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PAPER 67-46

NOTES ON QUATERNARY PALAEOECOLOGICAL PROBLEMS IN THE YUKON TERRITORY, AND ADJACENT REGIONS

(Report and 1 figure)

J. Terasmae

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ABSTRACT

The Yukon Territory has attained a prominent place among problem areas in Canada for Quaternary research, because parts of northern Yukon are unique in that they remained unglaciated throughout the Quaternary. Geological and palynological studies have indicated the presence of a long palaeoecological record in the unglaciated region, but this record is broken by frequent and important discontinuities. The recycling of deposits by erosion and redeposition, and their permanently frozen condition complicate the studies. Possible migration of plants across the postulated Bering Sea land bridge introduces several as yet poorly known factors into palaeobotanical investigations. Available evidence indicates that Quaternary climatic changes in Yukon have been approximately contemporaneous with, and probably of the same magnitude as those farther south in the temperate latitudes. Palaeoecological evidence indicates that human migration could have occurred from Asia to Yukon and thence southward in late-Quaternary time, some 14, 000 years ago, or possibly even earlier in the mid-Wisconsin nonglacial interval. Recent archaeological studies have confirmed the probable presence of human occupation in Yukon during late-Quaternary time. The late-Quaternary extinction of several mammal species in Yukon is an interesting problem; whether it occurred because of changing palaeoecological conditions or from other causes remains to be explained.

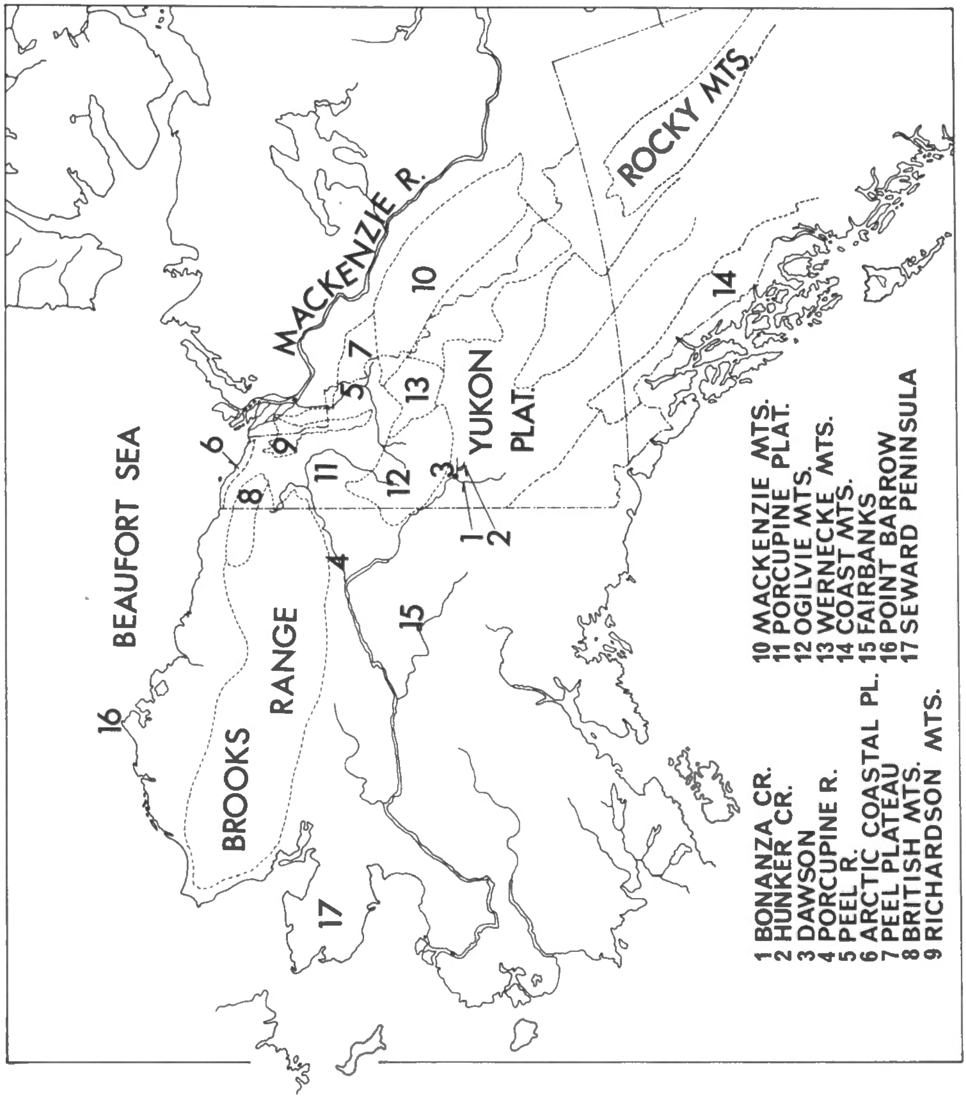

Figure 1. Index map.

