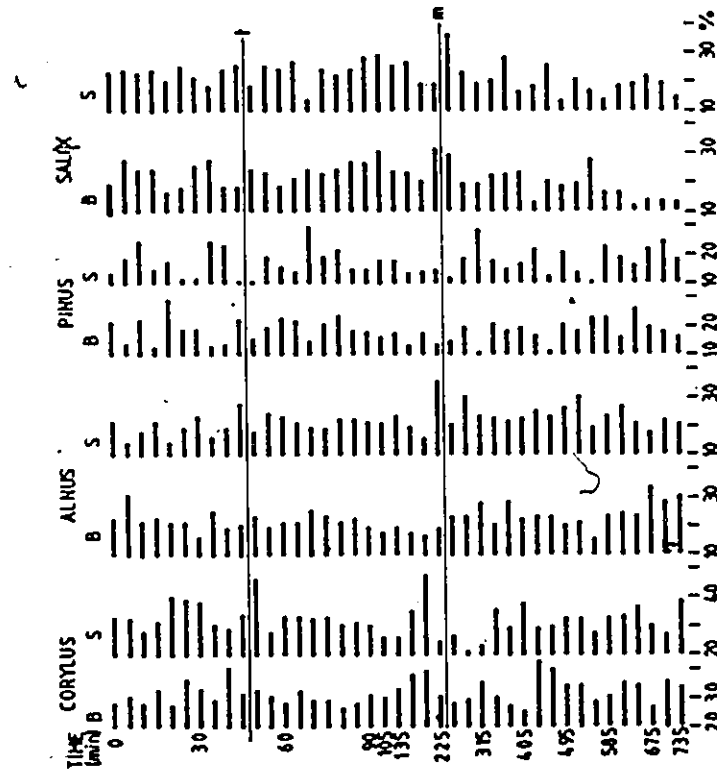


FIGURE 5. AQUEOUS TRANSPORT RESULTS. A. The proportion of total pollen in 1 cc at surface (S) and at bottom (B) in the basin, for the four major taxa. Other taxa with only sporadic presence not included. B. Percentage of each taxon which is undamaged, in both surface and bottom samples.

bypassing the abrasive tube and in the subsequent 690 minutes, appears to have been the removal of pollen grains into eddy deposits within the basin. These deposits, small but visible to the unaided eye, were rapidly established in spite of the turbulence caused by the pump and the magnetic stirrer. The deposits seem to have preferentially accumulated non-saccate and damaged saccate grains. This left the undamaged saccate grains to increase in relative abundance in the suspension. The damaged saccate grains seem to have been most rapidly removed from circulation indicating that the integrity of the bladders is of primary importance to the buoyancy of these grains. There was very little difference between the surface and bottom samples after the initial mixing and removal of damaged grains. The introduction of the glass tube with abrasive coating does not seem to have significantly affected the degree of damage sustained by the pollen grains.

We can conclude from this that the reworking of pollen by runoff would likely increase the relative representation of saccate grains in the receiving deposit and decrease it in the source deposit by preferential transport. It would probably not introduce any bias through differential destruction over short distances.

2.4 DAMAGE IN TURBID WATER TRANSPORT.

2.4.1 INTRODUCTION.

The previous experiment did not test damage to pollen grains over distances of aqueous transport in excess of 33 meters, or in turbid conditions. This third experiment was designed to test the hypothesis that very long distances of transport, in excess of 10 km, would damage pollen grains differentially according to taxon. It is impractical to arrange a 10 km long flume so a slightly different approach was used.

2.4.2 APPARATUS AND METHOD.

A 10 cm diameter rotating rubber barrel (an amateur rock tumbler) was filled with an mixture of fine sand and silt, with sufficient water to cover the mix, and pollen. The taxa used were Gramineae (mostly Zea mays), Picea, Salix, Pinus, Alnus, and Corylus. The barrel was set to rotate at a rate of 48.2 rpm. Samples were drawn initially at 5-minute intervals decreasing in frequency to 1 week intervals. No attempt was made to separate the pollen and mineral fractions in the samples in order to avoid possible differential loss of damaged pollen. The presence of abundant sand and silt in the samples made analysis extremely time-consuming so only 6 were

analysed.

The total rotation time for the final sample was 71920 minutes, or slightly under 50 days. This yielded a total distance of transport at the circumference of the barrel of 1090 km. Not all of the pollen will have travelled at the margin and assuming a uniform distribution within the barrel (assured by the rotation of the barrel), the average distance of transport was 767 km.

2.4.3 RESULTS AND CONCLUSIONS.

The results are shown in Figure 6. It is apparent that most of the taxa suffered little or no damage. Pinus and Gramineae did suffer some minor damage. Considering that the equivalent of 767 km of transport in exceptionally turbid conditions was required to produce this slight effect, it seems unlikely that damage during runoff or sheetwash (suggested by Solomon et al, 1982, to rapidly destroy pollen grains) could significantly alter a pollen spectrum. A much more likely mechanism for the distortion of pollen spectra through aqueous transport is the differential sedimentation of non-saccate and damaged saccate grains previously discussed.

These experiments suggest that damage during transport is probably not a factor of any significance within the Ruby Range where the longest possible aqueous transport would be from the head of Talbot Creek to Lake Kluane, a total distance

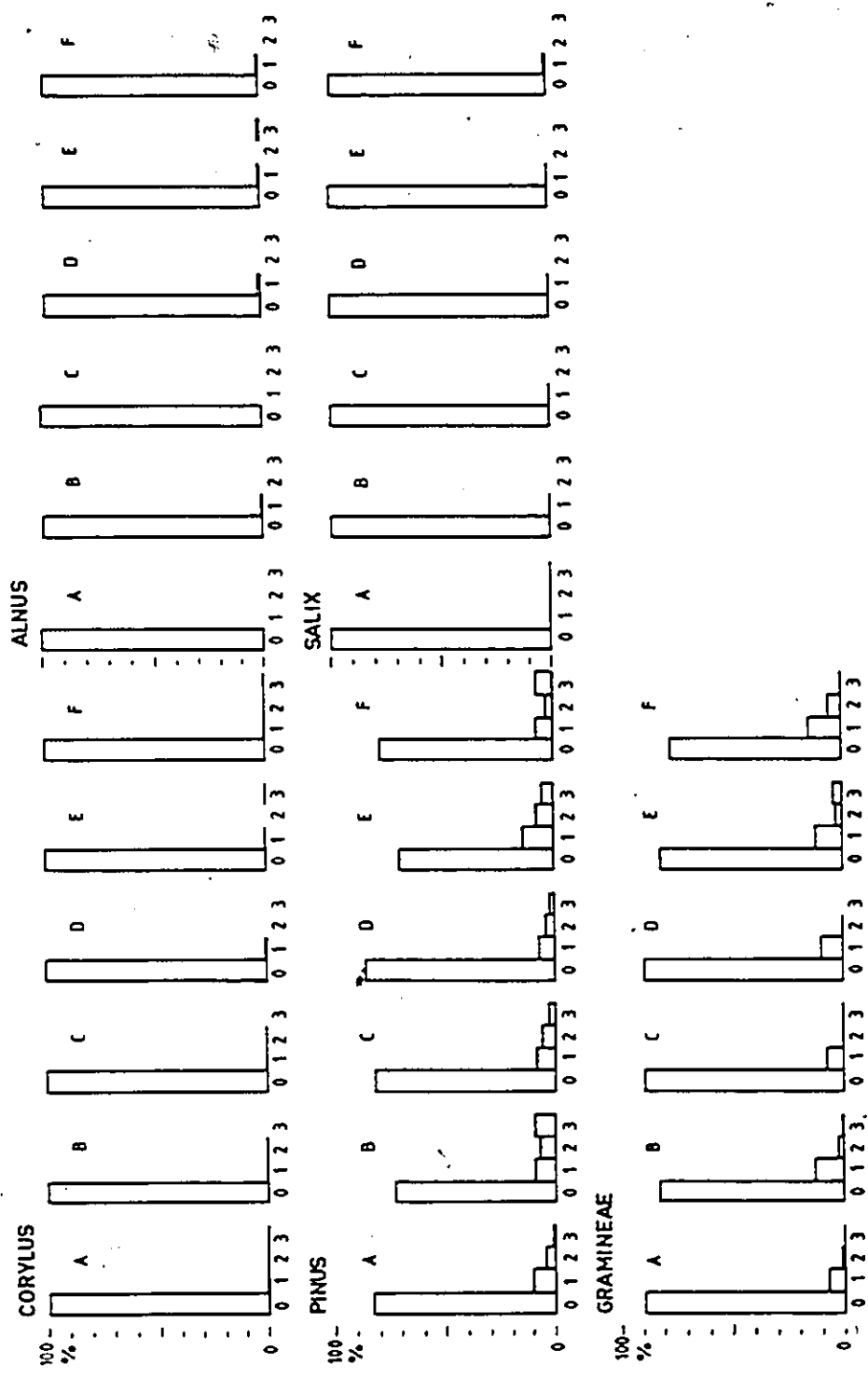


FIGURE 6. TURBID WATER TRANSPORT RESULTS. Proportional diagram of pollen classified in four damage groups: 0= no apparent damage; 1= slight tearing, no missing pieces; 2= major tears or small missing pieces; 3= very heavy damage with large missing pieces. A, B, C, D, E, and F represent sampling intervals. Total estimated distance of transport for each sample is 0 km, 9.4 km, 29.8 km, 75.9 km, 255 km, and 767 km. respectively.

of less than 65 km. Selective transport, on the other hand, may well be of importance and must be taken into consideration at all sites.

2.5 DAMAGE THROUGH REPEATED DESICCATION.

2.5.1 INTRODUCTION.

A previous study by Holloway (1982) indicates that although freeze-thaw cycles have very little effect on the condition of pollen grains, repeated wet-dry cycles can cause a rapid, taxon-dependent deterioration. A simple experiment was designed to test the rapidity of destruction of grains of Pinus in order to verify Holloway's results and to provide a basis for comparison of his results with those of the other pollen destruction experiments presented here.

2.5.2 APPARATUS AND METHOD.

A small amount of Pinus pollen was added to a drop of water on a microscope slide and covered with a cover slip. This sample was analysed and allowed to dry out. A drop of water was then added to the edge of the cover slip, and allowed to flow under the cover slip and wet the pollen grains. This was allowed to sit for 15 minutes and was then analysed. This procedure was repeated ten times. The addition

of the water to the edge of the cover slip produced currents displacing the pollen grains on the slide and sometimes obscuring them with the edge of the cover slip. Some pollen grains may have been entirely lost by being carried out from under the cover slip and then blowing off the slide when desiccated.

2.5.3 RESULTS AND CONCLUSIONS.

The results are presented in Figure 7. The degree of destruction is clearly much greater than with aqueous transport making this the most probable means of pollen destruction in the Ruby Range. As concluded by Holloway (1982), the effect is almost certainly in large part taxon dependant, with the saccate grains and thin-walled grains suffering the greatest damage. This could introduce a significant bias in the pollen spectra of subaerially exposed sites.

As in Holloway's study, the degree of new damage seems to fall off logarithmically with most of the damage probably occurring within the first ten desiccations. This suggests that damage may occur only where weaknesses were already present in the pollen exine and that no new damage is done once these weaknesses have all been exploited. If this is indeed the case, then subaerially exposed materials should rapidly achieve the same degree of destruction. The distortion of the

DAMAGE TO PINUS POLLEN FROM REPEATED DESICCATION

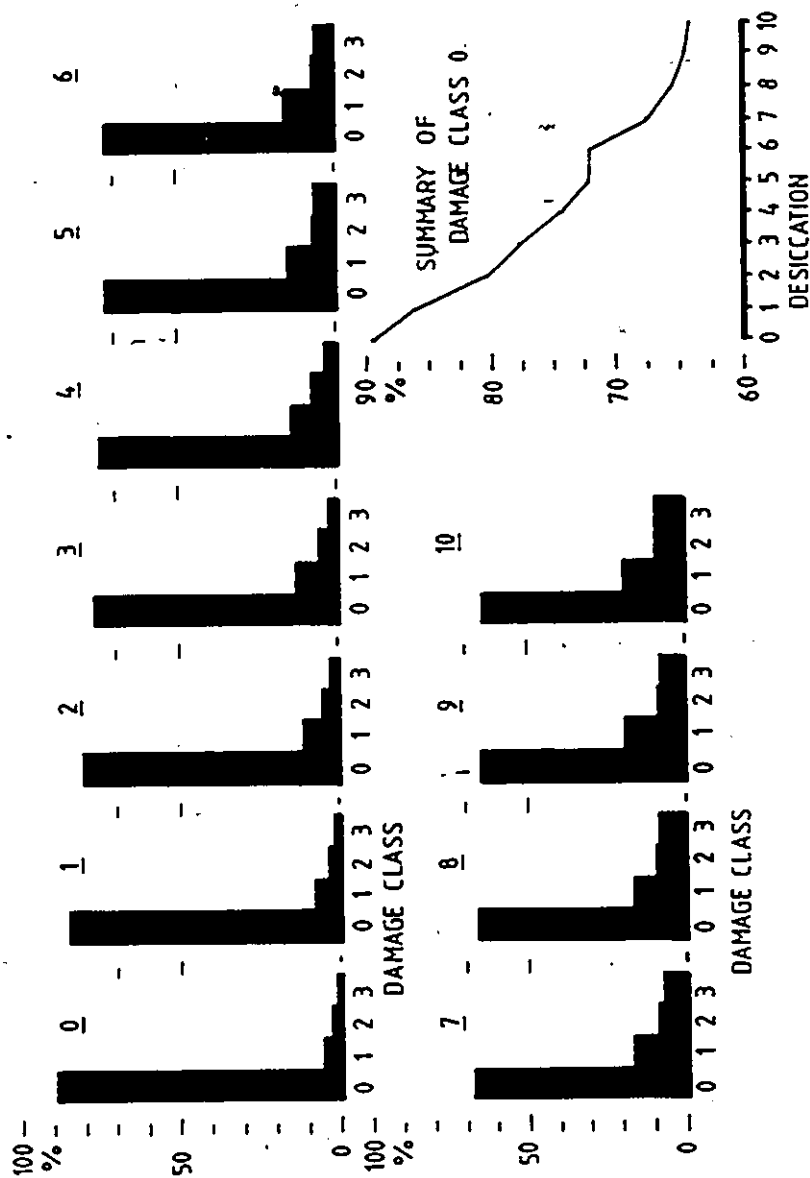


FIGURE 7. POLLEN DESICCATION RESULTS, Proportional diagram of pollen classified by degree of damage, using the same damage categories as Figure 6. Bottom right presents summary of percentage of pollen which is undamaged. The number above each histogram represents the number of desiccations to which the pollen was subjected.

pollen spectra through desiccation will then become equal in all cases and so need not be considered when comparing the spectra.

Havinga (1984) noted a logarithmic decline in the rate of damage to pollen in various soil types. The damage was attributed to chemical action, with the differences in soil chemistry from one site to another being responsible for small differences in the degree of damage to the pollen. It is possible that a large portion of the damage was not due to chemical action, but rather to wetting and drying. The differences between sites would then be due to differences in the hydrological properties of the different soil types. This would require further investigation, including a clarification of the roles of swelling and shrinking, and surface tension in damaging the pollen exine.

Although wetting is a rarer phenomenon in the Ruby Range than in eastern Canada, it occurs with spring melt and perhaps 40 or 50 times each year with rainfall. The number of days with measurable rainfall per year at Aishihik is 47, and 41 at Burwash (data from Environment Canada, 1982b). These are the two closest weather stations to the Ruby Range. The degree of damage to pollen due to repeated wet-dry cycles in subaerially exposed sites will therefore be equal after only a few years. Caution must still be used in comparing fossil spectra with modern pollen rain and moss polster samples.

2.6 DAMAGE THROUGH COMPACTION.

2.6.1 INTRODUCTION.

The Ruby Range is an area of discontinuous permafrost. Sediments in the Range are therefore subject to compaction through cryostatic pressure.

French (1976, p. 37) indicates that the maximum theoretical pressure that can be developed by freezing ice is 2100 kg/cm^2 . This corresponds roughly to 2.5 kb and to burial under approximately 7 km of rock. It is also noted that this theoretical maximum is almost certainly never reached and that 100 kg/cm^2 is probably a more realistic estimate of the maximum pressures actually attained in natural systems. This corresponds to burial at a depth of less than 500 meters.

