"Climatic Conditions in the Western and Northern Cordillera During the Last Glaciation: Paleoecological Evidence"

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CLIMATIC CONDITIONS IN THE WESTERN AND NORTHERN CORDILLERA DURING THE LAST GLACIATION: PALEOECOLOGICAL EVIDENCE

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ABSTRACT In the southern Cordillera, paleoecological evidence suggests that climate was variable, from cooler than present by up to 3°C, to possibly similar to modern during the Olympia non-glacial interval (> 59 το 25-29 ka). The development of open subalpine parkland vegetation in lowlands after 25 ka reflects slow cooling to glacial conditions. Assumptions about continuously cold and dry glacial conditions are tested and disputed. Between 18-19 ka, pollen, plant macrofossil and beetle evidence suggest relatively warm and moist conditions in the Fraser/Puget Lowlands. A tentative correlation can be inferred with the recently defined "Hanging Lake thermal event" around 18-22 ka in the unglaciated Yukon. Further work should be done to test this inference. Paleobotanical data suggest that increasing moisture, rather than increased cooling, was responsible for the late Vashon ice advance in the southwestern Cordillera. The controversy regarding the nature of the vegetation cover in eastern Beringia, north of the main Cordilleran ice sheet, is not yet settled, although evidence to date favours a complex mosaic of tundra and "steppe-tundra" plant communities supporting a greater diversity of grazing large mammals than exist in the area today.

RÉSUMÉ *Les conditions climatiques dans l'ouest et le nord de la Cordillère au cours de la dernière glaciation: les données paléoécologiques.* Dans le sud de la Cordillère, les données paléoécologiques indiquent que le climat était variable au cours de l'intervalle non glaιαιρφ δ]Ολυμπια Δ>ΘΥ — ×Θ[×ΥκαΕϖ πλθσ φροιδ d'environ 3°C que maintenant, il est devenu semblable à celui d'aujourd'hui. Le développement d'une végétation de toundra-parc subalpine dans les basses terres après 25 ka montre qu'il y eut refroidissement lent jusqu'à des températures glaciaires. Les hypothèses selon lesquelles les conditions de froid glaciaire sec ont été continues sont ici éprouvées et contestées. Ainsi, entre 18 et 19 ka, les données palynologiques, les macrofossiles de plantes et les coléoptères montrent que le climat était chaud et humide dans les basses terres de Fraser-Puget. À titre d'essai on fait la corrélation avec l'événement thermique récemment déterminé et appelé « Hanging Lake », survenu vers 18-22 ka dans un Yukon déglacé. Les recherches à venir détermineront si cette corrélation est juste. Les données paléobotaniques montrent que l'avancée glaciaire du Vashon supérieur dépendait davantage d'une augmentation de l'humidité plutôt que d'un refroidissement des températures. La controverse quant à la nature du couvert végétal de la Béringie orientale, à la limite nord de l'Inlandsis de la Cordillère, persiste, même si les indices semblent indiquer la présence d'une mosaïque de communautés appartenant à la toundra et la toundra-steppe dont se nourrissait une plus grande diversité de mammifères herbivores que maintenant.