NOTES ON QUATERNARY PALAEOECOLOGICAL PROBLEMS IN THE YUKON TERRITORY AND ADJACENT REGIONS.*

INTRODUCTION

The Yukon Territory and the adjacent Mackenzie River lowland in the Northwest Territories to the east have an important position among the prominent problem areas for Quaternary research in Canada. Northern Yukon holds a unique position among other problem areas in that it remained largely unglaciated throughout the Quaternary and served as a refugium for plant and animal life during the glaciations. Recent studies have indicated that it may be possible to establish a chronological and palaeoecological sequence in this region, based on the available fossil record and geological history, that will span most of the Quaternary epoch. These studies have clearly indicated that the problems encountered in Yukon are closely similar to those studied in Alaska, and extend via the postulated Bering Sea land bridge to adjacent northeastern Siberia. It is essential that Quaternary research in this part of northwestern North America should be closely correlated and considered in a regional context, including the areas west of Bering Strait. Such regional studies made in the fields of geology, botany and archaeology, for example, have adequately demonstrated the usefulness of the international approach in these investigations.

The following discussion of palaeoecological problems in Yukon and adjacent regions will attempt to evaluate in a regional context some of the evidence available from different sources bearing on ecology and climatic changes in late-Quaternary time.

Acknowledgments

The author wishes to thank Dr. J.A. Roddick of the Geological Survey of Canada for presenting the original version of this paper at the Tokyo Congress, for valuable discussion and criticism of the geological subject matter of this report, and for Figure 1. Special thanks are due Dr. O.L. Hughes of the Geological Survey of Canada, who for several years has helped this study by making extensive collections of samples and by supplying data on surficial geology of the region; by constructive criticism has helped to focus attention on many important problems related to this investigation.

PHYSIOGRAPHY AND CLIMATE

A comprehensive physiographical description of the Yukon Territory and adjacent areas was published by Bostock (1948), and more

* This paper was presented at the Pacific Palynology Symposium of the Eleventh Pacific Science Congress in Tokyo, 1966. Slight revisions have been made in order to incorporate recent discoveries.

Revised manuscript received June 23, 1967.

recently for northern Yukon (Bostock, 1961). In detail the physiography of this region is very complex, but it can be summarized following Péwé's (1965) physiographic description for Alaska.

Interior Yukon, consisting of intermontaine plateaux, is bordered on the south and southwest (Fig. 1) by high mountains of the Coast Ranges along the Gulf of Alaska coast. The Rocky Mountain System, including the ranges of the Mackenzie Mountains, forms the eastern boundary and the Richardson Mountains and the British Mountains complete the northeastern and northern boundary of Yukon. The Porcupine Plateau of northern interior Yukon is separated from the southern interior Yukon Plateau by the Ogilvie and Wernecke Mountains. The Peel Plateau forms another physiographic region between the Richardson Mountains and the Mackenzie lowland to the east. The physiography of the Mackenzie Delta region has been described in detail by Mackay (1963). The Arctic Coastal Plain, a narrow 10 to 20 mile wide zone, separates the northern Richardson Mountains and British Mountains from the Arctic Ocean.