This experiment was designed to test the destruction of pollen grains through compaction at pressures of approximately 2000 kg/cm^2 . This high pressure was used to ensure that the resulting damage would be over rather than underestimated.

Shear stress has not been considered in order to avoid complication of the experiment.

2.6.2 APPARATUS AND METHOD.

Rather than attempt to simulate natural cryostatic pressure through freezing, a more easily controlled apparatus

was used.

A steel tube, closed at one end, was half filled with a mixture of humid sand, silt, and pollen. A piston was inserted, and a pressure of 2000 kg/cm^2 was applied using a hydraulic press. The pressure was maintained for 20 minutes. A sample was removed before and after the application of pressure.

2.6.3 RESULTS AND CONCLUSIONS.

The compacted sample was found to be very difficult to remove since the compaction had partially lithified the material. The results are presented in Figure 8.

Some slight damage was sustained by the pollen, particularly the larger and more fragile taxa Pinus and Gramineae. These extreme hydrostatic pressures may therefore introduce a minor bias in pollen spectra of lithified material. Although the form of the relation between pressure and damage cannot be deduced from two points, it seems certain that damage would be negligible at the lower hypothesized maximum natural cryostatic pressure of 100 kg/cm^2 . It therefore seems unlikely that damage due to cryostatic pressure has had a significant effect on the pollen spectra of the Ruby Range. This is also indirectly supported by Holloway (1982) who found that freeze-thaw cycles do not appreciably damage pollen grains.

DAMAGE THROUGH SEDIMENT COMPACTION

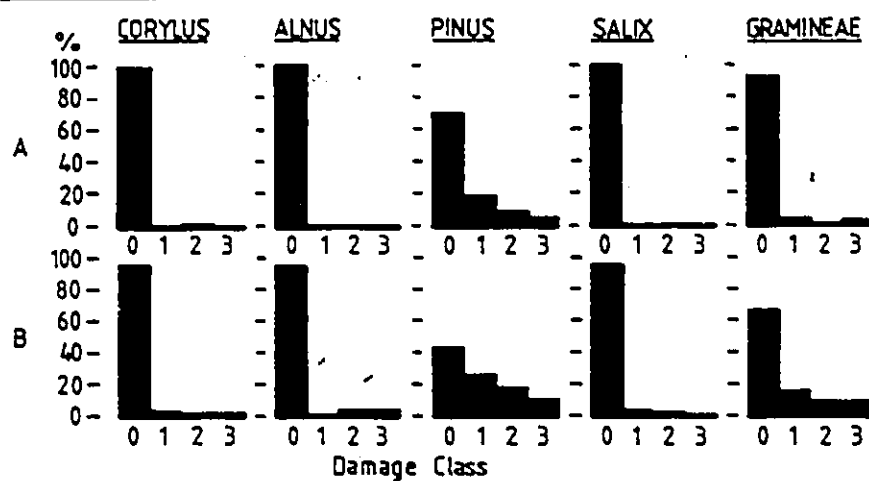


FIGURE 8. RESULTS OF SEDIMENT COMPACTION EXPERIMENT. Proportional diagram with pollen classified by degree of damage as in Figures 6 and 7. A is prior to compaction, B is after compaction to 2000 kg/cm.

2.7. GENERAL CONCLUSIONS.

These experiments indicate that beyond the differences in the pollen production of the various taxa, the pollen spectra of the Ruby Range are probably subject to three major modifiers. The first of these is the differences in the dispersivenesses of the various pollen grains. Altitude and distance from the trunk valley will probably both play a major role in determining the pollen spectra. Airstream turbulence due to the local topography may also be important at some sites.

The second is the differential reworking of pollen through runoff. The saccate taxa Pinus and Picea are both relatively easily damaged, and are not easily transported by water when damaged.

The third is the differential destruction of pollen taxa through wet-dry cycles. This effect will only be of concern in comparing samples which have undergone only a small number of wet-dry cycles, that is very young samples or samples from a water-saturated environment, with samples which have been subjected to many more wet-dry cycles.

Damage to pollen due to transport in runoff or through sediment compaction by cryostatic pressure is probably minimal.

The conclusions drawn from some of these experiments can be confirmed and extended by a study of the surficial

palynology of the Ruby Range. A comparison of the pollen spectra from different sedimentary environments but otherwise subject to the same pollen rain can also extend some of these results to a natural setting.

CHAPTER 3. SURFICIAL PALYNOLOGY.

3.1 INTRODUCTION.

An understanding of the spatial distribution of the pollen spectra in an area is needed for the interpretation of a palynostratigraphic diagram. Many authors have developed pollen-climate transfer functions using surficial palynology data (ex. Andrews et al, 1980 in the eastern Canadian Arctic).

Isopoll maps have been established for much of North America (Delcourt et al., 1984), but not for several regions, including northwestern Canada. Data acquisition in the area is severely limited by the lack of easy access, and the complex topography requires a greater density of data points than would be needed in a less mountainous region. The development of pollen-climate transfer functions for this area is further hampered by the shortage of meteorological data stations.

Orloci and Staneck (1979) describe the Ruby Range as a distinct ecoregion, but their sampling points of the vegetation were restricted to a transect along the Alaska Highway. They note the dominance of Picea glauca in the forest and the presence of Alnus crispa. Andersen (1973) noted that in his sites in Scandinavia, Alnus is approximately twice as overrepresented as Picea in the pollen rain. However, the species in Scandinavia are not the same as in the Ruby Range,

nor is the climate very similar.

Previous studies of the surficial palynology of the Ruby Range using moss polsters indicate that Picea, Alnus, Pinus, and Betula are all strongly overrepresented above the tree-line (Campbell 1985, Phipps unpublished). With the exception of certain ericale communities, the alpine herb tundra communities are generally poorly distinguished in the pollen rain (Phipps, unpublished).

With all of these difficulties it is essential that any palynostratigraphic study in this area be accompanied by a surficial palynology study.

3.2 SAMPLING AND ANALYSIS METHODS.

Moss polsters were sampled at 29 sites on the northern slope of Gladstone valley. The locations of the samples and the vegetational units are shown on Figure 9. The vegetation map was developed from air-photo interpretation supplemented by field observations.

The spruce forest can be seen to be confined to valleys mostly below the 1525 meter contour. Similarly, the shrub tundra only rarely exceeds the 1677 meter contour. The larger stands of Populus (small stands are not shown on the map) occur on active alluvial fans and similar deposits.

One sample of organic debris trapped on the surface of a snowbank was also sampled. This material appears to be

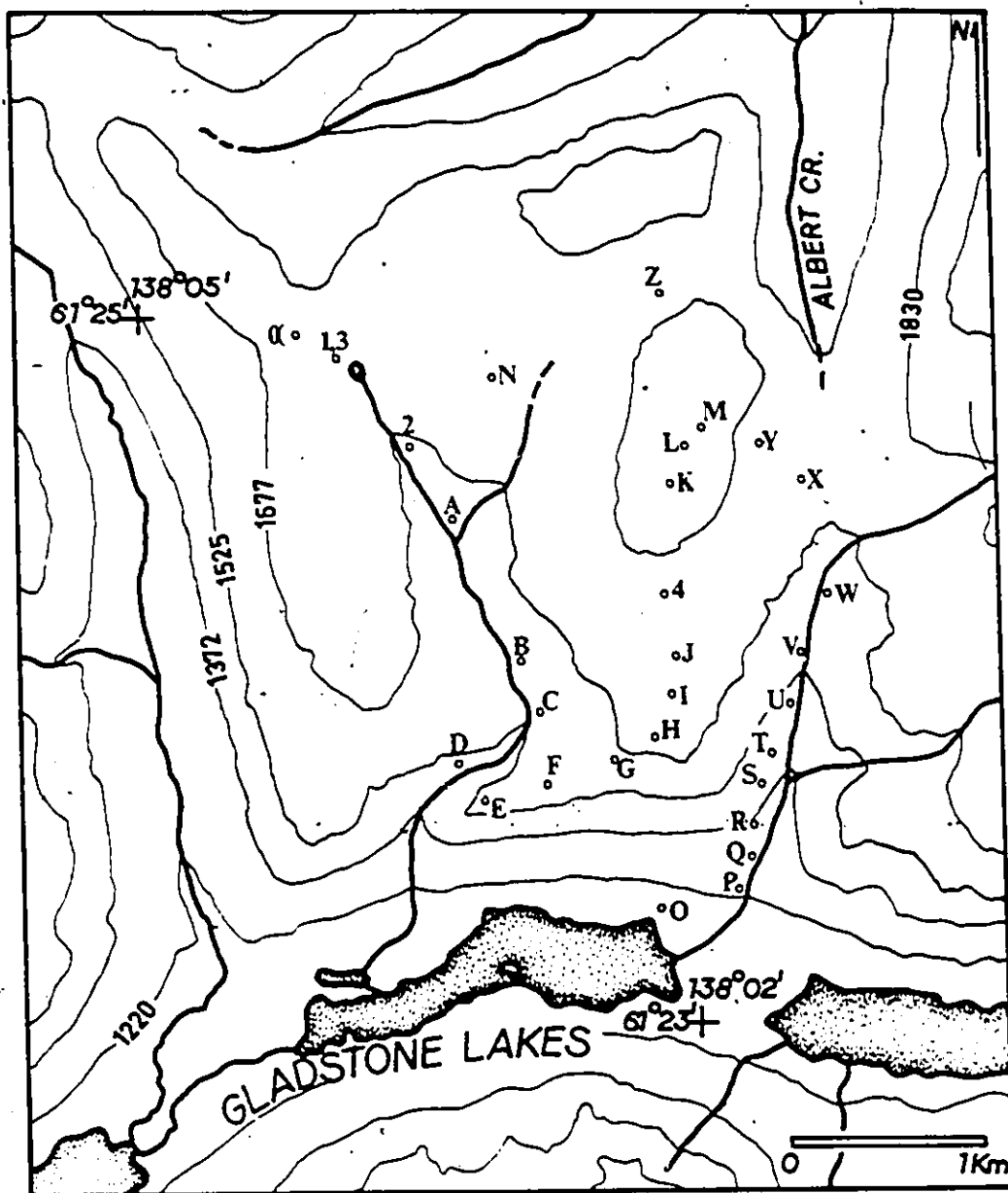


FIGURE 9a. LOCATIONS OF SURFICIAL SAMPLES. Letters indicate locations of moss polster samples. numbers indicate locations of sections sampled. Sections 1 and 3 (Kettle Camp) are accompanied by one moss polster sample; sections 3 and 4 have one moss sample each. X indicates the location of a snowbank. One sample was drawn from debris trapped in the snowbank, and a second from a nearby moss polster.

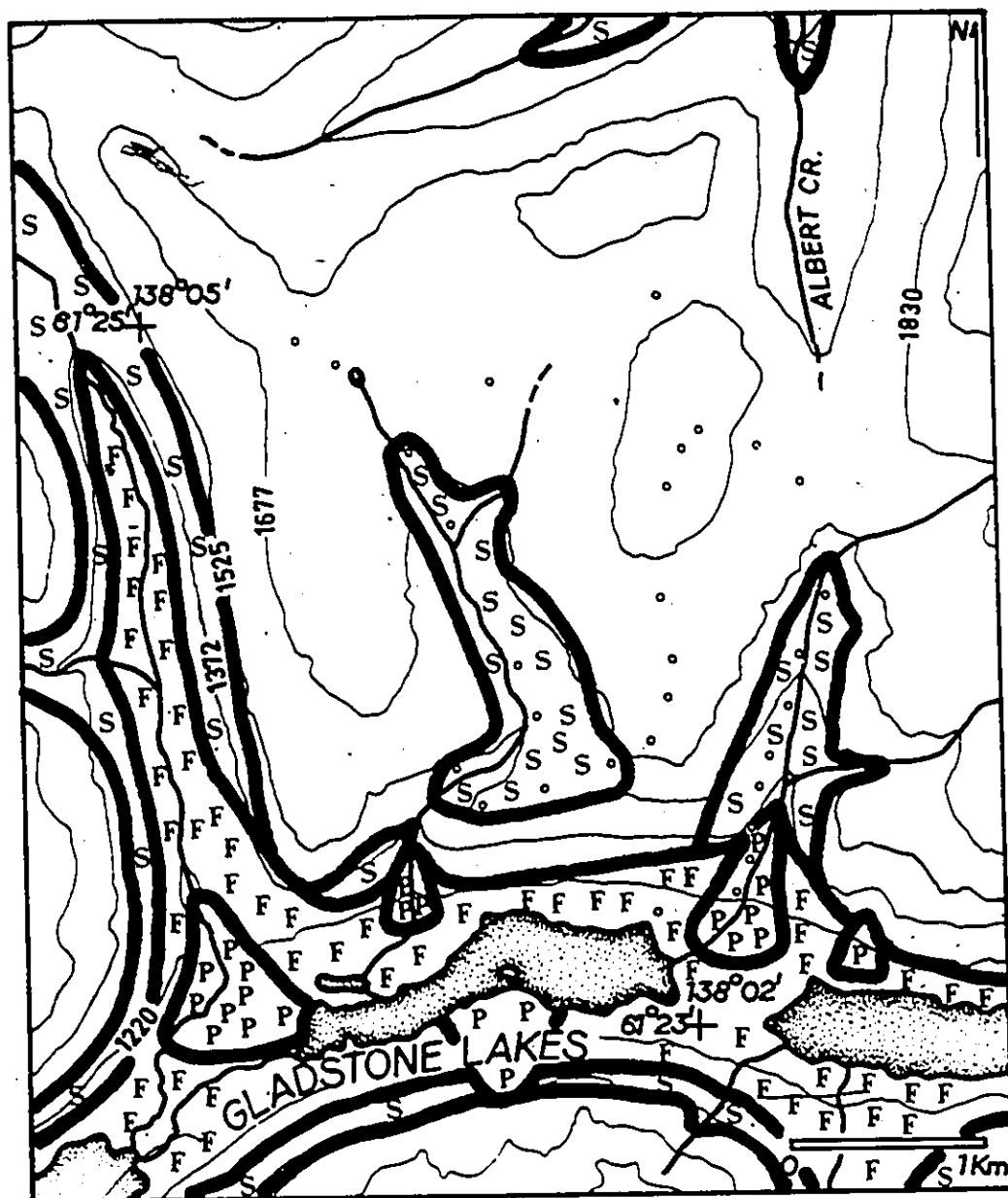


FIGURE 9b. VEGETATION OF THE KETTLE CAMP AREA. P represents large stands of Populus, F represents spruce forest, and S represents Betula-Salix shrub tundra. Unmarked areas are herb tundra.

windblown debris and occurs only on the surface of the snowbank. It is mostly Dryas leaves, and probably a spring accumulation which does not appear to remain in place after the snowbank has melted. There was no accumulation under the snowbank from previous years. Davis (1984) described the use of a snowbank as a seasonal pollen trap in the Southwestern United States.

All these samples were prepared using the techniques listed in Appendix 1. Although Gordon and Prentice (1977) described a statistical method for distinguishing mixes of morphologically similar taxa, no attempt was made to separate the Betula, Alnus, or Picea into species due to the high frequency of damaged pollen.