ZUSAMMENFASSUNG *Klimatische Bedingungen in den westlichen und nördlichen Kordilleren während der letzten Vereisung: paläoökologische Daten.* In den südlichen Kordilleren lassen paläoökologische Deten darauf schließen, daß das Klima variabel war, von bis zu 3°C kälter als gegenwärtig bis zu möglicherweise der Gegenwart ähnlichen Temperaturen während des nichtglazialen Olympia-Intervalls (>59 bis 25-29ka) Die Entwicklung von offener subalpiner Tundra-Park-Vegetation im Tiefland nach 25 kaaspiegelt eine langsame Abkühlung bis zu glazialen Bedingungen. Hypothesen, denen zufolge kalte und trockene glaziale Bedingungen durchgehend vorherrschten, werden geprüft und bestritten. Zwischen 18-19ka weisen Pollen, Pflanzen-Makrofossile und Käferbelege auf relativ warme und feuchte Bedingungen im Fraser/Puget-Tiefland. Versuchsweise kann man eine Korrelation mit dem kürzlich näher bestimmten thermischen Ereignis von "Hanging Lake" um 18-22 ka im nichtvereisten Yukon herstellen. Weitere Arbeit sollte geleistet werden, um diese Korrelation zu überprüfen. Paläobotanische Daten lassen glauben, daß eher zunehmende Feuchtigkeit als innere Abkühlung für den späten Vashon-Vorstoß im südwestlichen Bereich der Eisdecke verantwortlich war. Es besteht weiter eine kontroverse über die Natur der Vegetation im östlichen Beringia nördlich der Haupt-Kordilleren-Eisdecke, wenn auch Belege auf ein komplexes Mosaik von Tundra und "Steppentundra"-Einheiten hinweisen, welche eine größere Vielfalt von grasfressenden Säugetieren ernährten, als heute in diesem Gebiet vorhanden sind.

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INTRODUCTION

The Cordillera of western North America is a region of great physiographic, geological, climatological, and biological complexity. This diversity of present environments is also apparent in the past, thus providing both a challenge to earth scientists trying to reconstruct paleoenvironments, as well as unique opportunities to better understand the past influences of glacial and climatic events. Our understanding of late Pleistocene paleoenvironments in this region has grown substantially during the 1980's, as shown by a series of literature reviews and summaries (Hopkins *et al.*, 1982; Ager, 1983; Heusser, 1983, 1985; Ritchie, 1984; Ager and Brubaker, 1985; Mathewes, 1985; Mehringer, 1985; Barnosky *et al.*, 1987; Ritchie, 1987; Clague and MacDonald, 1989). The data base in the west is, however, still sparse compared to eastern North America and Europe, and many details of vegetation and climatic change remain to be worked out. As stated by Ritchie (1987, p. 137) in his summary of late glacial and Holocene climate in Canada: "I am unable to suggest similar reconstructions for the Pacific-Cordilleran area because of the complexity of the area and its very spotty fossil record." The data base has of course grown since Ritchie's book was written, but the preliminary nature of the paleoclimatic reconstructions that have been made is still very apparent.

The purpose of this paper is not to update and review again all the available paleoecological data for the region once occupied by the Cordilleran Ice Sheet. I will focus particularly on the Pacific-Cordilleran area and on the unglaciated Yukon/Alaska region, where controversies and apparent anomalies have arisen about interpretations of past vegetation or climate.

It is important here to remember that fossils such as pollen and spores, invertebrates, or vertebrates provide information primarily about past biotic populations and communities, and only secondarily about climate, based on modern analogies. Although climate plays a dominant role in controlling broad-scale vegetation patterns, many other factors must also be considered in trying to interpret a pollen diagram. These may include delayed immigration of plants from glacial refugia, soil development, fire history, or pathogen outbreaks (Ritchie, 1987). In practice, however, climatic changes are usually given overriding importance, since they influence vegetation directly, and since the other factors above may also be indirectly influenced by prevailing climate.

Figure 1 is a generalized view of the Cordilleran Ice Sheet at its last maximum position, and the ice-free areas to the north (Beringia) and to the south. Discussions in this paper are focussed on the two areas indicated — the coastal strip from the Fraser/Puget Lowland north to the Queen Charlotte Islands, and unglaciated eastern Beringia, north of the main Cordilleran ice mass. Prior to these discussions, however, and overview of paleoenvironmental conditions during the Middle Wisconsinan non-glacial interval is appropriate.

MIDDLE WISCONSINAN CLIMATE

The late Pleistocene Fraser Glaciation in British Columbia is preceded by a major non-glacial interval (Olympia) that is more than 59 ka old, and persisted until the beginning of glacial conditions between 29-25 ka (Ryder and Clague, 1989). On Graham Island in the Queen Charlottes, Warner *et al.* (1984) describe an outwash gravel deposited after 27.5 ka, suggesting glacial conditions in the mountains at this time. The vegetation patterns and climatic changes during early glaciation are not well-documented, but available evidence suggests a range of conditions from significantly cooler than today to possibly as warm as present. Forests were predominant in lowlands and montane valleys, while glaciers were restricted to mountain areas (Clague and Ryder, 1989).