The interior of the Yukon Territory is cut off from the maritime influence of the Pacific Ocean by the strong barrier of the Coast Ranges. On the east the Mackenzie Mountains comprise a less effective barrier to the winter cold waves from the Northwest Territories. In comparison with the Mackenzie lowland, winters in general are surprisingly mild in the Yukon Territory (Boughner and Thomas, 1960). In spite of the coastal mountain barriers, winters are milder in the southwest than in the interior. The January mean temperatures at Whitehorse are 5°F, but -16°F at Dawson. It is important to note that topography favours extremely low minimum temperatures during arctic cold waves. Snag holds the record for North America; it was -81°F on February 3, 1947. The intense cold periods, however, are commonly brief. The wide temperature variations during winter depend on the predominance of either the modified air from the Pacific or the extremely cold air from the Beaufort Sea. The spring and fall seasons are short in Yukon. The summers are usually relatively warm with mean temperatures above 50°F. The frost-free season, however, is limited and ranges from 21 days to 85 days. Freezing temperatures, nevertheless, have been reported for every month of the year. Mean annual precipitation ranges from 9 to 17 inches at the valley stations. Orographic effects are clearly noticeable in the distribution of precipitation. Winter snowfall averages from 40 inches to more than 80 inches, with heaviest falls in the coastal mountains and the westward slopes of the Mackenzie Mountains where permanent snowfields and glaciers occur.

GLACIAL GEOLOGY

During the early years of exploration it became apparent that some parts of the Yukon Territory lacked any evidence of glaciation and Bostock's studies over many years delineated the limits of glaciation more closely (Bostock, 1948). The coverage of the region by aerial photography has been particularly helpful in the search for geomorphological evidence supporting the assumed extent of unglaciated areas. In recent years the extensive studies of glacial history by O.L. Hughes in Yukon and the adjacent Mackenzie lowland have indicated that a complex and multiple sequence of mountain glaciations has occurred in central Yukon in the Wernecke and Ogilvie Mountains (Vernon and Hughes, 1966). The Laurentide ice-sheet, moving northwestward from central Canada, covered the Mackenzie lowland and extended into the eastern Foothills of the Rocky Mountain System. The complex relationships between the mountain glaciers and the continental ice-sheet require further detailed investigations. Both the stratigraphic and geomorphological evidence indicates that during the build-up and advance of the glaciers some of the existing drainage system was blocked, resulting in ice-dammed lakes in which fine-grained sediments were deposited. The cyclic changes of precipitation and temperature during the Quaternary caused the build-up of complex sequences of alluvial and lacustrine deposits and associated geomorphological features. Permafrost conditions are present throughout the Yukon Territory, with local exceptions associated with rivers and lakes where permafrost is absent or less extensive.

VEGETATION

Extensive forest cover exists in southern Yukon, the Mackenzie lowland, and along the Peel and Porcupine River systems in northern Yukon. Rowe (1959) distinguished four different sections (Dawson, Central Yukon, Eastern Yukon, and Kluane) in the boreal forest of southern Yukon Territory. The exposure such as a south- or north-facing slope, drainage, soils, and permafrost are important factors in limiting forest growth. The main forest tree species are: white spruce (Picea glauca), black spruce (Picea mariana), alpine fir (Abies lasiocarpa), tamarack (Larix laricina), balsam poplar (Populus balsamifera), aspen (Populus tremuloides), and white birch (Betula papyrifera). Lodgepole pine (Pinus contorta var. latifolia) is present in some parts of southern Yukon.

In the northern part of the region, according to Rowe (1959, p. 35), "between the Mackenzie Lowlands and the mountains along the Yukon-Mackenzie boundary, and on the interior Porcupine Plain of northern Yukon, an altitudinal transition takes place from forest to alpine tundra...". On mountain slopes open stands of stunted white spruce alternate with grassy and shrubby vegetation and rock barrens. Alpine fir commonly forms the tree-line at the transition to alpine tundra. Black spruce occurs at lower altitudes. On more favourable sites white birch is found together with white spruce. Tamarack and poplar are infrequent components of the forest vegetation.

In spite of the botanical studies made in Yukon and adjacent regions by Hulten (1941-50), Porsild (1945, 1951a, b, 1955), Wiggins and Thomas (1962), and in recent years by J.A. Calder of the Plant Research Institute, Ottawa, there are many large areas still unexplored botanically. Porsild (1964) stated that in the eastern North American Arctic the high mountains and elevated plateaux are commonly unrewarding for a botanist looking for new or rare plants, and he concluded that any plant refugia during the Quaternary must have been near sea-level. In Yukon, however, the interior plateaux harbour floras richer and more varied than those in the valleys. This apparent contrast can be explained by the known occurrence of Quaternary glaciers and ice-caps in the mountains and on the highlands of eastern Canadian Arctic, whereas in Yukon the mountain glaciers extended down the valleys but left extensive plateau areas ice-free.