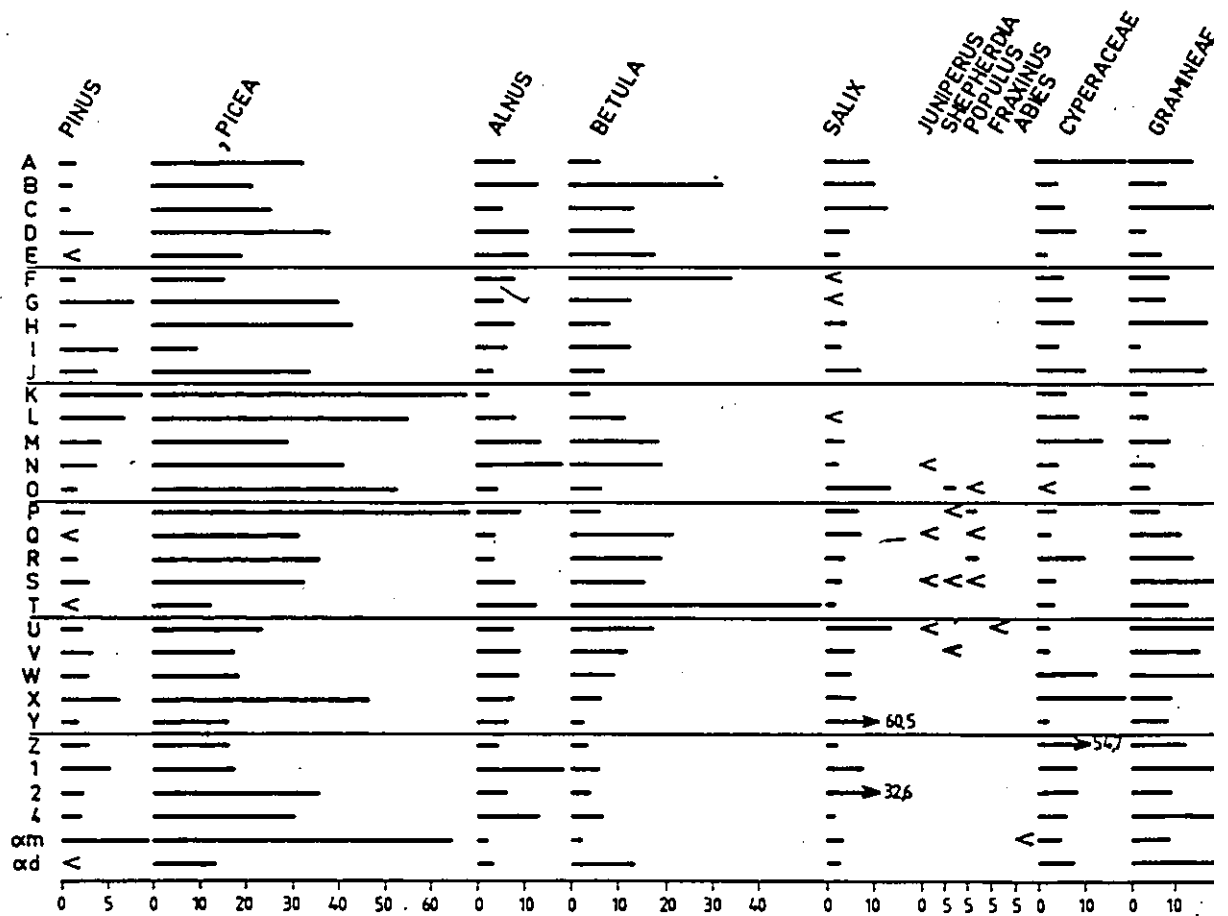
3.3 RESULTS AND CONCLUSIONS.

The results are shown in Figure 10a. Figures 10b-d show ratios of the major taxa Picea, Pinus, Alnus, and Betula. Betula seems to dominate in the mid-altitude valleys where it is a major component of the vegetation.

As with Bourgeois and Geurts (1983) and Campbell (1985), Pinus, Picea, Alnus, and Betula are all strongly overrepresented above the shrub-line. The proportions of these major taxa are very similar to those found by McDonald and Ritchie (1986) for the northern boreal forest and forest tundra in the Northwest Territories. The vegetation of the

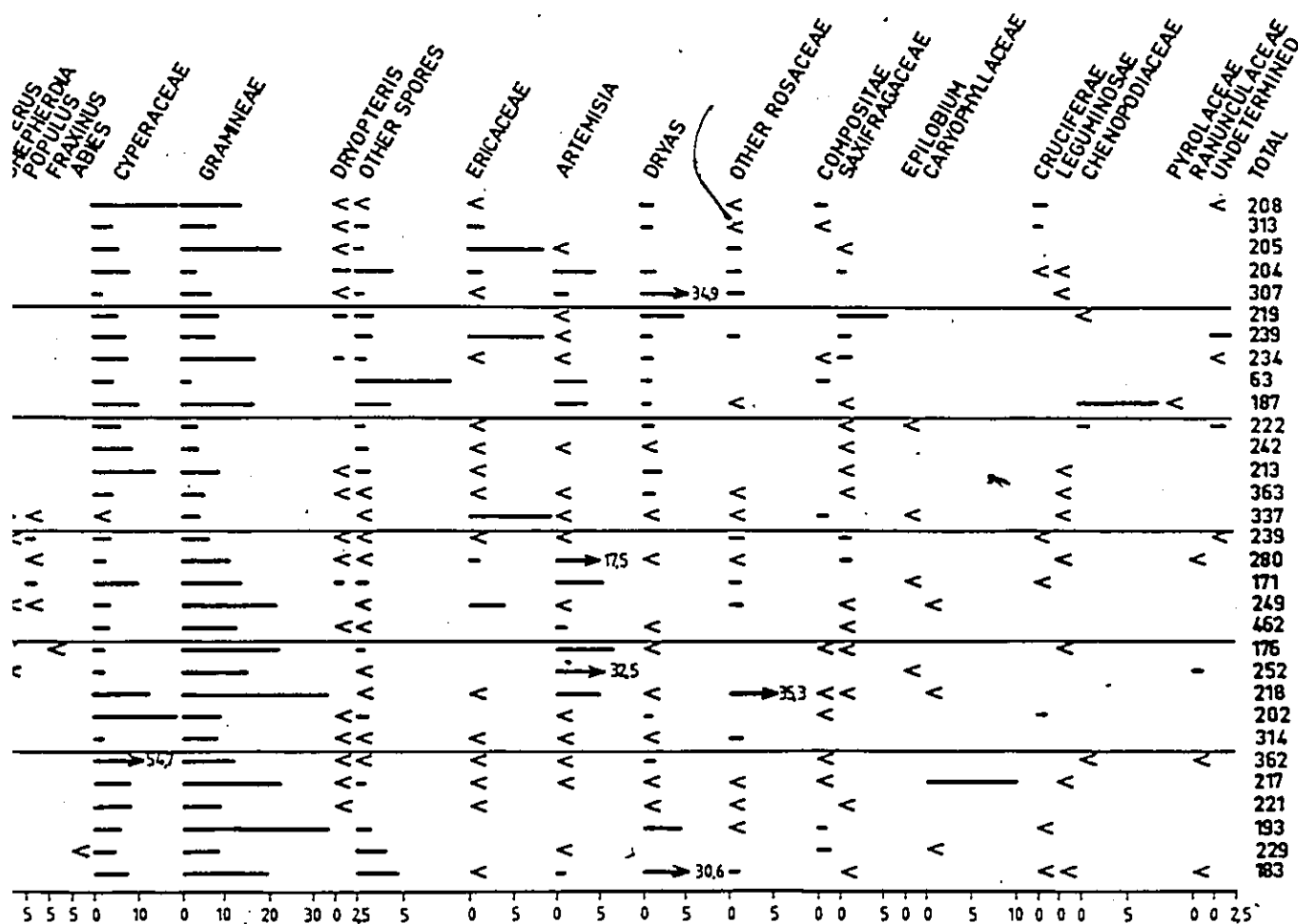
SURFICIAL PALYNOLOGY

ANALYSES: I. CAMPBELL 1987



< INDICATES <1%. NOTE SCALE CHANGES.

FIGURE 10a. SURFICIAL PALYNOLOGY results for all samples, in alphabetical order. C m and (from a snowbank. Horizontal t only, and have no other s excluded from the following grains counted.



Microfossil Palynology. Proportional diagram of the microfossil palynology of 18 samples, all taxa. Samples are arranged in order. C m and C d are moss and debris samples. Horizontal tie-lines are for ease of reading and have no other significance. Sample I has been given the following figures due to the low number of

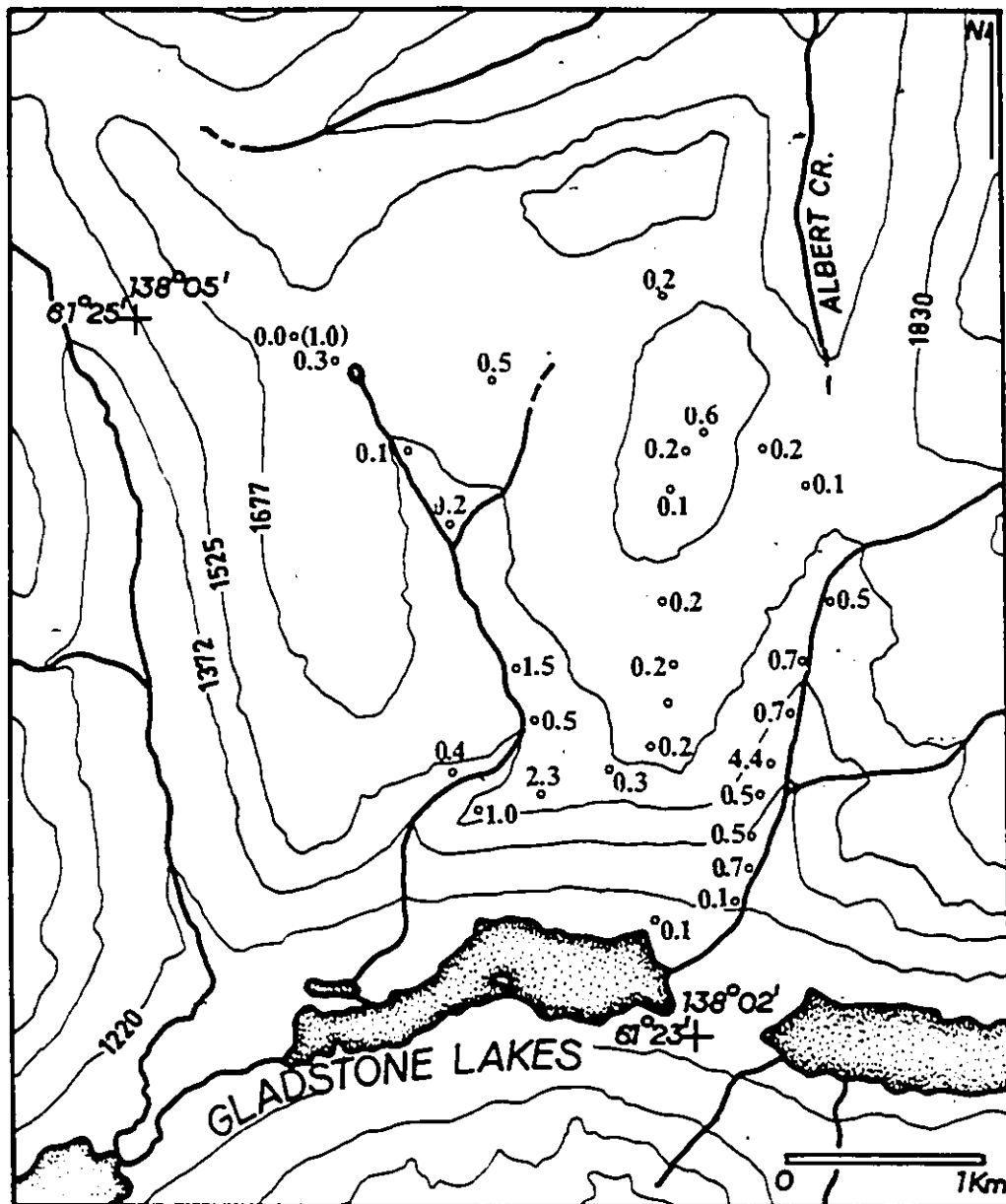


FIGURE 10b. *Betula/Picea* ratios for the moss polster and snowbank samples. Snowbank debris sample in parentheses. Note the clustering of high values in the mid-altitude valleys.

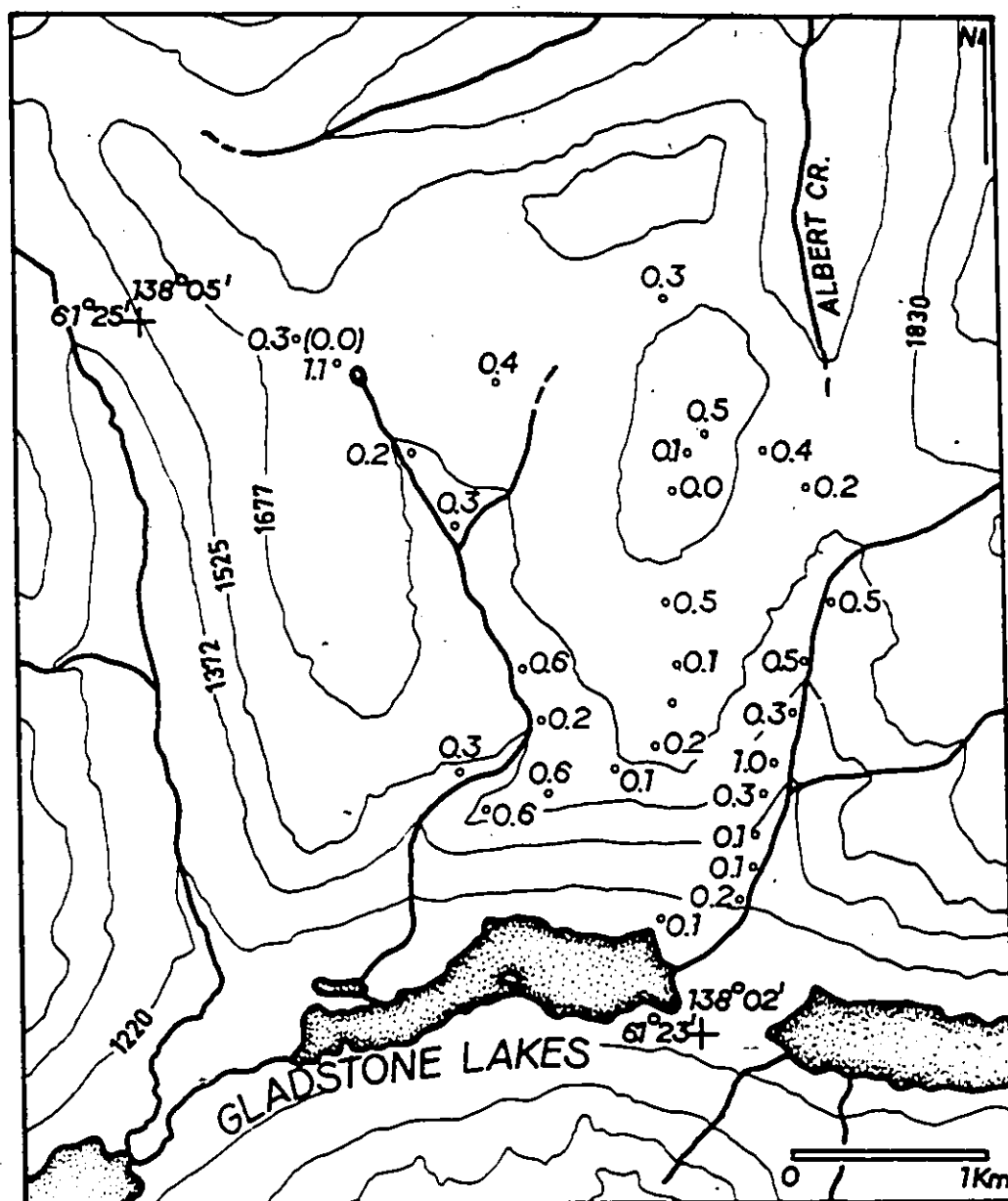


FIGURE 10c. *Alnus/Picea* ratios for the moss polster and snowbank samples. Snowbank debris sample in parentheses. Note the clustering of low values below 1372 meters, and the otherwise nearly random distribution.