Evidence of forest cover comes mainly from fossil wood and pollen records. On southern Vancouver Island, Alley (1979) suggested climatic conditions similar to present for most of the Olympia interval. Near Vancouver, open, possibly tundra-like vegetation gave way to forest before 48 ka at the Lynn Canyon locality of Hebda *et al.* (1983), suggesting cold Early Wisconsinan conditions that ameliorated to allow forest to develop. Forests with western hemlock and a beetle fauna similar to the present around 38-42 ka led the authors to argue for maximum warmth at this time, probably only slightly cooler than today. Herb-rich vegetation after 33 ka suggests a cooling trend leading up to glacial conditions. By contrast, long pollen records from unglaciated parts of the Olympic Peninsula (Ho-Kalaloch sites) were used by Heusser *et al.* (1980) to reconstruct paleoclimates using transfer functions. Their results suggest relatively warm and wet intervals at > 47 ka and again around 30 ka, with intervening cooler conditions (Heusser, 1985). The differences in these two records are fairly typical of other comparisons that have so far left us without a consistent picture of Middle Wisconsinan environments on the south coast. On the Queen Charlotte Islands, conditions between 45.7 and 27.5 ka were cooler than present (Warner *et al.*, 1984) with higher pollen frequencies of mountain hemlock (*Tsuga mertensiana*) and the presence of a now locally extinct species of true fir (*Abies*).

Similar discrepancies occur in interior records. Early paleoecological studies on Bessette Sediments in south-central British Columbia tended to suggest that climate during the Olympia non-glacial interval was not significantly different from present conditions (Clague, 1981). Alley *et al.*'s (1986) new studies of Bessette Sediments at Meadow Creek suggest a climate about 3° C cooler than today at 42 ka, based on abundant spruce pollen, followed by a warming to close to modern conditions around 34 ka. Recent palynological studies at Bullion Pit in central British Columbia reveal high spruce pollen values between 46-40 ka, also suggesting colder conditions at this time (Clague *et al.* 1990).

There are many problems that hinder Middle Wisconsinan paleoclimatic interpretations, and these will only be solved by more, and more comprehensive studies. Few exposures, often with questionable radiocarbon ages near or greater than the dating limit, and sub-optimal fossil deposition and preservation conditions are typical. Nevertheless, the available data suggest a generally colder (up to 3° C) Middle Wisconsinan climate, with evidence of occasional warming to conditions approaching those of today.