DISCUSSION OF PALAEOECOLOGICAL PROBLEMS

Evidence for palaeoecological reconstructions can be obtained from several different disciplines of Quaternary research. The most prominent of these are geology, biology, archaeology, and the various subdivisions of these disciplines such as, glaciology and soil science. However, it must be emphasized that there is no single specialized field of science which will provide fully satisfactory answers to all palaeoecological problems.

The Fossil Record

In 1961 the writer examined plant bearing deposits in the unglaciated area near Dawson. Previous studies by Campbell (1952) had indicated that although a long Quaternary record probably was contained in the surficial deposits, it was not easily recognizable. Geological studies made by Hughes in the following years showed that large discontinuities existed in the stratigraphic sequence. For example, in the river valleys southwest of Dawson, such as Bonanza and Hunker Creeks which were mined for placer gold, the old gravel (White Channel gravels) on bedrock remains undated but probably represents several cycles of deposition and erosion because it is overlain by silt and peat which post-date the last glaciation. Abundant vertebrate fossils of extinct species, such as mastodon, mammoth, horse, and bison occur beneath the silt and peat in a silty gravel unit. Radiocarbon dating has indicated that the peat layer is postglacial; 9520 $\pm$ 130 years (GSC-73) was the age obtained for base of the peat (muck) deposit. An age of more than 35,000 years (I/GSC/-181) indicates that the auriferous gravel (at least some of it) and the vertebrate fossils in the overlying silty gravel unit may belong in the last interglacial.

A similar stratigraphic sequence has been described from the Fairbanks area, Alaska, by Péwé (1958, p. 16-18). The presence of terrace remnants high above the present valley bottoms indicates the occurrence of erosional and depositional cycles, older than the last glaciation. Péwé has suggested that permafrost may have thawed and disappeared during the warm interglacial interval. The slight postglacial warming some 5,000 to 6,000 years ago (the hypsithermal episode) caused only a small amount of permafrost to thaw (Péwé, 1952) and hence the postglacial climate has remained cooler than that of the last interglacial.

The extensive recycling (deposition-erosion) of surficial deposits during the Quaternary makes the extraction of a long and legible fossil record very difficult. Redeposition of fossils is a serious possibility of error in most palaeoecological reconstructions. This difficulty is further aggravated by the almost exclusive occurrence of natural exposures in river valleys where alluvial deposits have been subject to redeposition.

In palynological studies of valley bottom silts, which contain abundant finely divided plant detritus, the poor preservation or absence of pollen has been attributed to the large-scale movement and recycling of this deposit. Well preserved and abundant pollen is found occasionally in this stratigraphic unit and indicates that destruction of pollen has occurred during accumulation of this silt unit which originated when loess was redeposited in the valley bottoms from the adjacent slopes.

Where in situ lake sediments have been studied (Terasmae and Hughes, 1966) the pollen preservation has been good. Coring of peat deposits away from rivers, and on upland surfaces by the use of a motor-powered SIPRE corer (Hughes and Terasmae, 1963) has provided excellent samples for palynological studies.

A study of modern pollen deposition related to the existing vegetation is essential for a satisfactory interpretation of the Quaternary palynological record and the inferred palaeoecological conditions (Livingstone, 1955; Colinvaux, 1967).

During Operation Porcupine, a large-scale geological reconnaissance study carried out in northern Yukon by the Geological Survey of Canada, Hughes described and sampled numerous exposures along the major rivers. The preliminary palynological studies have supported the presence of interglacial deposits in several of these sequences as suggested by Hughes on basis of stratigraphic evidence.

It can be concluded from the studies made that a long Quaternary fossil record, possibly covering all of post-Pliocene time, is present in the Yukon Territory. However, long-term and extensive studies are required to extract and compile this record in sufficient detail for meaningful palaeoecological reconstructions.

Postglacial Climatic Changes

Livingstone concluded from his palynological studies made at sites on the northern slope of the Brooks Range in Alaska (Livingstone, 1955) that "... conditions in tundra regions are not favourable for the registration of even such major climatic phenomena as the postglacial thermal maximum." He found that, "... the most striking thing about all these diagrams is the slightness of the vegetational changes which they reflect by comparison with pollen profiles from temperate latitudes." He came to the conclusion that, "a likely deduction is that climate changes during the late Pleistocene have been much smaller, at least in terms of vegetational consequences, in this part of the arctic than in the temperate zone." Livingstone inferred from the results obtained that the area studied may have been an important refugium during full-glacial conditions.