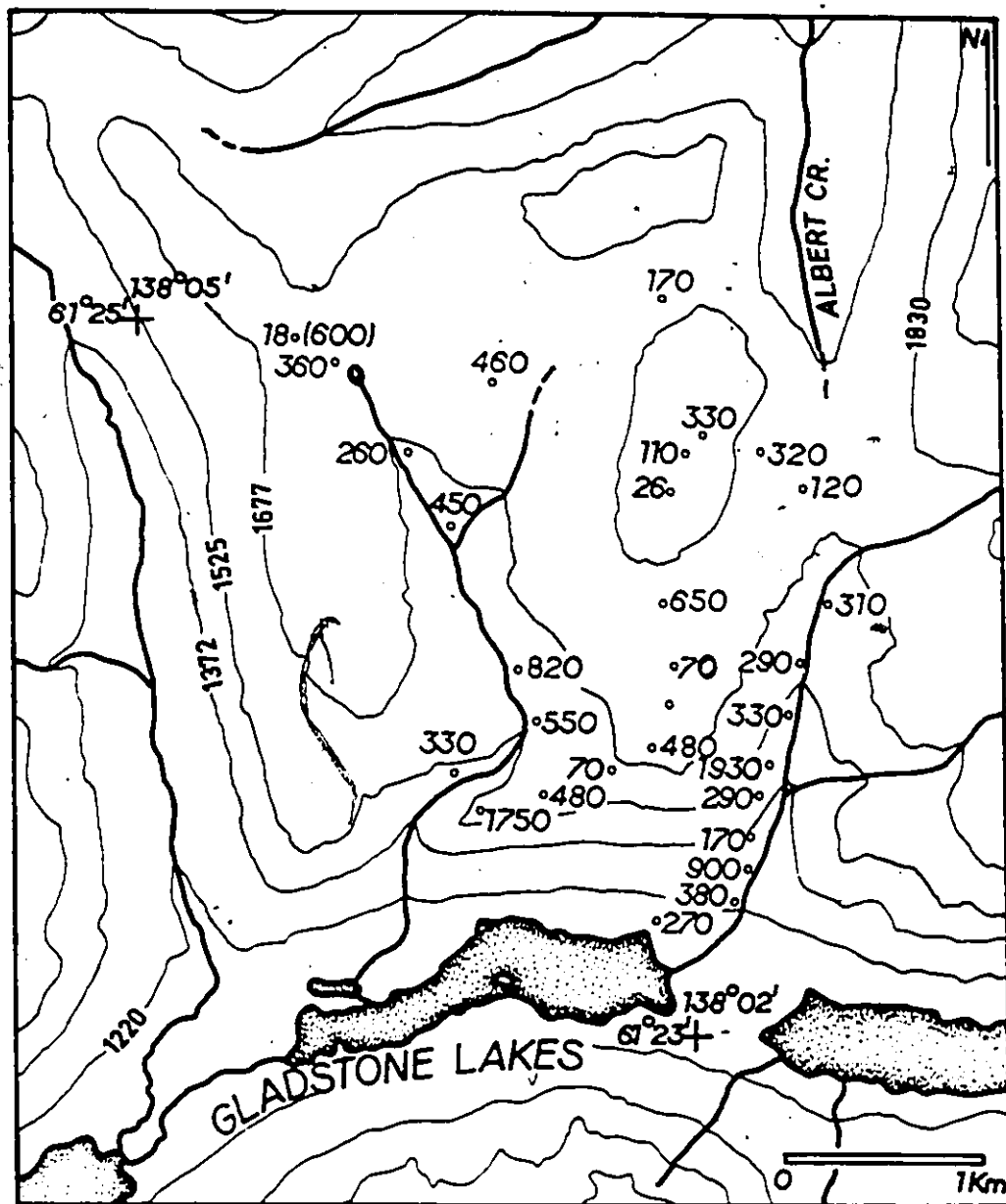


FIGURE 10e. *Alnus*/100 *Pinus* ratios for the moss polster and snowbank samples. Snowbank debris sample in parentheses. Note the high values in the mid-altitude valleys.

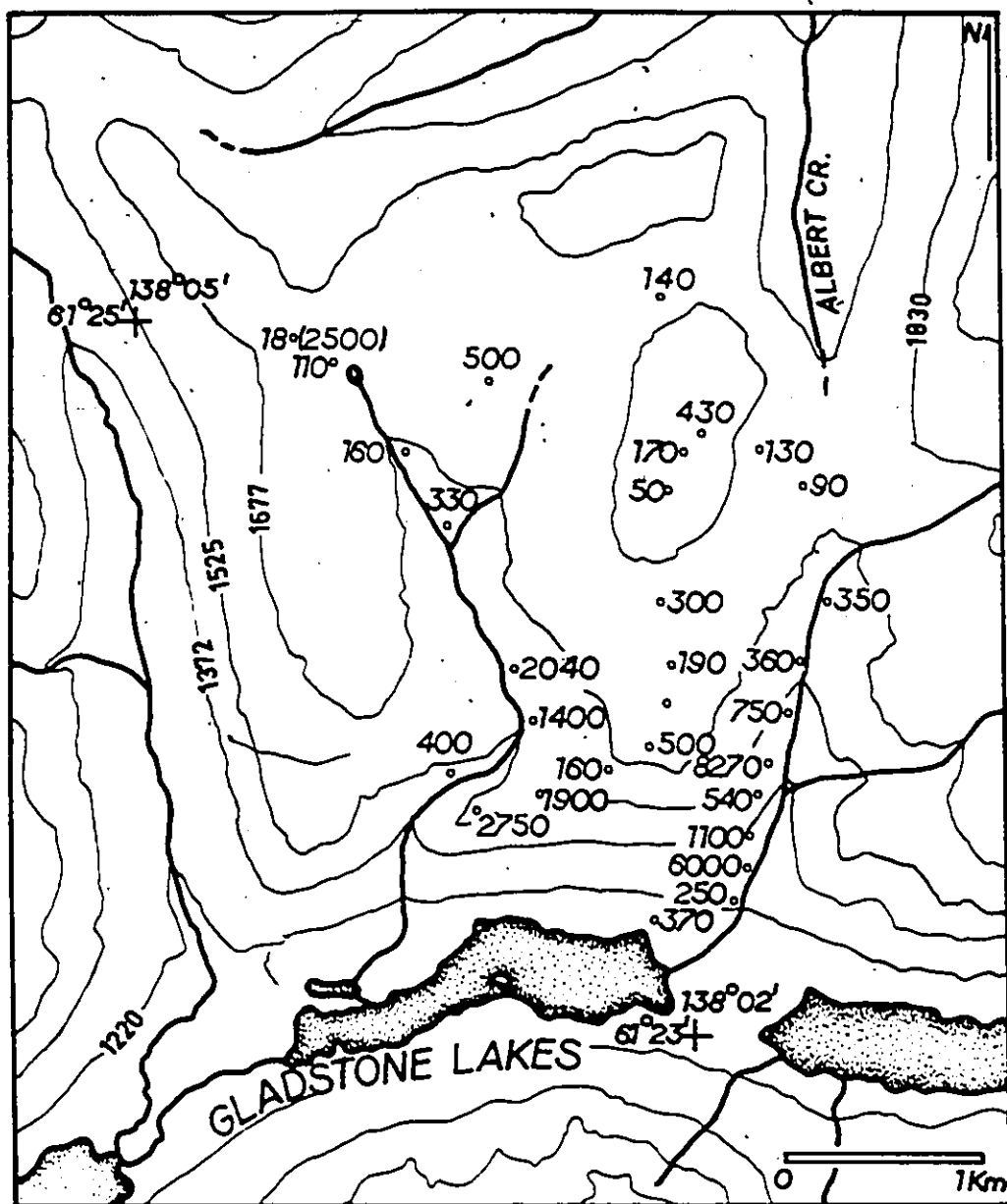


FIGURE 10f. *Betula*/100 *Pinus* ratios for the moss polster and snowbank samples. Snowbank debris sample in parentheses. Note the clustering of high values in the mid-altitude valleys.

Ruby Range corresponds to a patchwork of herb tundra, forest tundra, and northern boreal forest. The difference between the Ruby Range and the study area of McDonald and Ritchie lies mainly in this patchworking of the same vegetational zones due to altitude. McDonald and Ritchie used samples of lake sediment, which average the pollen rain from a large area (Prentice, 1985). The low productivity of the alpine herb tundra (Markgraf, 1980) results in open sites at high altitude of the Ruby Range accumulating a regional pollen spectrum in much the same way as would a lake (Crowder and Cuddy, 1973). The differences between a lake sample and an alpine herb tundra moss polster sample can be expected to lie principally in the NAP portion of the pollen spectrum, where the moss polster will better reflect the ultralocal vegetation.

The major differences between the herb tundra samples in the Ruby Range and the forest tundra spectra of McDonald and Ritchie are the low values for Alnus and the higher NAP ratios in the Ruby Range. The lower Alnus values are probably due to the lower abundance of Alnus in the forest of the Ruby Range compared to the forest tundra of their study area. The more abundant NAP is expected, due to the difference in material sampled.

The Pinus/Picea ratio shows a relation with both altitude and the distance from the trunk valley. The ratio is more favorable to Picea nearer to the spruce forest in the trunk valley.

This suggests that updrafts following the valleys are more important than dominant winds for the dispersal of forest pollen above the tree-line. This is different from the conclusion of Markgraf (1980) who found that the dispersal of forest pollen above the tree-line in the Swiss Alps is mostly through dominant winds. The difference between the two studies may be mostly a matter of the proximity of the pollen source-area. The narrower, shorter valleys of the Ruby Range may also reduce the effectiveness of dominant winds compared to the long, broad valleys studied by Markgraf. The proximity of the spruce forest allows Picea pollen dispersal through local winds. The occurrence of Pinus pollen in the Ruby Range probably follows Markgraf's model of dominant wind dispersal, as local winds cannot transport Pinus pollen from the source area to the central Ruby Range. Lagarec and Geurts (1984) demonstrated that Pinus pollen is brought to the Ruby Range mainly during periods of cyclonic, rather than anticyclonic, activity.

Since Pinus does not grow near the Ruby Range, we can assume that the influx of Pinus pollen is fairly uniform over a small area such as this. Figures 10e-f show the number of grains of Alnus and Betula per 100 grains of Pinus for each site. They indicate that Betula pollen is strongly linked to the occurrence of the shrub in mid-altitude valleys.

The distribution of Alnus pollen is more complex, with highs in two of the mid-altitude valleys. There are two

possible explanations for this distribution: 1) there are individuals or small stands of Alnus in these mid-altitude valleys which have escaped notice in the field, or 2) airstream turbulence in these valleys causes preferential sedimentation of Alnus grains in these locations.

The mean and standard deviation of the values for Betula shown in Figure 10f are $\mu = 1026$ and $\sigma = 1809$. This indicates a much broader distribution than for Alnus, which has $\mu = 437$ and $\sigma = 437$. This suggests that the pollen rain of Alnus is more uniformly distributed in this area than that of Betula. The quantity of Alnus pollen at high altitudes approaches that of Betula, indicating that Alnus is more dispersive than Betula. This is in agreement with the experimental results presented in Chapter 2.

Figures 10b, c, e, and f show an interesting distribution in the three highest altitude samples (mosses K, L, and M). A strong gradation occurs from sample K to M in each of these four figures. Both Betula and Alnus seem to increase in abundance at the end of the plateau nearest to Albert Creek. It is possible that the Albert Creek valley itself may be a major source area for Betula pollen. It may also serve as a corridor for the aeolian transport of Alnus pollen from the Aishihik-Sekulmun basin, where Alnus is far more abundant than in the Ruby Range (Geurts, personal communication). This situation would be analogous to the "pollen-shed" in Wales described by Price and Moore (1984).

The differences in the palynology of the snowbank and the neighboring moss sample are quite extreme. They lie primarily in the very low percentages of saccate grains and extremely high value of Dryas in the snowbank debris. These differences are probably due in large part to the seasonal nature of the snowbank deposit. The samples were collected in mid-June, and Dryas, the dominant species on the nearby slope, was in flower at the time. Dryas leaves were the dominant component of the snowbank debris.

Pinus, which is nearly absent in the snowbank debris, has its peak pollen production in early July (Geurts et al., 1983). The pollen production peak of Picea occurs sometime prior to the middle of June (Geurts et al., 1983). This suggests that the snowbank debris collects only a very seasonal fraction of the pollen rain.

High values of the other taxa, such as Artemisia in samples Q and V, Shepherdia in samples O, P, S, and V, and Juniperus in samples Q, S, and U, are related to the presence of the plant in question within a few meters of the sampling site. Single grains of some shrub taxa are found at some of the high altitude sites, such as the grain of Juniperus in sample N. This is not unusual in the Ruby Range, and is a result of the low productivity of the alpine herb tundra.

The surficial palynology of this area is quite complex and involves altitude, distance from source area, and possibly air turbulence due to micro-relief. The interpretation of a

palynostratigraphic section in the Ruby Range must take this complexity into account.

CHAPTER 4. KETTLE CAMP PALYNOLOGY.

4.1 INTRODUCTION.

An understanding of the relations between pollen spectrum and sedimentary environment is necessary for the interpretation of a pollen diagram from a sedimentologically varied deposit. Rampton (1971) noted the presence of reworked pollen grains in a section from the Kluane Range, and Catto (1986) notes differences in the hydrodynamic behaviour of different pollen taxa as revealed by their distribution in river deposits. The experiments presented in Chapter 2 noted differences in both the aerodynamic and hydrodynamic behaviour of certain pollen taxa. These experiments were conducted under highly artificial conditions and did not test the interaction of the various influences in a natural setting.

In order to extend these results to field conditions, two sections within 5 meters of each other were sampled at the Kettle Camp site (Figures 1, 9 and 11). One section is mostly fibric organic material and the other is silt and reworked volcanic ash. The mineralic section appears to have formed through the rillwash transport of sediment from the surrounding slopes, including the area of the organic section. A comparison of the two sections provides a "natural conditions" backup for the laboratory experiment on the effects of rillwash transport.

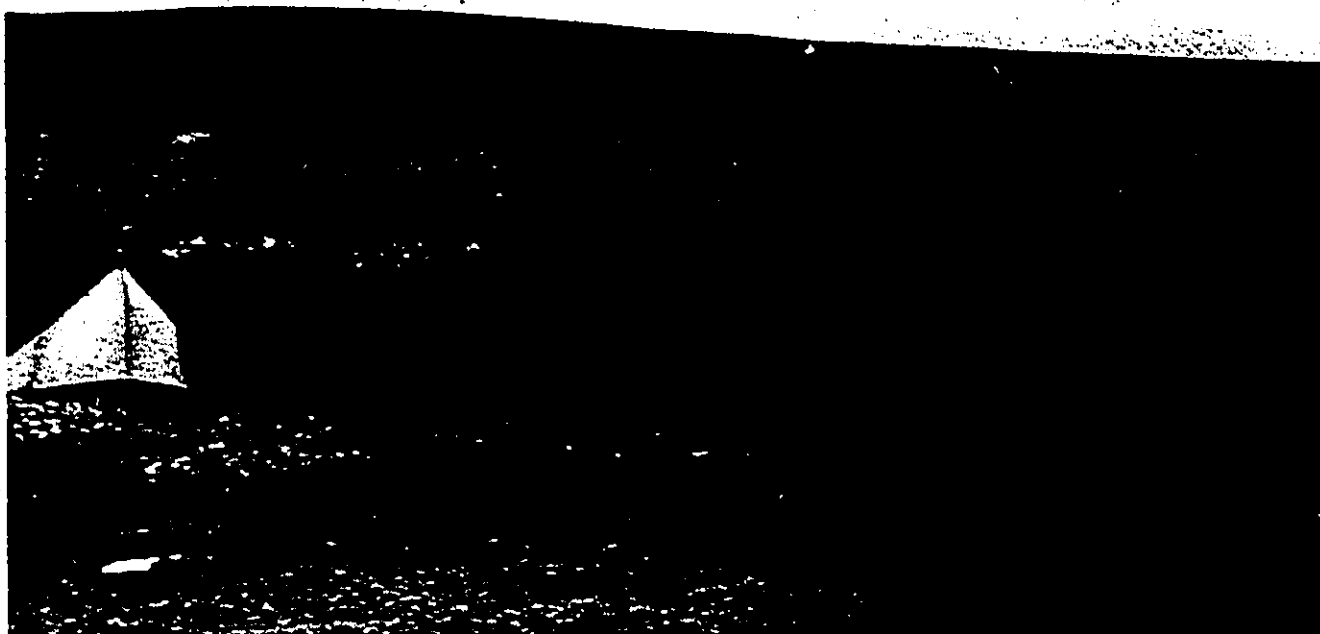


FIGURE 11. KETTLE CAMP. Organic section marked with arrow on left, mineralic section marked with arrow on right. The site is in a small kettle. The tent is approximately 2 m high.

4.2 SITE DESCRIPTION.

The site is located in a kettle on a medium-elevation plateau overlooking the Gladstone Lakes (Figures 1, 9 and 11).

The plateau vegetation is predominantly a Carex-grass-Dryas-Salix herb tundra. A boggy area near the site supports a diverse flora dominated by cottongrasses. Within the kettle complex, the ridges are populated by Dryas, Androsace chamaejasme (rock jasmine), Silene acaulis (moss campion), and herb Salix. The slopes have a similar but denser assemblage. The kettle floors are essentially barren, with only sparse grasses.

The organic section was taken from the inner wall and the mineralic section from the floor of one of the kettles. The sections can be correlated by the occurrence of the White River volcanic ash, dated at ca. 1250 BP by Lerbekmo et al (1975), and at 1230 BP by Denton and Karlen (1977).