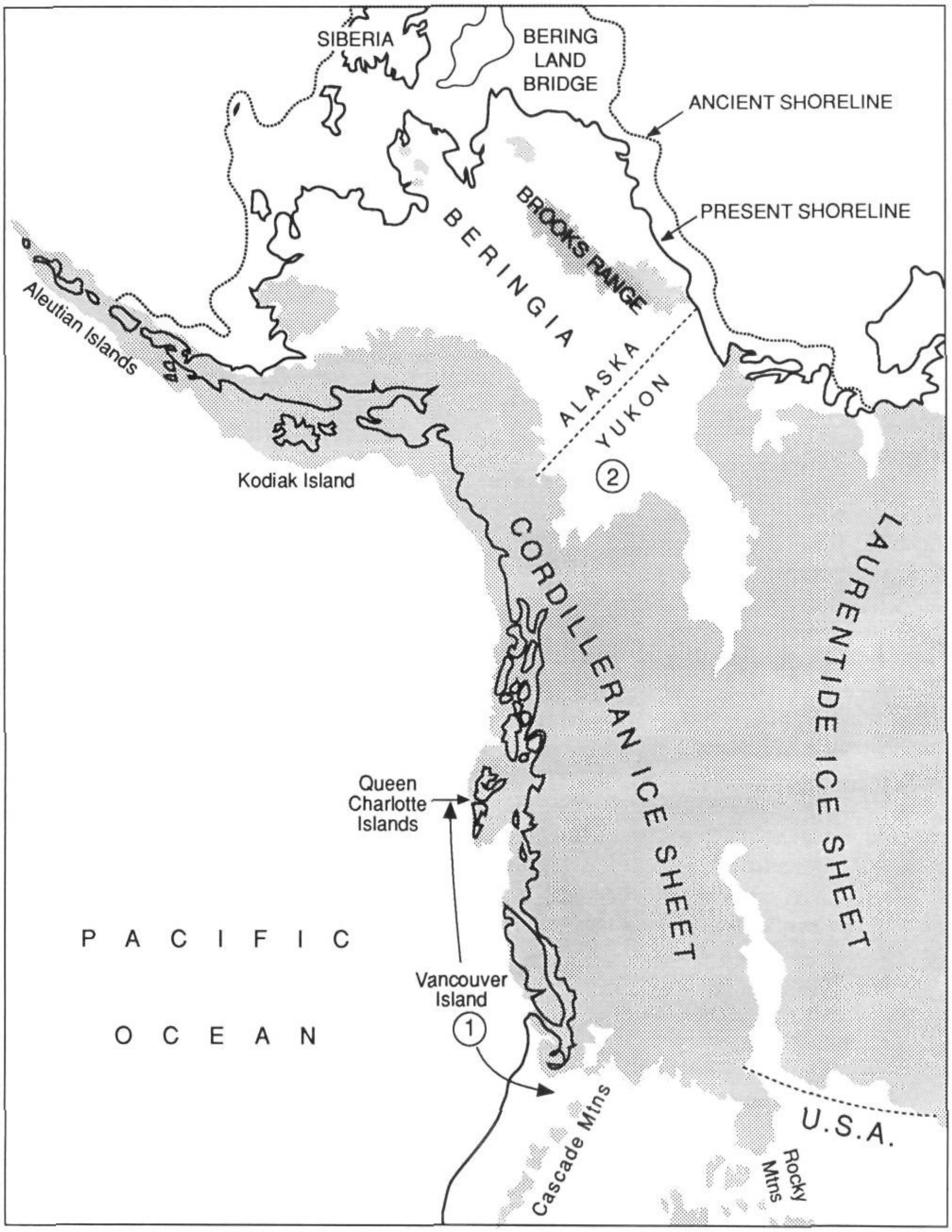

FIGURE 1. Generalized map of the Cordilleran Ice Sheet and unglaciated areas of eastern Beringia (Alaska/Yukon) to the north, and the northwestern United States in the south. Numbered circles identify discussed regions. No. 1 refers to the coastal strip from the Fraser/Puget Lowlands to the Queen Charlotte Islands, and no. 2 is easternmost Beringia (adapted from Harris and Matthews, 1987).

Carte généralisée de l'Inlandsis de la Cordillère et des régions non englacées de l'est de la Béringie (Alaska et Yukon), au nord, et du nord-ouest des États-Unis, au sud. Le n° 1 identifie la côte à partir des basses terres de Fraser-Puget jusqu'à l'archipel de la Reine-Charlotte et le n° 2 montre la Béringie extrême-orientale (adapté de Harris et Matthews, 1987).

PACIFIC NORTHWEST COAST (Fig. 1, area 1)

The transition from the Olympia non-glacial interval to early Fraser (Wisconsin) Glaciation was apparently gradual on the coast, beginning about 29 ka and continuing until the Coquitlam (Evans Creek) Stade of alpine glaciation between 21.5 and 18.5 ka (Hicock and Armstrong, 1981). Lowland vegetation near Vancouver appears to have been open coniferous parkland with abundant subalpine indicator herbs such as *Bistorta, Polemonium*, and *Valeriana sitchensis* recovered from Quadra Sand dated at 24.5 ka (Mathewes, 1979). It is interesting that evidence of totally treeless tundra conditions is lacking for this area. Instead, open subalpine parkland seems to have been the predominant vegetation type until about 20-17 ka in south-coastal British Columbia, the Puget Trough and Olympic Peninsula (Barnosky *et al.*, 1987). The presence of xerophytic plants like *Artemisia* and the subalpine *Picea* cf. *P. engelmanii* implies cold and dry conditions in the southern Puget Trough at this time (Barnosky, 1984, 1985), in keeping with the general view of a cold-dry glacial maximum around 18 ka (CLIMAP, 1976).