Colinvaux (1964a and 1964b) concluded from his palynological studies in the Point Barrow and Seward Peninsula regions of northern and western Alaska that although his long Imuruk Lake record showed a glacial-nonglacial succession, as reflected by the vegetational history of alternating types of warm and cold tundra, "... the climate of Seward Peninsula has never been significantly warmer than it is at present (Colinvaux, 1964b, p. 312)". He further concluded that, "this record of the arctic coastal plain tundras of the last 14,000 years implies an uninterrupted succession of cold climates, in which the present inclement weather of the place must be regarded as comparatively mild. The trend over the whole period has been one of warming" (Colinvaux, 1964a, p. 708). In a recent paper, however, Colinvaux (1967) has come to the conclusion that there was, in fact, a significant advance of spruce (Picea) beyond its present limit about 10,000 years ago, and a corresponding climatic warming.

Heusser (1960 and 1965) concluded on the basis of his comprehensive studies in coastal Alaska and the Pacific Northwest, that the palynological record definitely showed significant climatic changes in late-Quaternary and postglacial time. Geological observations, including studies of glaciers, seem to support Heusser's conclusions (Goldthwait, 1966; Borns and Goldthwait, 1966; Denton and Stuiver, 1966). Studies of permafrost by Péwé (1958) have indicated that some thawing of permafrost occurred during mid-postglacial time (the hypsithermal episode). Botanical studies have shown that several species extended their range northward during the hypsithermal interval. Archaeological studies also have indicated the occurrence of rather significant climatic changes during postglacial time in the arctic (Taylor, 1965). Postglacial climatic changes have been inferred from palynological studies by the writer in the Mackenzie lowlands as well as in central Yukon (Mackay and Terasmae, 1963; Terasmae and Hughes, 1966). A rather good correlation appears to be present between pollen diagrams from central Yukon and those published by Livingstone (1955) from the northern Brooks Range in Alaska.

The writer is inclined to suggest that on the basis of available evidence postglacial (and late-Quaternary) climatic changes did occur in the Pacific Northwest (McCulloch and Hopkins, 1966) and were in fact comparable in magnitude and time to those of the temperate latitudes. However, because of the greater environmental tolerance of arctic species in general, climatic changes may be more difficult to detect by palynological means. The necessity and importance of multi-disciplinary investigations in Quaternary palaeoecological studies is clearly brought into focus.

Archaeological Implications

The rather natural relationship between archaeology and palaeoecology rests on the singularly important assumption that no human population however scattered and small can subsist without food and shelter in the form of clothing and some sort of dwelling. Land fauna and flora coexist in a multitude of combinations and are influenced by many environmental factors and hence, palaeoecological discussions play an important role in archaeological studies.

Archaeological studies in Alaska and Yukon have established the presence of a complex, although as yet incomplete, postglacial record (Giddings *in* Péwé *et al.*, 1965; MacNeish, 1959; Taylor, 1965; Campbell, 1962, and Russel, 1960). The central question on a more intercontinental scale in archaeology has been the postulated migration of Indian peoples from Asia to North America. Such a route would have to have crossed the Bering Sea land bridge and thence headed either through interior Yukon and Alaska, or south along the Pacific coast. The archaeological evidence from regions south of the Quaternary glaciations seems to require that this migration must have occurred before the last major ice advance of the Wisconsin glaciation. The available geological and palaeoecological data are insufficient to determine whether this migration could have occurred during the long mid-Wisconsin interval from 20, 000 years to perhaps as much as 50, 000 years ago (Dreimanis, Terasmae and Mackenzie, 1966; van der Hammer *et al.*, 1967). On the other hand it seems probable that in late-glacial time, some 14, 000 to 15, 000 years ago, a possible migration route through interior Yukon and south along the eastern foothills of the Rocky Mountains may have become available (Hughes, personal communication). At that time sea-level was still considerably lower than the present (Jelgersma, 1961) and palaeoecological conditions were probably becoming tolerable for human migration through a postulated corridor between the ice masses remaining in the Canadian Cordillera and the Canadian Shield. Extensive glacial lakes along the western margin of the Laurentide ice-sheet (Craig, 1964) may have been, in fact, helpful for such a migration.