4.3 ORGANIC SECTION PALYNOLOGY.

The most striking feature of the pollen diagram of the organic section (Figure 12) is the perturbation of both the Gramineae and Caryophyllaceae curves following the deposition of the volcanic ash. The Caryophyllaceae in this region (at

KETTLE CAMP-ORGANIC SECTION

ANALYSES: I. CAMPBELL 1987

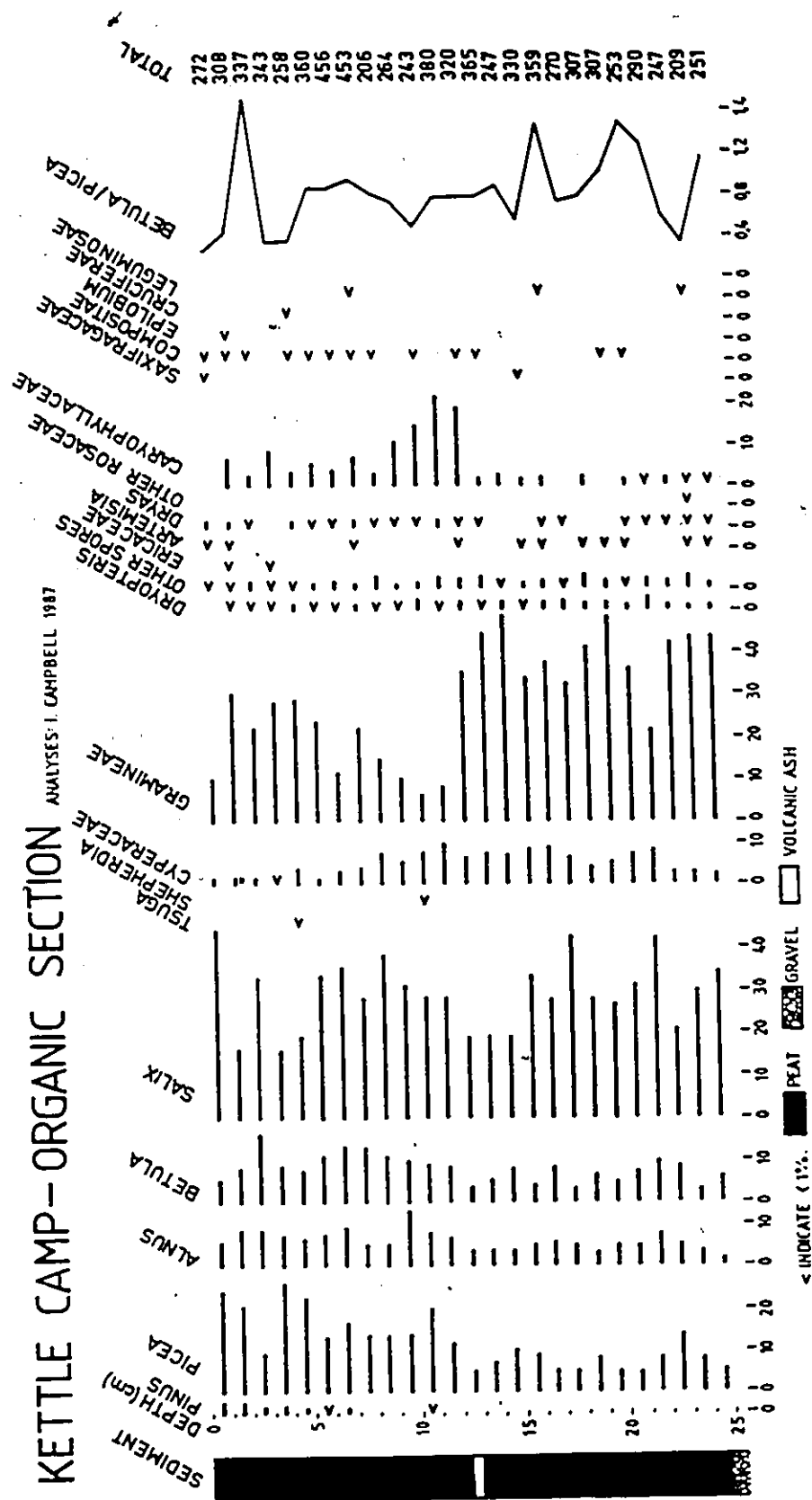


FIGURE 12. KETTLE CAMP ORGANIC SECTION PALYNOLOGY. Relative pollen frequency only.

present mostly moss campion) thrive on well drained substrates and are common on moraine ridges. The deposition of the volcanic ash seems to have caused a substantial reduction of the Gramineae and provided a favourable substrate for the Caryophyllaceae.

The ashfall appears to have been preceded by a slight decline in Salix, which recovered following the ashfall. This may be a simple coincidence, or it could be that Salix was being replaced by Gramineae when the ash covered the area. Salix appears to be and to have been in competition with Gramineae, and the ash may have reset the balance to again favour Salix.

Dewez *et al.* (1984) did not find a pronounced peak of Caryophyllaceae following the eruption of the ash, but did note that the short term effect in most herb tundra communities was a reduction of Pteridophytes in favour of Cyperaceae.

It is worth noting that the percentage of Salix in this pollen diagram is much higher than in the accompanying surficial moss polster (over 40% in the section but only 10% in the accompanying moss polster, see Chapter 3). This is explained by the difference in material used. The sediment samples from this section are grass-Salix peats and probably contain numerous Salix stamens.

The Betula/Picea curve has a negative average slope. This suggests that either the shrub-line has been gradually

receding in this area, or the spruce forest has been gradually increasing its pollen production in response to more favorable conditions. The curve shows a reasonably broad peak near the base of the diagram which may correspond to the zone 2 of Bourgeois and Geurts (1983) and Campbell (1985). Another possible explanation for this trend will be explored in the discussion of the mineralic section.

The gradual rise and fall of the Cyperaceae is probably related to edaphic factors such as the gradual silting up of the kettle. It is difficult to interpret this curve since Carex and cottongrass, both sedges, indicate very different edaphic environments.

4.4 MINERALIC SECTION PALYNOLOGY.

This pollen diagram (Figure 13) has some of the same features as the organic section. The differences are probably due to either the difference in the vegetation within 1 meter of the sites, or to the reworking of pollen grains in the mineralic section.

The strong increase in Betula and Alnus following the deposition of the White River Ash is not accompanied by a parallel increase in Picea. Since there is no indication that the ashfall had any effect on the shrub and tree taxa of this area (Dewez et al, 1984), some other explanation is needed.

Although no formal count was made, it was observed during

KETTLE CAMP - MINERALIC SECTION

ANALYSES: I. CAMPBELL 1967

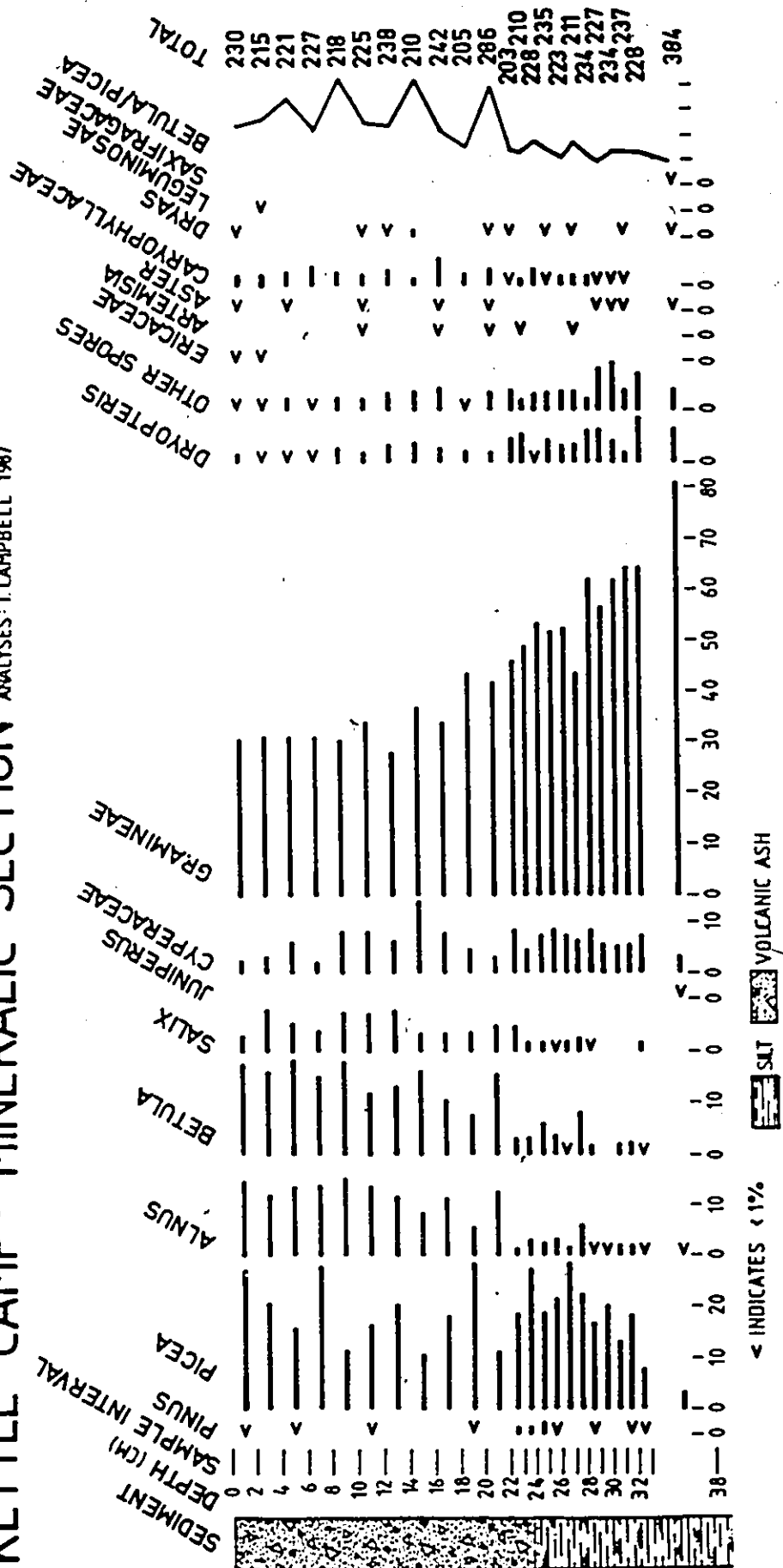


FIGURE 13. KETTLE CAMP MINERALIC SECTION PALYNOLOGY. Relative pollen frequency only.

analysis that the ratio of intact to damaged grains of Picea pollen was much higher in the mineralic section than in the organic section. The ratio of Picea to other taxa is also slightly higher in the mineralic section. This suggests that the mineralic section received much of its pollen through surface runoff, which was found in Chapter 2 to carry undamaged saccate grains more easily than non-saccate or damaged saccate grains.

The deposition of the ash may have provided a more porous substrate throughout the kettle complex. This would result in more rapid absorption of water at the surface, reducing the distance over which pollen could be transported in runoff. This in turn would reduce the importation of undamaged saccate grains to the floor of the kettle. It would have simultaneously increased the relative frequency of undamaged saccate grains (both Picea and Pinus) in the deposits on the surrounding slopes. This hypothesis will be referred to as the "runoff-percolation" hypothesis.

This explanation accounts for the discrepancies between the organic section from the kettle wall and the mineralic section from the kettle floor. It also explains the broad peak in the Betula/Picea curve at the base of the organic section.

The gradual decline of Gramineae in the mineralic section prior to the deposition of the ash also requires explanation. Gramineae also fails to recover as it does in the organic section. The gradual decline could be due to sediment mixing

within the basin or to percolation of pollen down into the sediment. Both of these possible explanations fail in the face of the suddenness of the increases in Betula and Alnus. The gradual decline in Gramineae pollen may result from the gradual replacement of grasses by other taxa. Of the other herb tundra taxa, only Salix shows a slight complementary increase.

The taxa which do show a significant complementary increase are Picea, and to a much lesser extent Betula. This indicates that the decline in Gramineae may be a result of the increase in Picea pollen production. The obverse hypothesis, that the increase in Picea representation is a result of the die-out of Gramineae, would require that all other taxa show either a similar increase. In fact, many of the herb tundra taxa show no significant change.

The very low values for all forest and shrub-tundra taxa at the base of the diagram suggest a barren landscape prior to the arrival of spruce in the valleys. This would correspond to the immediately post-glacial period. Beaudet (1986) found a similar Picea low corresponding to 8900 BP in the MacKintosh basin in the Aishihik-Sekulmun area. A Picea high prior to this was interpreted as representing a barren immediately post-deglaciation landscape (Beaudet, 1986).

In the absence of a more detailed palynostratigraphy of this site or sufficient ~~organic~~ organic material for radiocarbon dating, the age of the base of this section must remain in

question.

Gramineae fails to recover following the deposition of the ash. Although this may be in part due to runoff percolation, the gradual nature of the return of Gramineae in the organic section argues that at that site there was a measure of true recovery. This suggests that the recovery of Gramineae in the organic section may have been restricted to only part of the kettle complex. Salix increases significantly in the mineralic section, suggesting that in most of the kettle complex the ash provided a substrate more favorable to Salix than to Gramineae.

The very low incidence of Caryophyllaceae pollen in the mineralic section indicates that either the Caryophyllaceae bloom noted in the organic section was restricted to one part of the kettle complex or else the pollen grain of Caryophyllaceae is not well transported in runoff. This latter explanation is favored by virtue of both the present distribution of Caryophyllaceae in the complex and the thick heavy exine of the Caryophyllaceae pollen grain.

The gradual reduction in the relative frequency of the spores is probably due to silting up and therefore drying out of the basin.

4.5 CONCLUSIONS.

The runoff-percolation model of pollen transport within

this basin has important implications for the interpretation of palynostratigraphic sections in the Ruby Range and elsewhere. It suggests that a major component of the pollen in a basin may be transported through runoff. This was not considered to be a major factor in Tauber's model of pollen transfer in forested areas (1967). Whether runoff is likely to be as important in a forest as it appears to be at this site is a matter needing further field investigation.

The runoff-percolation model does suggest that the porosity of the substrate surrounding a basin site can be of major importance to the interpretation of the pollen spectra. In the particular case of the Kettle Camp sites, either section considered separately would have suggested either an increase or a decrease in the pollen productivity of the spruce forest over the last 1250 years. In fact, considering both sections together in the light of the runoff-percolation hypothesis, there is no evidence for any major change in pollen production or climate after 1250 BP. All differences between the two sections can be ascribed to either the differences in the ultralocal vegetation or to the effects of runoff-percolation.

Special care must be taken in interpreting changes in the palynostratigraphy at other sites where there has been a change in the surrounding substrate, such as the addition of the volcanic ash. When dealing with climatic changes, it must be remembered that the aggradation or degradation of

permafrost will affect the porosity of the surface. The gradual development of organic soils may also affect pollen assemblages in this way. Any site where runoff may be a major contributor or remover of pollen at the surface must be used with caution.

Lake deposits will be strongly affected by changes in runoff, as will any subaqueous deposit. Slope deposits may suffer from the selective removal of pollen by runoff. The sites which are probably least affected by runoff are those with flat surrounding topography. Since small-scale climatic changes in the Ruby Range will only show in the pollen diagrams of sites above the tree-line (Chapter 1), and accumulation of thick deposits of sediment does not occur on the open plateau, the only flat areas suitable for palynostratigraphic study will be in mid or high altitude valleys.

CHAPTER 5. SHAKY HAND CREEK PALYNOLOGY.

5.1 INTRODUCTION.

Shaky Hand Creek is located in the central part of the Ruby Range to the northwest of the Kettle Camp area (Figure 1). It is the most promising site found so far for palynostratigraphic analysis in the Ruby Range. It is located well above the tree-line, has 243 cm of Holocene accumulation above a gravel base, and is undisturbed by solifluction or cryoturbation. The section does include several grainflows, but these are unavoidable in the Ruby Range and do not pose a great problem for the interpretation of the palynostratigraphy.

The site is at the confluence of two creeks (Figure 14), where the valley floor is broad and flat. Problems with runoff-percolation should therefore be minimal.

The vegetation at the site is mostly Betula-Salix shrub tundra, with abundant herbs and other small shrubs. The section is mostly in permafrost, and was sampled by Dr. Peter Johnson and his field crew in the summer of 1985. The samples were taken as 38 cm monoliths in plastic boxes, on a fresh vertical exposure in a stream cut.