How cold and dry was the climate during this early Fraser phase of glaciation? Based on pollen records and radiocarbon dated wood between 21.7 and 18 ka (Clague *et al.*, 1980; Hicock and Armstrong, 1981), trees were always present in the proximity of lowland glaciers. As expected, the common genera were true fir (*Abies*) and spruce (*Picea*) but usually without species identifications, except when needles or cones are also recovered, which generally confirm subalpine species. It is thus surprising and significant that wood of red cedar (*Thuja plicata*) dated at 21,500 ± 240 BP (GSC-2536) was buried in lodgement till of the Coquitlam ice advance (Hicock and Armstrong, 1981). Red cedar is a temperate mesophytic tree that does not thrive in very cold and dry environments (Klinka *et al*., 1989). The presence of western yew (*Taxus brevifolia*) at Mary Hill and Port Moody, near Vancouver, with abundant shoots and needles of this species at 18.3-18.7 ka is another surprise. Yew is also not a species of dry habitats, but grows best in humid coastal sites, and also up to subalpine elevations in the Cordillera (Hicock *et al*., 1982; Klinka *et al*., 1989). It is classified as a species characteristic of temperate and mesothermal coniferous forests (Klinka *et al*., 1989). Hicock *et al*. (1982) also report very abundant macrofossils of the moss *Isothecium stoloniferum* at Port Moody, associated with yew, true fir, and spruce. This moss, like yew, is a shade-tolerant species of mesothermal forests, submontane to subalpine, and is uncommon in the interior Cordillera (Klinka *et al*., 1989). It is recorded commonly in postglacial sediments of Marion Lake (Mathewes, 1973) near Vancouver, where it is to be expected in the coastal western hemlock zone, but its occurrence at 18-19 ka is surprising. Another anomaly is apparent in both pollen percentage and influx diagrams at Battle Ground Lake in the southern Puget Trough (Barnosky, 1985, Fig. 4), well south of the maximum ice limit, where a brief but significant peak of western hemlock pollen is recorded at 19 ka. The earliest pollen evidence for a warm interval during this time was published by Heusser (1972) from the long section near Kalaloch on the Olympic Peninsula. His pollen diagram shows dramatic peaks of spruce and western hemlock pollen in zone I-8, dated at 18.1 ka. Subsequent reconstructions of temperature and annual precipitation from this data set (Heusser *et al*. (1980) show prominent peaks both in mean July temperature and precipitation at this time. These indicators of humidity and relatively temperate climate have been largely ignored to date, perhaps by assuming that they must represent local microhabitats rather than regional vegetation and climate. Fossil beetles are also interesting at Port Moody (18.3-18.7 ka), representing an assemblage of bark beetles and ground beetles typical of coniferous forest litter (Miller *et al*., 1985). The authors suggest a wooded environment with both standing and flowing water nearby. Based on these data, the case for a glacially cold and arid climate at the southwestern edge of the Cordillera is not conclusive for the interval between *ca*. 18-19 ka, which might in fact represent the early part of an unnamed interstade prior to the late Fraser (Vashon) maximum (see Barnosky, 1984, 1985).