Recent palaeonotological and archaeological investigations by C.R. Harington and W.N. Irving of the National Museum of Canada in the Old Crow Plains area of Yukon Territory have found evidence indicating that man, in fact, may have arrived in North America during or before the last glaciation (Harington and Irving, 1967). In summary they state that, "... we have identified artifacts on mammoth and other bones, from what we believe to be middens dating from before the maximum of the Wisconsin glaciation. The evidence we now have permits estimates of age in the range of more than 20, 000 years." In the same context, a recent report in Science News (13 May, 1967) indicates that evidence of man in association with ice age mammal species, dated as old as 35, 000 or 40, 000 years, has been found from the Valsequillo Gravels, close to the town of Puebla near Mexico City. Munson and Frye (1965) reported a discovery of an artifact from the Roxana loess in west-central Illinois which has been dated at about 35, 000 to 40, 000 years. In spite of some uncertainties about the dating of these artifacts and their association with datable events or deposits there seems to be sufficient evidence to suggest that man probably did arrive in North America much earlier than assumed until recently.

There is an obvious need for integrated geological, archaeological and palaeoecological studies in order to solve these problems.

Geobotanical Problems

The following brief discussion includes problems which overlap into the fields of geology and botany, although they might be primarily concerned with palaeoecology.

As stated by Heusser (1965) the present vegetation patterns of northwestern North America began to develop late in the Tertiary and continued to differentiate during the Quaternary as uplift of the mountains comprising the western Cordillera proceeded. The vegetation has therefore always been dependent on the geological evolution of the region considered. However, more strictly botanical factors have also been active and have influenced the vegetation at the same time (Löve, 1962). The resultant development of vegetation has been complex and in any palaeoecological reconstruction it is important to consider the relative importance of both geological and botanical factors, as indicated, for example, by Beschel's studies in the Eastern Canadian Arctic (Beschel, 1961 and 1963). Sigafoos (1958) has discussed the usefulness of geobotanical studies in the interpretation of geological data from Alaska. The problems of survival of plants on nunataks have been summarized by Gjaerevoll (1963), and Erdtman (1963) has pointed out some important problems relevant to palynological studies and Quaternary ecology.

In his summary on phytogeographical problems of the Pacific Northwest Heusser (1965) has noted that glaciers and especially muskeg delimit the extent of the forest. Muskeg, which includes bogs and fens, is rather extensive in many areas of the region considered in this discussion. In southeastern Alaska, for example, lodgepole pine, because of its inability to compete on the forested upland, grows almost entirely on muskeg. The distribution and depth of permafrost largely determine the type of plant cover (Péwé, 1958; Hopkins and Sigafoos, 1950). Equally as profound as permafrost in its effects upon vegetation is fire (Lutz, 1953). The extent of alluvial lowlands and their stability or instability comprise an important environment for several characteristic types of vegetation. Plant composition and distribution in the arctic tundra (Heusser, 1965, p. 471) are strongly influenced by topography (elevation and exposure), drainage, soil, and permafrost, with the result that a wide variety of local types is encountered over the extremes of wetness and dryness.

In addition to the local and regional factors which are significant to geobotanical discussions in Yukon and Alaska, the probable effects introduced by the assumed existence of the Bering Sea land bridge (Hopkins, 1959) further complicate the issue. For example, white spruce and sitka spruce (Picea sitchensis) produce hybrids where their distribution ranges overlap (Little, 1953), and birch is a taxonomically complicated genus in Alaska and Yukon, and so are the willows (Salix). These problems will be an important consideration in palaeobotanical studies of Quaternary deposits. At present it is not known whether these taxonomical problems have their origin in late-Quaternary time or reflect botanical introductions across the Bering Sea land bridge during earlier Quaternary episodes.

From a palaeoecological point of view it is hoped that further studies will demonstrate the extent and changes in the muskeg, permafrost and alluvial environments during the glacial-nonglacial cycles as such have been caused by climatic changes. The availability of these data will greatly improve the palaeoecological interpretation and reconstructions of the history of vegetation in the Pacific Northwest during the Quaternary epoch and this in turn will also help to eliminate much speculation now inherent in archaeological and palaeoclimatological discussions.

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