The samples were prepared for palynological analysis by Fern Jensen under the supervision of the author using the methods described in Appendix 1. Given the apparent variation

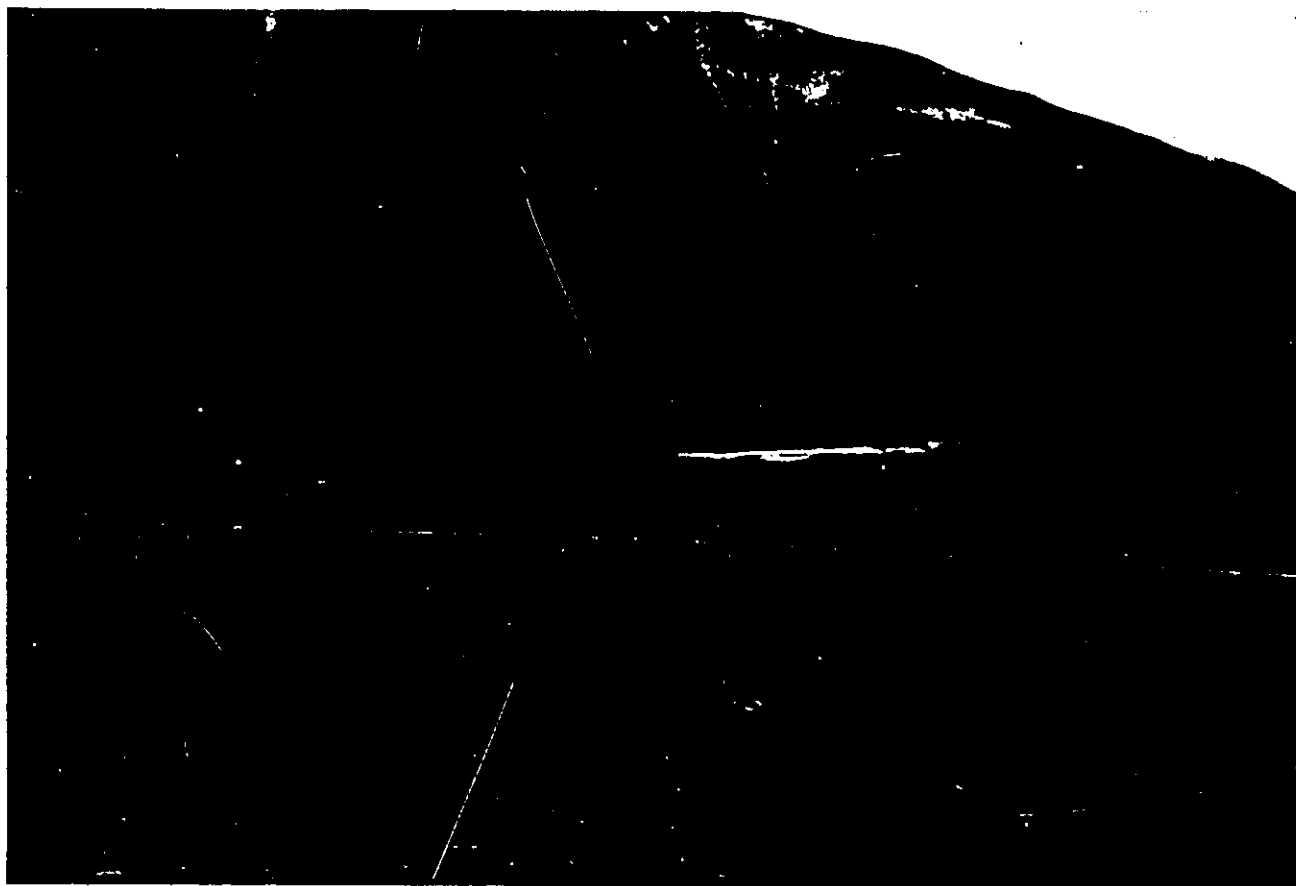


FIGURE 14. SHAKY HAND CREEK. Section location marked by arrow. Pale area on center-left is a cryoturbated dry lake bed. Vegetation is shrub birch and willow with herb tundra.

in the rate of sedimentation in the section, no attempt was made to determine pollen influx. Three moss polster samples from the immediate area were inadvertently destroyed during preparation.

5.2 SEDIMENTOLOGY.

The lithology of the section is shown on the left side of Figure 15. The section is dominated by fibric peat, which contains recognizable stem and leaf fragments of Gramineae and Cyperaceae, as well as a few recognizable Dryas leaves. Root penetration in the section is minimal, limited by the permafrost table.

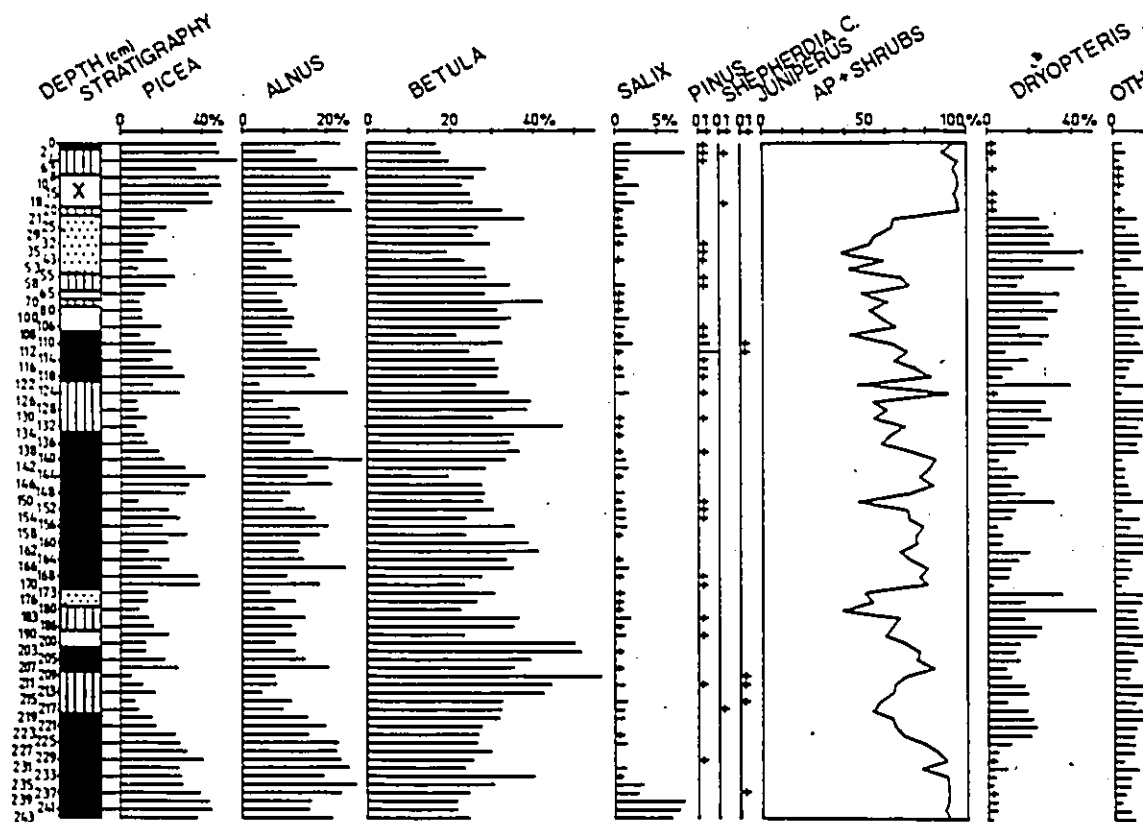
The base of the section is gravel, presumed to be glacial or fluvioglacial in origin. This is overlain by successive layers of peat, silty peat, and sand. The White River volcanic ash (of the 1250 BP eruption) occurs as a disseminated layer near the top of the section.

The layers of coarse sand appear to represent grainflow deposits. The silts and fine sands probably represent flooding events. Some of the silts may also be aeolian in origin.

The chronology of the deposit will be discussed in Chapter 6, in conjunction with the palynostratigraphic correlation with other sites.

SHAKY HAND CREEK

ANALYSES: IAN CAMPBELL 1986.



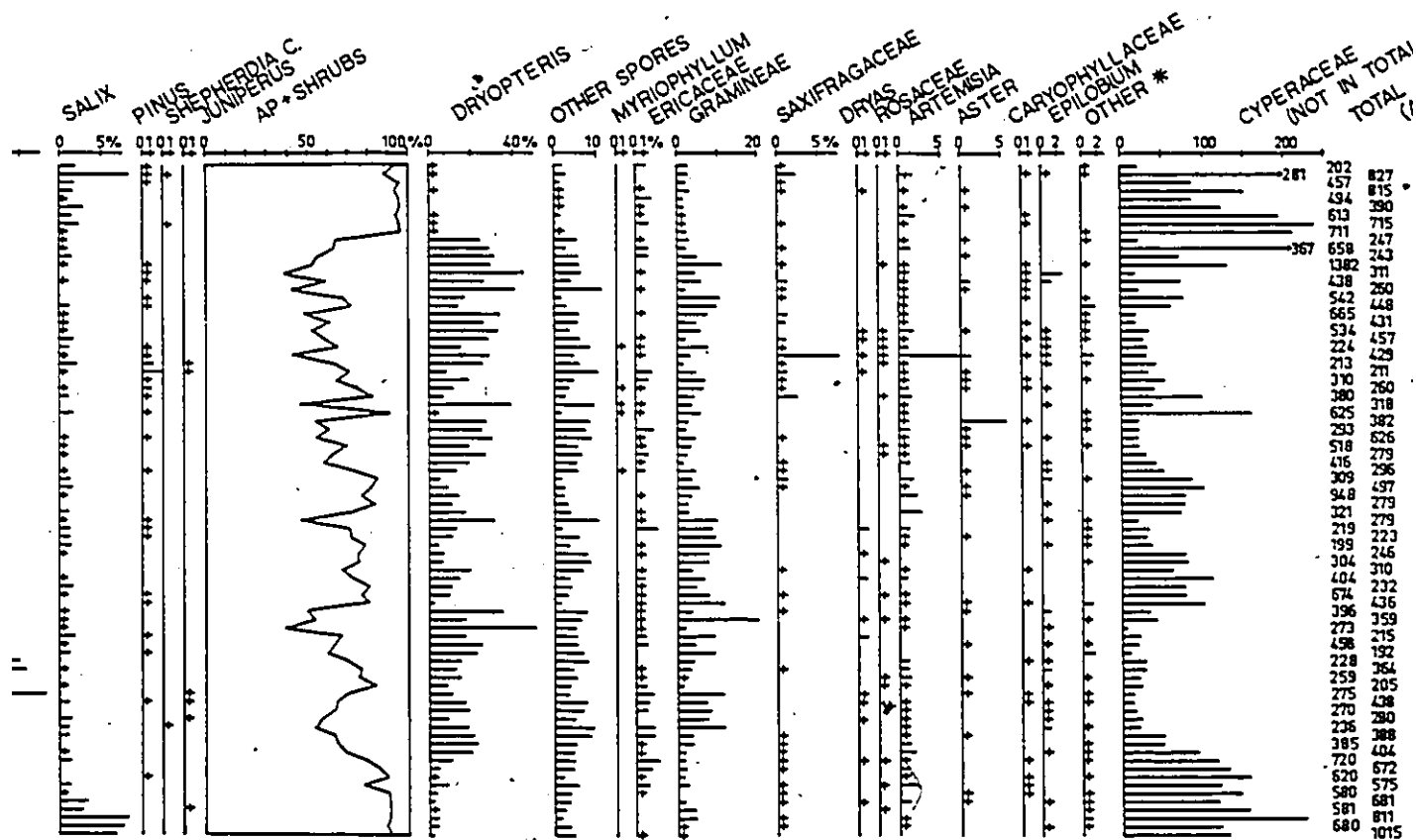
* AMBROSIA, CHENOPODIACEAE, CRUCIFERAE, LEGUMINOSAE, POLEMONIUM, POTAMOGETON, RANUNCULUS

LEGEND: PEAT PEAT WITH SILT OR FINE SAND X PEAT WITH SILT AND VOLCANIC ASH

FIGURE 15. SH
CHRONOLOGY, Rel

EK

ANALYSES: IAN CAMPBELL 1985.

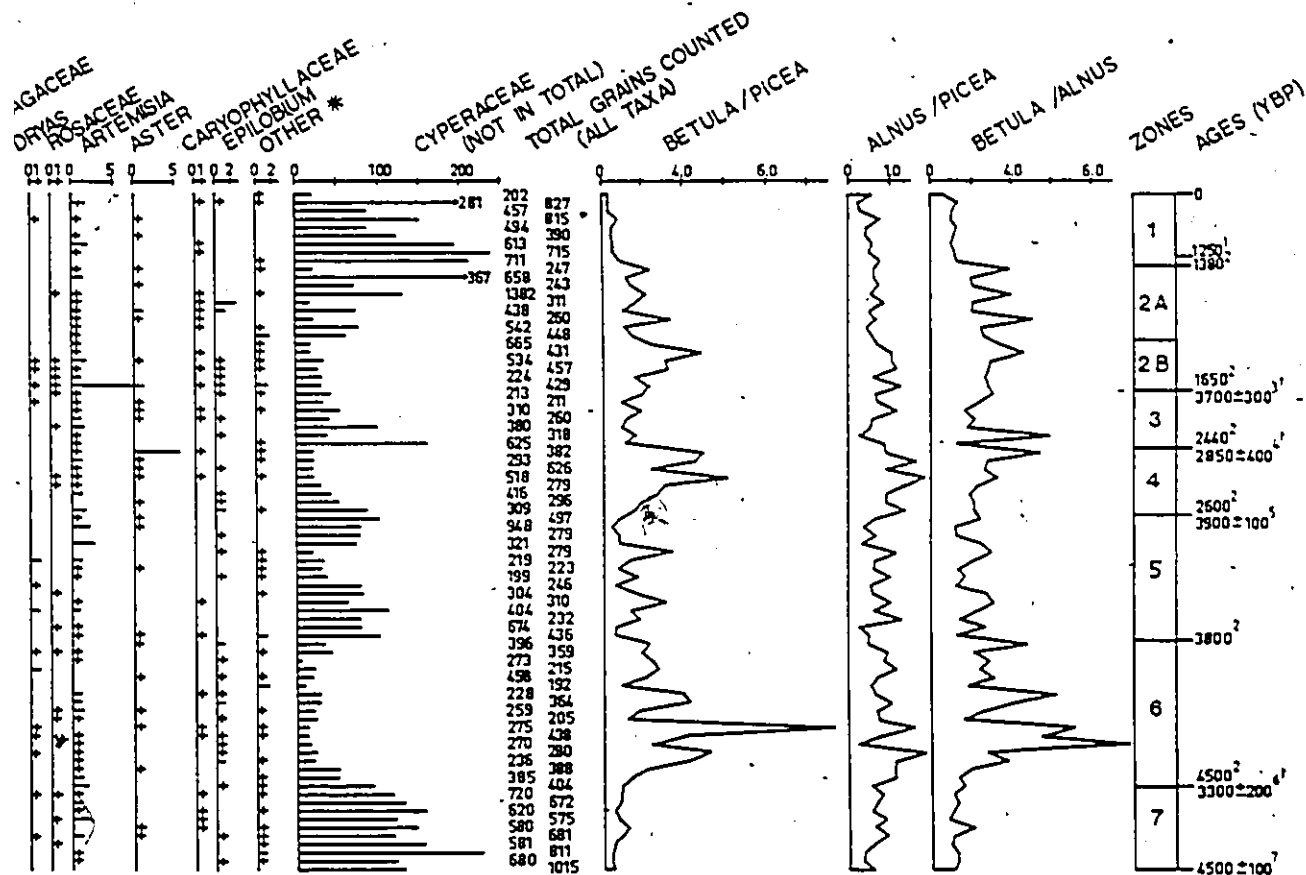


UMINOSAE, POLEMONIUM, POTAMOGETON, RANUNCULACEAE, TYPHA, UMBELLIFERAE, URTICA, VALERIANA, UNIDENTIFIED.

THE SAND [X] PEAT WITH SILT AND VOLCANIC ASH [dotted] FINE SAND [stippled] COARSE SAND [white] — % TAXON * PRESENT <1%

1 BASE OF T1
2 BY PALYNO
3 C14 UG-1421
4 C14 UG-1427

FIGURE 15. SHAKY HAND CREEK SEDIMENTOLOGY, PALYNOLOGY CHRONOLOGY, Relative pollen frequency only.



RAE, URTICA, VALERIANA, UNIDENTIFIED.