GLACIAL MAXIMUM AND EARLY DEGLACIATION

The greatest extent of the Cordilleran Ice Sheet occurred "late" by global standards, certainly after 17 ka when Barnosky (1984) suggests a more maritime influence became apparent in the Puget Trough, based on Douglas-fir and Sitka spruce macrofossils, and increasing lodgepole pine pollen. Similarly, warming is suggested on the Olympic Peninsula to the west, where lowland forest replaced open herb-dominated vegetation around 16.8 ka (Heusser, 1978; Barnosky *et al*., 1987). This warming trend (presumably during the growing season) based on plant remains is reinforced by the preliminary interpretation of Nelson and Coope (1982) of a diverse insect fauna at Fort Lawton, near Seattle, dated at about 16.6 ka. They conclude from the present distribution of beetles found at this site that summer temperatures were likely similar to those of the present (*ca*. 18° C in July)! Several fossil beetles now found in open and dry habitats suggest that inadequate moisture, rather than cold temperatures was most important in controlling their distributions. These data have not been published in detail, but if the single date is confirmed, the Vashon glacial advance is unlikely to have begun before 16.6 ka.

More recently, radiocarbon dates from spruce and unidentified wood in the Chilliwack Valley of southwestern British Columbia (Clague *et al*., 1988), well within the maximum glacial limit, indicate ice free conditions as late as 16 ka. It thus appears that trees and temperate beetles inhabited lowland areas at a time when glaciers were already advancing elsewhere (Clague, 1981). It is likely that the maximum buildup of ice in the Fraser/Puget Lowland region occurred rapidly between 16 ka and the peak of glaciation around 14.5 ka. Paleoecological evidence does not indicate significant cooling at this time, although there is good evidence of more effective moisture than before, based on increasing pollen of mountain hemlock and spruce near the southern ice margin (Heusser, 1985; Barnosky, 1985). The fossil data thus support a hypothesis of increasing wetness, probably mostly in winter, during late Vashon time (Hicock *et al*., 1982).

Paleobotanical evidence suggests that trees were always present at the southwestern margin of the Cordilleran ice during the Fraser Glaciation, either as forest or as open subalpine parkland. The proximity of ice and forests with trees such as mountain hemlock, lodgepole pine, and species of spruce, true fir, and alder, set the scene for rapid recolonization of deglaciated terrain by woody plants. This explains the absence or restricted extent of a treeless tundra phase in the Pacific Northwest, in contrast to many other parts of North America.

GLACIAL REFUGIA ON THE NORTHWEST COAST

The presence of ice-free areas to the north and south of the Cordilleran Ice Sheet at its maximum has long been known. On the other hand, the possibility of smaller ice-free or periglacial biotic refugia during glacial maxima has long engendered great interest and controversy, particularly on islands such as Kodiak, the Queen Charlotte, and Vancouver Island (Heusser, 1960; Karlstrom and Ball, 1969; Fladmark, 1975; Warner *et al*., 1982; Heusser, 1989; Mathewes, 1989 a,b; Hebda, 1984). Biologists are fascinated by the evidence of endemic species and subspecies on the coast, and hypothesize frequently about long periods of isolation and ice-free conditions to account for the evolutionary novelties. Heusser (1989) recently reviewed the evidence for coastal refugia, and argues that good cases for their existence can be made, particularly for the Queen Charlotte Islands and parts of coastal Alaska. It is now clear that deglaciation on the central coastal shelf was underway before 15 ka, before Vashon glaciers on the south coast had reached their maximum extent (Blaise *et al*., 1990). Continuously ice-free conditions on part of eastern Graham Island of the Queen Charlotte archipelago were demonstrated by Warner *et al*. (1982) who describe a terrestrial postglacial flora beginning as early as 16-15.4 ka. It is important to remember that conclusive evidence, such as primary fossils and radiocarbon dates spanning the whole of Cordilleran Ice Sheet time, has not yet been published for any site on the coast to establish a *continuous* glacial refugium throughout the Fraser Glaciation.

The above data of early deglaciation on the central coast also bear on paleoclimatic inferences for the climactic Vashon ice advance in the south that ended around 14.5 ka. Since glaciers were already in retreat before 15 ka, it seems unlikely that macroclimatic cooling contributed significantly to this final ice advance. It seems more probable, therefore, that moisture increases were primarily responsible, or that glacial surging, perhaps due to warming, precipitated the final advance that produced the Puget ice lobe.

