Beringia Paleoenvironments Workshop

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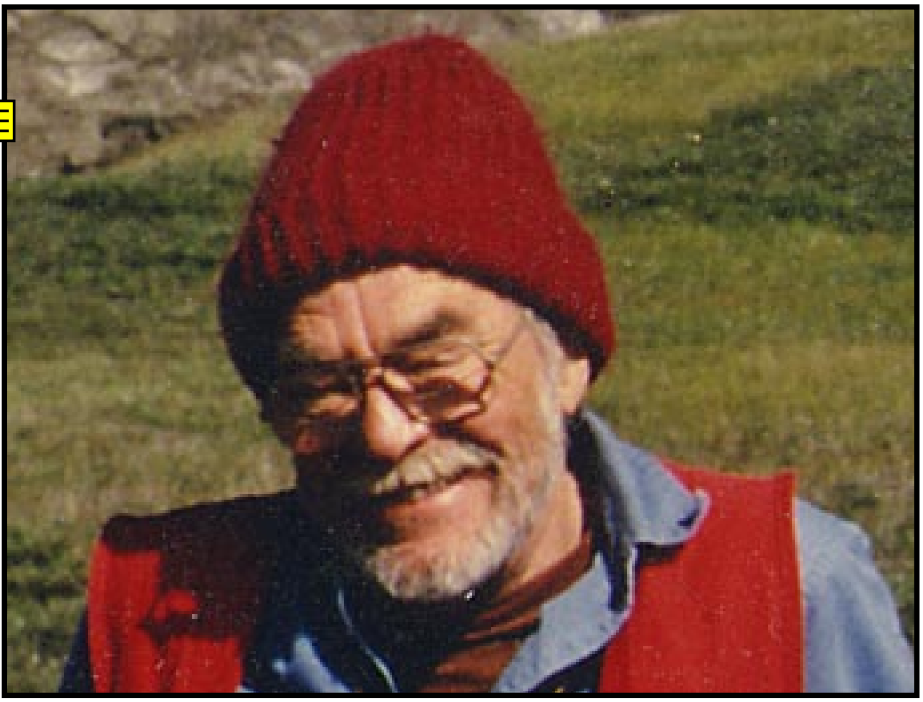

David M. Hopkins, North Slope of Alaska, 1989

workshop participants

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THE ARCHAEOLOGY OF LIME HILLS CAVE, SOUTHWESTERN ALASKA: A MULTIDISCIPLINARY APPROACH

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Excavation of seventeen 1 x 1 meter units in 1993 and 1995 provided an extensive sample of organic and lithic artifacts, cave sediments, pollen, and plant and animal remains. The early cave occupation is reflected by a date cluster of 38,000-27,000 (horse, mammoth and bison) and a second date cluster of 15-13,000 BP (caribou). The third date group of 9500-8400 BP is associated with clear evidence for a human presence in the cave. Following this occupation, there is one isolated date at 3780 BP and a late cluster of dates (500-200 BP). The artifacts from the 9500-8400 BP interval include side-slotted antler arrowheads, a side-slotted antler spearhead and medial microblade segments as insert blades. While we can point to these date clusters and occupation intervals with some confidence, there are temporal gaps which undoubtedly indicate stratigraphic discontinuities, and in some squares there are notable dating anomalies due to cryogenesis. The potential for mixing is also evident by the presence of rodent bones throughout all levels of the cave and bear teeth at the cave entrance. Thus far our analysis indicated that there is clear evident for a human presence at 9500-8400 BP or perhaps a bit earlier. Following this interval, the evidence of human occupation is less clear probably due to bioturbation of the upper levels and the apparent distribution of near surface charcoal throughout the uppermost levels of the cave deposit. Recovery of a non-slotted antler arrowhead type does indicate a later cave occupation. While the radiometric dates thus far suggest stratigraphic discontinuities, plant macrofossils (Mastrogiuseppe) and pollen (Ruter) suggest a gradual transition from a late Pleistocene steppe/herb zone through a shrub zone followed by the appearance of spruce. The faunal data (Georgina) is more discontinuous with a sharp break between the Pleistocene fauna and that which continue into the Holocene. Onset of forest conditions is reflected by the appearance of beaver, pine martin and red fox.

From the data recovered, it is evident that the hunters who stopped over at the cave utilized bow and arrows, and spears which were edged with microblade insets (cf. Paleoarctic tradition) and who hunted caribou and other game during a period when the landscape was still covered with heath/shrub vegetation. Occupation of the cave prior to and following the 9500-8400 BP cultural interval requires further study and is the subject of continuing research.