1. BASE OF THE WHITE RIVER ASH - LERBERMO ET AL. 1975

2. BY PALYNOSTRATIGRAPHIC CORRELATION - SEE TEXT

3. C¹⁴ UQ-1420¹ 5. C¹⁴ UQ-1422 7. C¹⁴ UQ-1424

6. C¹⁴ UQ-1421¹ 8. C¹⁴ UQ-1423¹

1. DATE CONSIDERED UNRELIABLE BY ORIGINATING LAB
DUE TO INCOMPLETE COMBUSTION IN PROCESSING.

ARSE SAND | — % TAXON | PRESENT <1%

NEK SEDIMENTOLOGY, PALYNOLOGY AND
frequency only.

5.3 PALYNOSTRATIGRAPHY.

5.3.1 GENERAL.

The palynostratigraphy of the section is shown on Figure 15. Salix has been included with the arboreal and shrub taxa due to the dominance of shrub Salix at the site. Herb Salix is dominant at higher elevations. Cyperaceae have not been included in the total due to their great abundance and extreme variability.

Picea, Alnus, and Salix show peaks at the bottom and top of the diagram, where Betula shows lows. Dryopteris, other spores, and Gramineae follow the same trends as Betula, whereas Cyperaceae follows Picea, Alnus, and Salix.

Both the Picea suite and the Betula suite show secondary peaks and lows within the body of the diagram. These are shown most clearly on the Betula/Picea curve on the right side of the diagram. The accompanying Alnus/Picea and Betula/Alnus curves indicate that although Alnus reacts in much the same way as Picea, it is less strongly opposed to Betula than is Picea.

Given the dominance of Betula and Picea in the arboreal and shrub portion of the diagram, the Betula/Picea curve is used as the primary basis for zoning the pollen diagram. The resulting zones are shown on the right side of the diagram.

Although the evolution of the deposit is of course from

the bottom up, the zones are numbered and will be discussed from the top down. This is to facilitate the comparison of this diagram with Campbell (1985) and with possible future diagrams which may add further zones prior to the base of this diagram. It is also necessary to interpret the lower zones in relation to present-day conditions, which is facilitated by the prior discussion of the upper zones.

5.3.2 ZONE 1.

This most recent zone comprises the highest peak in the Picea suite and the lowest trough in the Betula suite of the entire diagram. This is probably due in large part to the stream-cutting of the section lowering the water table at the site. This caused a decline in the Dryopteris population, which is a major component of the Betula suite. Dryopteris was replaced by Cyperaceae which is a major component of the Picea suite.

The drying out of the site by stream-cutting cannot explain the low Betula values. The coincident, albeit small, decline in the Alnus/Picea ratio suggests that a climatic fluctuation may be involved. A climatic fluctuation may also have initiated the stream cutting.

The Cyperaceae peak may also be an effect of the deposition of the volcanic ash near the base of this zone. Similar Cyperaceae increases in herb tundra communities

following the ash were noted by Dewez et al (1984). The effect ascribed by Dewez et al to the ash may in fact be the result of the change in climate represented by the boundary between zones 1 and 2. The low rate of sedimentation in most herb tundra environments may leave so little material between zone 2 and the base of the ash that the samples in Dewez et al. (1984) taken from below the ash may be in zone 2, while those taken above the ash would be in zone 1.

The climate represented by this top zone can be assumed to be essentially similar to that of today.

5.3.3 ZONE 2.

This zone represents a Picea suite trough and a Betula suite peak. It is divided into two subzones, 2a and 2b. Subzone 2a shows intermediate values for the Betula/Picea ratio, and can be considered transitional between subzone 2b and zone 1.

Subzone 2a corresponds to sandy lithology which is probably a grainflow or a single flooding event deposit. It may have no significance in paleoclimatic terms since the transitional character of the subzone could be a result of pollen infiltration in the sandy sediment.

Subzone 2b is mostly in silty peat. The origin of the silt is unknown and it could be either aeolian or a flooding deposit. It is more likely aeolian than from flooding, since

the silt is disseminated within the peat rather than concentrated in bands. Loess is a common deposit in the nearby Shawkak Valley. If it is aeolian, it probably indicates a drier climate, with sparser vegetational cover in the silt source-area.

Bourgeois and Geurts (1983) studied the palynology of the Grizzly Creek basin (Figure 1) and found that a drier climate would increase the moisture-stress on the spruce forest. This would in turn cause a decrease in Picea pollen production. If the dry period were sufficiently long and severe, then it might cause a regression of the tree-line.

A drier climate would be the probable result of a climatic warming. Warmer air can hold more moisture than cold air, so precipitation would occur less frequently in a warmer climate with the same absolute humidity. It is as yet unclear how much of a warming would be required to have a noticeable impact on the pollen rain. This same interpretation is also applicable to subzone 2b.

The inclusion of Dryopteris and other spores in the Picea suite peak appears to argue for a wetter, rather than a drier, climate. These taxa are mostly of local importance and the incidence of their pollen in the section may be strongly affected by edaphic factors such as local drainage.

A cooler and wetter climate would possibly increase the production of spores through greater moisture availability, but since the site is located along a stream, moisture may not

have been the limiting factor on the local sporophytes prior to the stream cutting. Another possibility is that a warmer climate would lower or eliminate the permafrost table and provide a more suitable substrate for rooting. A warmer climate would also be expected to increase the length of the growing season possibly allow several "crops" in one year.

The paleoclimatic interpretation will be further discussed with the correlation of this site with other studies (Chapter 6).

5.3.4 ZONE 3.

Zone 3 represents a trough in the Betula suite and a peak in the Picea suite. The differences between zone 3 and zone 1 can for the most part be ascribed to the edaphic effects of the stream-cutting or of the volcanic ash. Zone 3 can therefore be presumed to represent a climate similar to that of today.

Of particular interest in zone 3 is the Betula/Alnus curve at the boundary of zone 4. Throughout the diagram, the Betula/Alnus and Betula/Picea curves are roughly parallel. At the transition from zone 4 to zone 3, the Betula/Alnus curve lags noticeably behind the Betula/Picea curve. In addition, the Betula/Picea curve is generally slightly more volatile than the Betula/Alnus curve. This suggests that Picea is a more sensitive paleoclimate indicator than Alnus.

The changes in lithology suggest that runoff-percolation may be affecting the pollen spectra of this site. This is a possibility which cannot be completely eliminated, but it should be noted that runoff was found to result in a decrease of the Betula/Picea ratio in the mineralic (sediment receiving) section at Kettle Camp. In the Shaky Hand Creek diagram, the more mineralic zones have a higher Betula/Picea ratio than do the more organic zones, which is contrary to the tendency expected to result from the runoff-percolation model. We can therefore conclude that the observed changes in the Betula/Picea ratio at Shaky Hand Creek are a true reflection of changes in the pollen rain, and not merely a result of the changing sedimentary environment.

5.3.5 ZONE 4.

Zone 4 is essentially similar to subzone 2b and therefore probably represents a similar climate. Like subzone 2b, the lithology of zone 4 is mostly silty peat. The palynology is a Betula suite peak and a Picea suite trough.

The slight lag between the Betula/Picea and Betula/Alnus curves has already been discussed (section 5.3.4).

5.3.6 ZONE 5.

Zone 5 consists of a series of troughs in the Betula

suite curves, separated by small peaks. These troughs and low peaks can be separated into different subzones (not shown on the Figure) for the purpose of discussion.

The first, third, and fifth subzones are Betula suite troughs and the second and fourth show intermediate values for the Betula suite. The wavelengths and amplitudes are small. The subzones may be related to minor climatic or edaphic shifts. They may also be the result of lower than average pollen counts through this part of the section, and cannot be interpreted with any certainty. They cannot form the basis for any conclusion without corroboration from another, more detailed pollen diagram covering this same time interval in the Ruby Range.

Other than these minor fluctuations, zone 5 is essentially similar to zone 1. We can therefore assume that it represents a similar climate to that of today.

5.3.7 ZONE 6.

Zone 6 is similar to zone 4 and subzone 2b and has the highest and broadest of the Betula suite peaks. This may be due either to a more pronounced climatic fluctuation, or to edaphic factors. This zone is near the base of the section and may therefore represent a more volatile edaphic regime.

Zone 6 probably represents a climate similar to that of ~~zone 4 and subzone 2b.~~

5.3.8 ZONE 7.

This is the bottom zone of the section. It consists of a Betula suite trough nearly as deep as that of zone 1. Cyperaceae peaks nearly as strongly as in zone 1.

This similarity between the two zones argues that both climatic and edaphic factors are probably involved here as well. Since this zone represents the base of the section, it is possible that the gravelly base provided sufficient drainage to prevent the development of a dense Dryopteris community. Instead, a drier Carex community may have been dominant.

Another possibility is that the Cyperaceae are not the same species in both cases. Both Carex and cottongrass are common in the Ruby Range. Carex represents a much drier edaphic setting than does cottongrass. The sedge pollen dominating zone 7 may be cottongrasses rather than the currently dominant Carex.

In this case, the interpretation of the local edaphic characteristics of the site would be quite different. Cottongrasses prefer shallow standing water, and would represent a much wetter, more poorly drained local environment. This could have been the result of permafrost aggradation within the basal gravels blocking the drainage.

Either interpretation seems possible with the available information. The climate could have been similar to that of

today in either case.

5.4 POLLEN-SEDIMENT RELATIONS.

Zones 1, 3, 5, and 7 appear to represent a climate similar to that currently dominant in the area. Zones 2, 4, and 6 appear to represent a warmer and drier climate. Zone 1 has been affected by the deposition of the volcanic ash. The lithology of the other zones must be related to edaphic, geomorphologic, and climatic factors. Figure 16 brings together the lithology and the pollen zones of Figure 15.

The odd-numbered zones representing conditions similar to those of today are dominated by peats, with the exception of zone 1 which is dominated by volcanic ash and silty peat. The silt in the peat may be in large part fine reworked volcanic ash.

The even-numbered zones are dominated by more mineralic sediments, including large amounts of silty peat and several mud-flows.

This is consistent with the paleoclimatic interpretation of the palynology of the section. Peaty soils will develop well in a wet environment whereas mudflows will be more frequent if the permafrost table is lower or absent. Loess will also be more common in a drier environment and will produce silty peats.

It can be seen that the changes in the section's

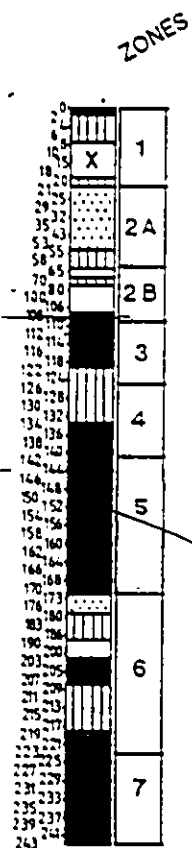


FIGURE 16. SEDIMENT-POLLEN RELATIONS. From figure 15.

lithology do not quite coincide with the changes in its palynology. This essentially eliminates the possibility that the changes in palynology could be artefacts of a changing sedimentological environment, since changes in the pollen record are seen to precede changes in the lithology at the tops of zones 7, 5, and 4. This further suggests that the pollen rain is more sensitive to climatic fluctuations than is the sediment record.

CHAPTER 6. SHAKY HAND CREEK - CHRONOLOGY AND CORRELATION.

6.1 WHITE RIVER VOLCANIC ASH.

The White River volcanic ash is disseminated in silty peat from 7 to 19 cm depth within the section. The greatest concentration of the ash occurs between 18 and 19 cm.

The ash erupted in two episodes from Mount Bona, Alaska. The second eruption yielded the thickest deposit in this area, ca. 1250 BP (Lerbekmo et al, 1975) or 1230 BP (Denton and Karlen, 1977). We can therefore take 1250 BP as an approximate date for the base of the ash in this section, at 19 cm.

6.2 RADIOCARBON DATING.

Five samples from this section were submitted to the Géotope lab at the Université du Québec à Montréal for radiocarbon dating. The results are shown on the right of Figure 15.

Three of the five samples (marked with a 't' on Figure 15) were incompletely oxidized in the radiocarbon dating process. This can lead to substantial fractionation of the carbon isotopes in the sample. The lighter carbon isotope C-12 tends to react more easily than the heavier C-13 and C-14 (Olsson, 1979). This results in less radioactive carbon in the final gas and gives an older date. These three dates must

therefore be considered unreliable and cannot be accepted without strong corroboration.

The incomplete oxidation is believed to have been caused by the high mineral content of the samples, inhibiting oxygen circulation within the material. Sample UQ-1420 was 80% mineral material, UQ-1421 90% , and 1423 was 30% mineral (determined by loss on ignition). It is possible that other samples with similarly high mineral contents may have been incompletely oxidized without this being noticed by the processing laboratory. Incomplete oxidation is determined by checking for glowing embers after combustion. Any radiocarbon date on material with a greater mineral concentration than that of UQ-1423 may therefore be suspect.

The statistical error margin shown with the dates (ex: ± 100 on UQ-1422) does not include these variables. It is in fact only the calculated error margin on the activity of C-14. More recently developed but more expensive techniques using accelerator mass-spectrometry are able to date very small samples, on the order of 0.5 mg of graphite (Hedges and Goulett, 1986). This technique allows accurate measurement of the C-14 activity of different fractions within the same sample, for instance the humin fraction and the humic acid fraction. In this way it can determine the approximate degree of contamination of the sample. However, these methods are extremely expensive, and beyond the budget of this research project.

The two remaining dates, UQ-1422 and UQ-1424, appeared to oxidize completely in the processing. However, they were not treated for carbonates. The central part of the Ruby Range is entirely granodiorites and related intrusives, with no known carbonates. Carbonates do occur in the northwestern part of the Range and on the other side of the Shawkak trench. Carbonate loess is abundant around Lake Kluane. It has long been recognized that contamination of a sample with non-contemporary carbonate material could cause a significant error in the age-determination of the sample (Deevey, 1952).

Several samples from this section, including UQ-1422 and UQ-1424, showed a slight reaction to concentrated hydrochloric acid, indicating the presence of traces of carbonate, probably loess. The amount of carbonate is probably small, but sufficient to cast serious doubt on the validity of these dates.

In future studies, some of the uncertainty may be removed by pretreating the samples. Hydrochloric acid could be used to destroy carbonates and the organic material could be concentrated through flotation using a non-organic heavy liquid such as Thoulet's solution (an aqueous solution of cadmium iodide and potassium iodide used in some pollen separation procedures).



6.3 PALYNOSTRATIGRAPHIC CORRELATION.

6.3.1 CORRELATIONS WITHIN THE RUBY RANGE.

The only previous study within the Ruby Range with which this section may be correlated is that by Campbell and Geurts (unpublished, modified from Campbell, 1985). This paper presents pollen diagrams from the Bonanza Pup and Alaskite Rock Glacier sites in the central Ruby Range (locations shown on Figure 1).

Both sections show the same four pollen zones, which correspond in general terms with the top four zones of the present study. In all three sections, the top zone represents a climate similar to that of today. The second zone shows a decrease in Picea and Alnus accompanied by an increase in Betula. The third zone returns to current conditions, and the bottom zone is similar to the second.

The Alaskite Rock Glacier (ALRG) section shows strong Cyperaceae and Dryopteris curves. These are interpreted as representing edaphic changes within the small basin in which the section is located. The section is entirely silt, with more than 95% mineral material in all samples. No samples were submitted for radiocarbon analysis.

The Bonanza Pup section is composed of layers of different materials ranging from highly organic peat to coarse sand and volcanic ash. A single sample from the base of the

section was submitted to the Geological Survey of Canada for radiocarbon dating (Table 3). The GSC lab pretreated this sample for carbonates and used a quartz oven for combustion, which is considered reliable for mineralic samples (St.-Jean, personal communication).

An untested method of interpolating ages (Table 3) using the organic content of a soil was applied to the Bonanza Pup section (Campbell, 1985). This yielded a date of ca. 2440 BP for the base of zone 3. This date is consistent with other correlations outside the Ruby Range (sections 6.3.2 and 6.3.3). It is also consistent with the radiocarbon date from the GSC and with the position of the White River ash in the section.

Three more samples from the Bonanza Pup section (Table 3) were submitted to the Geotope lab in Montreal. These were not pretreated in any way, and were not combusted in a quartz oven. In addition, a sample of silt from the section also tested positive for carbonates. The resulting dates must therefore be considered unreliable.

Of the four radiocarbon dates from this section, the date from the GSC must be considered to be the most reliable since it was pretreated and burnt in a quartz oven. The three Geotope lab dates are inconsistent with the GSC date and are inconsistent with each other. It is therefore reasonable to reject the Geotope lab dates.