EASTERN BERINGIA (Fig. 1, area 2)

Various interesting controversies have arisen during the past two decades regarding interpretations of paleoenvironments and biotas in the ice-free regions of the Yukon/Alaska region during the last glacial and interglacial periods. These range from interpretations regarding the earliest evidence of human occupation in the Old Crow basin of the Yukon (Morlan, 1986; Bobrowsky *et al*., 1990) to arguments over the diversity, abundance, and contemporaneity of mammals such as mammoth, horse, and bison recovered from gravels and silty mucks during and after the Klondike gold rush (Ritchie, 1984; Harington, 1989). Intimately associated with reconstructing glacial and interglacial mammalian communities, is the problem of vegetation reconstruction during the last interglacial (Boutellier interval), and particularly during the Duvanny Yar glacial interval (Late Wisconsinan, *ca*. 25-14 ka). The ongoing debate centers on the question of whether or not the Beringian plant cover during Duvanny Yar time was significantly different from any extant tundra — in particular if it was more steppe-like, with more grasses, and more productive for grazing mammals than present-day tundra. The suggestion of a late Pleistocene grass-rich environment, variously called "mammoth-steppe", "arctic steppe", or "steppe-tundra" (Matthews, 1982; Guthrie, 1985, 1990) in the unglaciated north has been attacked primarily by palynologists (Cwynar and Ritchie, 1980; Colinvaux, 1980, 1986; Ritchie and Cwynar, 1982; Ritchie, 1984). For example, Ritchie and Cwynar (1982) concluded from analyses of two lake cores in the Yukon that the uplands of northeastern Beringia were an unproductive, sparse alpine tundra or fell-field, based on low pollen influx rates (*ca.* 100 grains /cm^2/yr or less). Such low values for pollen accumulation produced the concept of the "productivity paradox" — how can large numbers and many species of large herbivores be reconciled with the pollen evidence of unproductive tundra during glacial time?

Supporters have argued instead that pollen spectra with abundant grass, sedge, and *Artemisia* pollen during the "Herb Zone" suggest the presence of significant areas of xeric steppe-like plant cover rather than true tundra, since no modern analogue is known to exist which matches the high sage (*Artemisia*) values. Proponents have also used evidence other than pollen and spores to argue for greater grass dominance in the past, such as grazing adaptations in large mammals recovered as fossils from Duvanny Yar time (such as horse, mammoth, and bison), modern steppe or grassland affinities of mammals such as badger, ferret, and saiga antelope, and fossil beetles and seeds of plants not found in modern tundras (Guthrie, 1982, 1985, 1990; Matthews, 1982).

There is an awareness that late glacial biotic communities are generally difficult to match with any modern analogues; they generally appear to be a mixture of discordant biogeographic and ecological elements. This generality applies to the paleoecology of Beringia in particular, where the mixture of vertebrates, invertebrates, and plants reflects a complexity of environments that no longer exist in the same form. The cold, dry glacial climate, coupled with evidence of widespread and intense aeolian activity, in winter as well as summer (Hopkins, 1982), was perhaps the most important environmental difference between today and the last glaciation. It would be surprising indeed if such conditions of cold, drought, and wind did not profoundly affect the distribution and abundance of plants and animals, and create communities different from those of today. As suggested by Schweger (1982), the vegetation of glacial Beringia may have been a complex mosaic, reflecting the physiographic, edaphic, biotic, and climatic variations in the area. This mosaic view, combining patches and strips of communities similar to present tundra with other areas of more steppe-like aspect, probably on loess-rich areas, seems to be a reasonable interpretation of glacial conditions. Recent palynological work in Alaska, south of the Brooks Range (Fig. 1) has shed new light on these speculations. Anderson (1985) analyzed two cores (Kaiyak and Squirrel Lakes) that produced interpretations very different from those of Ritchie and Cwynar (1982). Pollen accumulation rates were higher than those from the Yukon at the time of the Herb Zone, high enough to parallel accumulation rates in recent shrub tundra. Together with pollen of mesic indicator species, she inferred that vegetation of river valleys included mesic meadows that appear to be much more productive than sparser upland vegetation. Anderson's pollen data, in conjunction with data from other areas, supported a mosaic model of vegetation, with lowland meadows of restricted extent, surrounded by more xeric tundras of mid-elevations. The high-elevation barrens or fell fields suggested by Ritchie and Cwynar (1982) were also considered to be limited in extent by Anderson. More recently, Anderson (1988) has modified this view somewhat, suggesting that the arctic "meadows" may actually be more similar to mid-Arctic tundra, based on "adjusted modern pollen percentages" from Banks Island. She does conclude from further studies that mesic tundra was more common in northwestern Alaska than in north-eastern Beringia, and that graminoid-dominated tundra characterized the vegetation cover in valleys *ca*. 18.5-13.5 ka. Another recent study (Eisner and Colinvaux, 1990) from north of the Brooks Range in Alaska shed further light on upland vegetation during the Herb Zone. At Ahaliorak Lake, vegetation cover remained significant throughout the glacial interval, and the authors go on to largely exclude the possibility of widespread polar desert as a common vegetation cover type. Previous suggestions of aridity as a major climatic feature of Beringia during the Herb Zone are confirmed by Eisner and Colinvaux (1990), partly due to charcoal counts from their lake core, which suggest frequent fires. They also reconfirm the non-analogue nature of Herb Zone vegetation (p. 47), since... "modern upland spectra do not show a dominance of grass over sedge, nor high levels of *Artemisia* (Ritchie *et al*., 1987)". How different does the plant cover need to be to qualify for a new name, different from modern analogues? This is a subjective matter, but Ritchie (1984) provides some thoughts on the touchy topic of "steppe-tundra". He argues (1984, p. 165) that "...any paleoenvironmental reconstruction of a herb-tundra assemblage should not invoke a steppe concept that is equivalent to grassland in North American usage, unless there is strong supporting evidence of grassland elements in the paleobotanical record". He also states that the "steppe-tundra" as used by Russian ecologists may be appropriate for some modern plant communities, as long as they are used to describe azonal communities on well-drained slopes.

The recent report of needlegrass (*Stipa* sp.) remains in a fossil ground squirrel nest appears to be the first evidence of the kind that Ritchie specified (Bombin, 1984, cited in Guthrie, 1990). This prairie and steppe genus establishes an affinity with present-day grasslands and Beringia around 18,230 ± 410 BP (QC-668), in the middle of Duvanny Yar time. If this data is confirmed, the concept of "steppe-tundra" as a vegetation type in its own right may be validated. The areal extent of such vegetation in Beringia, and its association with mammalian faunas will need to be more intensively investigated.

Ritchie (1984) summarized climatic conditions in the Yukon, based largely on paleoecological evidence. He interprets the climate of ice-free uplands and valleys during the last glacial as much colder and drier than at present, similar to modern mid-Arctic environments on Banks or Victoria Islands. Slow warming occurred between 15-12 ka, followed by rapid warming, and peaking with conditions warmer than present by 10-11 ka (mean July temp. 3-5° C higher).

HANGING LAKE THERMAL EVENT AND A POSSIBLE CORRELATION

At Hanging Lake in the northern Yukon, Cwynar (1982) recognized a possible warm interval that has been postulated also for other sites, based on increases in pine, alder, and birch pollen as well as other evidence. Matthews *et al.* (1989) have summarized the evidence so far, and propose the existence of the "Hanging Lake Thermal Event" at 18-22 ka. In my earlier discussion of the Pacific Northwest region of the Cordilllera, I proposed that relatively warm and moist conditions prevailed there (compared to cold and arid previous concepts) between 18-19 ka near Vancouver, based on evidence from the Port Moody site, the Olympic Peninsula, and from Battle Ground Lake in the Puget Trough. Since this temperate period occurs within a generally glacial period, it might be considered a brief interstadial. Such tentative correlations are usually made in the hope that further research will be done to test these hypotheses. It is important to describe such large-scale patterns, if they exist, since at their source will likely be macroscale climatic events, such as regional shifts in mean air mass positions.

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