These sections therefore correlate with the top four

<u>SAMPLE #</u>	<u>%LOI</u>	<u>EST. AGE</u>	<u>CUM. AGE</u>	<u>RADIOCARBON AGE</u>
4	12.53	130	1380	
7	23.79	275	1655	4350 +/-100 (UQ-1412)
8	6.47	75	1730	
9	14.01	145	1875	4150 +/-100 (UQ-1413)
11	7.13	85	1960	
12	12.56	130	2090	
13	6.25	75	2165	
14	3.43	45	2210	
15	7.74	90	2300	4600 +/-100 (UQ-1414)
16	3.14	45	2345	
17	8.21	95	2440	
19	5.19	65	2505	
21	9.34	110	2615	
23	26.86	400+	3015+	3840 +/-60 (GSC-3752)

TABLE 3. BONANZA PUP CHRONOLOGY. The three middle columns are from Campbell (1985), and represent an-untested method for interpolating dates through the percentage of organic material in a paleosol. The radiocarbon dates on the right can be seen to be internally inconsistent. Due to known problems with other dates from the UQ lab, and the added security of a pretreatment for carbonates for the GSC sample, the GSC date is considered more reliable than the UQ dates.

zones of the Shaky Hand Creek diagram but cannot provide dates for the lower three zones. The Bonanza Pup and Alaskite Rock Glacier sections have been previously correlated with a study by Bourgeois and Geurts (1983) to the west of Lake Kluane.

6.3.2 CORRELATIONS WITHIN THE YUKON.

Bourgeois and Geurts (1983) presented three pollen diagrams from the Grizzly Creek area (Figure 1). The diagrams show three pollen zones corresponding to the top three zones of Shaky Hand Creek. The zones are distinguished mostly by the reduction of Picea and the increase of Betula in the second zone from the top.

They interpret the Picea decline as representing a warmer and drier climate than that of today. The dryness is hypothesized to have increased the water-stress on the spruce forest causing a decrease in pollen production. Some thinning of the forest near the tree-line may also have occurred. This is the same interpretation as that proposed for the even numbered zones in Shaky Hand Creek.

The Grizzly Creek sections are partially radiocarbon dated and have relatively uniform sedimentation rates. The radiocarbon dates are from the Geological Survey of Canada and were pretreated for carbonates.

Correlation of Shaky Hand Creek with Grizzly Creek provides a date of 1380 BP for the top of zone 2. This is

consistent with the thin accumulation between the top of zone 2 and the base of the White River ash. The same correlation provides a date of ca. 1650 BP for the base of zone 2.

6.3.3 CORRELATION WITH SOUTHERN ALASKA.

Heusser et al (1985) reported the results of several palynological analyses treated with pollen transfer functions. Two of the core sites are located to the north of the Malaspina Glacier in southern Alaska.

They presented curves describing paleotemperature and paleoprecipitation estimates for the past several thousand years. They noted the strong warming and drying of the Hypsithermal which ended ca. 5500 BP. They also noted that other shorter duration fluctuations are present in the curves. They suggest that these fluctuations may be meaningful but do not attach any importance to them in the absence of corroboration from other sections.

The top four fluctuations appear to correspond well with the top four zones of Shaky Hand Creek, Bonanza pup, and Alaskite Rock Glacier. The top three zones correspond well with those found by Bourgeois and Geurts (1983) in the Grizzly Creek basin.

In the absence of reliable contradictory evidence, we can correlate the lower three zones of Shaky Hand Creek with the following three fluctuations of Heusser et al's curves. The

correlation is shown in Figure 17.

This provides dates through palynostratigraphic correlation for the remainder of the Shaky Hand Creek diagram. The base of zone 4 would correspond to ca. 2600 BP, that of zone 5 to ca. 3800 BP, and the base of zone 6 to ca. 4500 BP.

These dates do not correspond very well with the radiocarbon dates obtained for Shaky Hand Creek. However, as already mentioned, these radiocarbon dates are not very reliable. The two dates considered reliable by the originating lab, UQ-1422 and UQ-1424, would allow only 600 years for the accumulation of over 80 cm of peat and silty peat. This would be an extraordinary rate of accumulation for this part of the Yukon and for this climate. Total accumulation in zone 1 was only 20 cm over nearly 1400 years including the contribution of the volcanic ash.

These difficulties with the radiocarbon dates suggest that they are unreliable. We must therefore use the dates obtained through palynostratigraphic correlation.

At present, no other study in the Yukon or Alaska shows paleoclimate fluctuations with which this study can be reliably correlated. Glacier fluctuation studies in the St. Elias mountains cannot be reliably correlated on such a fine scale with each other, let alone with the palynostratigraphy of these sections (Lambert, 1982). Other palynological studies in the Yukon have been either below the tree-line, where such fluctuations do not show, or else with too large a sampling

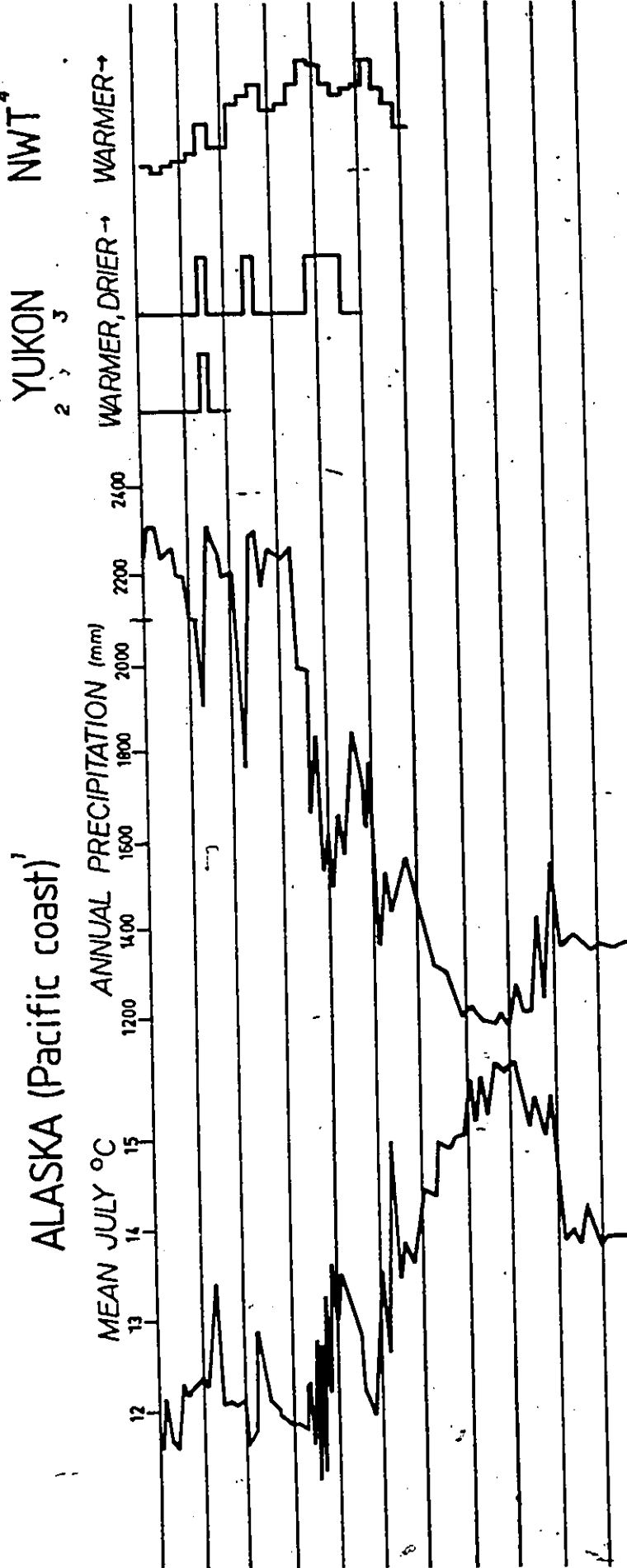


FIGURE 17. CORRELATION WITH OTHER SITES. The curves on the left side are redrawn from Heusser et al (1985). Leftmost is mean July maximum temperature, next is mean annual precipitation. Their site is near the Malaspina Glacier, on the Alaska coast. The next curve is a summary of Bourgeois and Geuphs (1983), from the Grizzly Creek basin in the Klutane Ranges. The next curve is a summary of the Ruby Range data from Campbell (1985) and from Shaky Hand Creek. The rightmost curve is from Andrews and Diaz (1981) in the eastern Canadian Arctic.

interval to show such small fluctuations (Ritchie, 1984).

6.3.4 CORRELATION WITH THE EASTERN CANADIAN ARCTIC.

Andrews and Diaz (1981) studied the July paleotemperatures of the Baffin Island-Keewatin-Ungava region through partial collective analysis of previously published pollen diagrams. They found a broad temperature trend on which is superimposed a series of small oscillations over the past 5625 years. Temperature peaks occurred from 1375-1625 BP, 2125-2875 BP, 3625-4125 BP, and 4875-5625 BP. The alternate intervals represent temperature lows.

Although they attach no importance to these small oscillations, the correspondence of the dates for the first warm period (1375-1625 BP) with the dates found in the Ruby Range (1380-1650 BP) is well within acceptable limits of error. The remaining dates from Andrews and Diaz (2125 to 2875, and 3625 to 4125 BP) are only slightly out of phase with those found for the Ruby Range (Table 4). Given that Andrews and Diaz rounded all their dates to fit the 250-year sampling interval of their lowest-resolution section, the differences in the dates are not sufficient to justify interpreting the fluctuations they found in the eastern Canadian Arctic and those of the Ruby Range as asynchronous.

Andrews and Diaz do note that temperature departures appear to be of opposite sign east and west of 110°; however,

this conclusion is based on their inclusion in their data-base of a single site west of 110°, at Tuktoyaktuk (studied by Ritchie and Hare, 1971). The correspondence of their dates and the sign of their temperature departures with ours (Figure 17) and with those of Heusser et al suggest that it may not be a matter of east or west of 110°, but rather a question of a difference which may be restricted to the Tuktoyaktuk area.

Without better chronological control, no attempt can be made at correlating these results with European or Asian data.

SHC	ANDREWS AND DIAZ	DIFFERENCE	%DIFFERENCE
1380	1375	+5	0.3%
1650	1625	+25	1.5%
2440	2125	+315	12%
2600	2875	-275	11%
3800	3625	+175	4.7%
4500	4125	+375	8%

TABLE 4. COMPARISON OF DATES FOR SHAKY HAND CREEK AND ANDREWS AND DIAZ (1981). Note that Andrews and Diaz rounded their dates to the nearest 250 year interval, so that differences of less than 125 years are meaningless.

CHAPTER 7. CONCLUSIONS:

7.1 POLLEN-SEDIMENTARY ENVIRONMENT RELATIONS.

The five laboratory experiments presented in Chapter 2 yield several important conclusions. The first is that pollen morphology plays a very important role in determining the dispersiveness of pollen grains in air. Such small features as vestibules may act as sails to aid the dispersion of pollen grains.

Pollen dispersion may be strongly affected by airstream turbulence. This can be caused by microtopography or by vegetation. Large differences in pollen rain may occur between adjacent sites with similar vegetation but different microtopography. This is confirmed by the analysis of moss polster samples in the Kettle Camp area.

Another important finding is the possible effect of runoff on a pollen spectrum. Undamaged saccate grains are transported more easily than non-saccate or damaged saccate grains. Sites on a slope may suffer preferential removal of undamaged saccate grains, while sites in accumulation zones may receive a greater influx of these grains. This is also confirmed by a comparison of two sections at the Kettle Camp site.

Tests of pollen destruction through sediment compaction, turbulent water transport, and rillwash transport indicate

that pollen grains are highly resistant to mechanical destruction. Sediment compaction has only a minor damaging effect, as does extremely long turbulent water transport. Rillwash transport over short distances has no noticeable damaging effect on pollen grains. This may have implications for the use of fossil pollen in lithified material, of particular interest to the petroleum industry.

By far the most effective of the various factors which are likely to cause pollen destruction in the Ruby Range appears to be wet-dry cycles. This had previously been tested by Holloway (1982). The wet-dry cycle test presented here confirms Holloway's results. It also indicates that although wet-dry cycles damage pollen grains quite rapidly, the rate of new damage decreases logarithmically with successive cycles. After only a few years, therefore, the degree of damage will be equal in all samples.

Damage through wet-dry cycles requires that caution be used in comparing very recent samples, such as mosses or aeropalynological samples, with fossil material.

7.2 SURFICIAL PALYNOLOGY OF THE KETTLE CAMP AREA.

The analysis of moss samples from the Kettle Camp area confirms some of the conclusions regarding pollen dispersion obtained in Chapter 2. It also indicates that regional pollen dispersal from the spruce forest is probably mostly through

updrafts. Extra-regional pollen is dispersed mostly by dominant winds.

The assumption that extra-regional pollen is uniformly distributed through this area allows the determination of pollen-altitude relations for single taxa. A possible pollen shed was found involving Alnus and Betula pollen. Updrafts in the Albert Creek valley are hypothesized to transport Alnus pollen from the Aishihik-Sekulmun area. The valley itself would serve as a source area for Betula pollen.

Most of the pollen spectra from this area are similar to those of the forest tundra or the herb tundra studied by MacDonald and Ritchie (1986). This is not unexpected given the lateral compression of the ecozones due to the topography in the Ruby Range. The herb tundra moss samples are from within a few kilometers of both the shrub tundra and the forest tundra. The highly dispersive forest tundra pollen is therefore abundant in the herb tundra samples. The high degree of correspondence between pollen spectrum and local vegetation found by MacDonald and Ritchie is thereby lost in this area.

One result of this lowered correspondence is the need for a much larger data-base for the development of pollen-climate transfer functions. Although altitude should always be considered in developing these functions, it becomes necessary to include other variables such as distance from the trunk valley and microtopography. This multiplication of variables increases the size of the data-base required (Bryson and

Kutzbach, 1974).

7.3 PALYNOSTRATIGRAPHY OF THE RUBY RANGE.

The Shaky Hand Creek section provides a palynostratigraphy of the late Holocene in the Ruby Range. It shows 7 small-scale short-duration climatic fluctuations over the past 4500 years. These fluctuations show in the pollen diagram as shifts in the ratio of Picea suite pollen to Betula suite pollen. These suites are defined in Chapter 5.

The climate appears to have fluctuated between two states; one similar to today's climate and one slightly warmer and drier. These shifts correlate with similar fluctuations found by Campbell and Geurts (unpublished), by Bourgeois and Geurts (1983), by Heusser et al (1985), and further to the east by Andrews and Diaz (1981).

The Hypsithermal shows in Heusser et al (1985) as a longer duration and slightly more pronounced period similar to the warm and dry periods found here. When surface albedo is taken into account, the Milankovitch theory of global climatic change satisfactorily explains the occurrence and timing of the Hypsithermal and the subsequent cooling following 5000 BP (Ritchie et al, 1983). It does not suggest any mechanism for the smaller-scale fluctuations found here.

Small fluctuations of the position of the Arctic front may be responsible for these pollen zones (Geurts et al,

1984). These fluctuations may in turn have been caused by changes in the thermal regime of the North Pacific, or by the currently popular El Niño. Other factors may also be involved.

This study indicates that short duration, low amplitude climatic fluctuations have been a frequent occurrence in the Holocene. A return to warmer and drier conditions in the southwestern Yukon could have a profound effect on the frequency of forest fires, ecology, and economy in this region. Further study of both the present climate and paleoclimates is urgently needed to understand the mechanisms governing the climate of northern Canada.

APPENDIX 1. SAMPLE PREPARATION TECHNIQUES.

The following is a list of the techniques used for the preparation of palynological samples for this paper. Each sample was treated using the selection of techniques best adapted to it. Centrifugation was for 10 minutes at 2000 RPM. Centrifugation and decantation is indicated by C+D.

ORGANIC MATERIAL: -humic bonds broken by boiling for five minutes in 10% NaOH and sieving through 200 μ wire mesh. C+D.

-acetylation (Erdtman acetolysis). Preceded by washing in glacial acetic acid and C+D. Followed by C+D, water wash, C+D.

MINERAL MATERIAL: -heating in HF 45-52%. Preceded and followed by HCl rinse with C+D.

-Fine silts and clay removed by wet-sieving through 7 μ Nytex membrane. C+D.

MOUNTING: -all samples mounted in glycerine-water mixture.

COUNTING: whole slides with a minimum of 10 μ l of were counted, to a total of at least 200 grains or 100 μ l, whichever came first.

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