THE HISTORY OF LATE TERTIARY FLORAS AND VEGETATION CHANGE IN BERINGIA BASED ON THE FOSSIL RECORDS OF NORTHWESTERN CANADA, ALASKA, AND NORTHEASTERN ASIA

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The present-day vegetation of Beringia consists of lowland tundra, alpine tundra, shrub communities, and boreal forest/taiga. The taxonomic composition of the modern forests of east Beringia (Alaska and NW Canada) and west Beringia (in NE Asia) differ markedly at the species level (e.g., Picea glauca*,* P. mariana*, Larix laricina, Betula papyrifera, Populus balsamifera, P. tremuloides* in east, *Larix dahurica, Pinus pumila, Betula middendorfii, Chosenia, Populus tremula,* in west). How long have these forests been separated? When did the modern Beringian floras and vegetation types develop, and from what were they derived? What was Beringian vegetation like prior to the onset of Pleistocene glacial climates? What other events caused earlier changes in Beringian vegetation? Answers to these and other challenging questions about this fascinating region are emerging from ongoing studies of the fossil record of plants from numerous localities across Beringia.

The fossil evidence shows that the modern forest flora of Beringia is a small remnant of far more diverse ancestral forests that existed in the region during the Tertiary. Most species of Beringia's modern trees and shrubs are descendants of taxa that first appeared in the region during the Paleocene or Eocene. Spore-producing plants now found in Beringia have even longer ancestral histories in the region. Herbaceous families and genera that compose modern tundra and forest understory communities of Beringia have much shorter fossil records, because they evolved more recently than most trees and shrubs. Most herb taxa first appeared in Beringia during the Miocene, Pliocene, or Pleistocene. Studies of the floral history of Beringia during the late Cenozoic are not only useful for understanding the origins of modern high northern latitude vegetation, but also provide insights into ecologic responses of various genera to a variety of climatic and environmental changes. The records of fossil floras through time are also of great biostratigraphic value and have practical applications in regional correlation and mapping.

The late Cenozoic fossil record of Beringian plants is not as well known as in many more accessible regions of the world, in spite of several decades of research by paleobotanists and palynologists from Russia, USA, and Canada. Although many gaps remain in the fossil records of Beringia, the emerging floral history is becoming increasingly detailed. Improvements in age estimates of fossil-bearing deposits in the region by means of isotopic methods, fission-track dating, and magnetostratigraphy have greatly facilitated interpretation of the regional histories, and allow correlation and comparision of widely separated fossil assemblages.

The great changes seen in the history of floras of Beringia during the Miocene and Pliocene are the result of multiple influences (e.g., varying orbital parameters of Earth; changes in large-scale oceanic circulation; the rise of the Tibetan Plateau, and the rise of high mountain ranges in southern Alaska and NW Canada). During nearly all of the Cenozoic, land connections of varying extent existed between NE Asia and Alaska. These long-persisting land connections permitted essentially continuous exchange of plants and animals between the American and Eurasian continents for millions of years. The flooding of the Bering Strait by marine waters about 4 to 3 Ma created a significant obstacle to biotic migration. This geographic change, along with subsequent cooling climates, substantially limited exchange of terrestrial forest plants between NE Asia and NW North America during the late Pliocene and Quaternary.

During the early Miocene (24-16 Ma), Beringian forests may have been a mixture of broadleaf deciduous and coniferous taxa, but the record of leaf fossils suggest there were largely separate lowland broadleaf communities and upland conifer forests. Beringian fossil assemblages of probable early early Miocene age (24-18 Ma) include such taxa as *Metasequoia, Pinus, Picea, Larix,* Cupressaceae, *Ulmus, Quercus, Cocculus, Cladrastis, Carya, Nyssa, Populus,* and *Alnus.* Estimated mean annual temperature (MAT) in central eastern Beringia at this time was probably ca. 7°C, compared with modern MAT in that region in the range of -3° to -8° C.

During the late early Miocene, beginning about 17.5 Ma, the largest magnitude global warming event of the past 26 Ma or more began. The causes of this warming event are uncertain, but one possible cause is greenhouse warming of the Earth from massive eruptions of basaltic lava that formed the Columbia plateau during the late early to middle Miocene. The influence of this warming event was felt worldwide in both oceanic and terrestrial realms. Taxonomically diverse broadleaf deciduous forest communities spread over the lowland landscapes of Beringia, spreading northward well north of the Arctic Circle. Conifers appear to have dominated upland, coastal and northernmost habitats. The taxa present across Beringia were part of a temperate flora that occupied much of the land areas adjacent to the North Pacific from northern China and Japan to the Pacific Northwest of the U.S. Many of the tree and shrub genera that occurred in Beringia during this warming event now grow in China, Korea, northern Japan, the Pacific Northwest and eastern North America. Tree and shrub taxa common in Beringia during this warm interval include *Carya, Quercus, Acer, Juglans, Pterocarya, Ulmus, Zelkova, Fagus, Liquidambar, Cercidophyllum, Alangium, Tilia, Castanea, Castanopsis, Betula, Myrica, Alnus, Salix,* Ericaeae, *Ilex, Sequoia, Metasequoia, Taxodium, Picea, Pinus, Larix, Thuja,* and *Ginkgo.* Climatic estimates, based upon temperature requirements of modern representatives of the Beringian flora from this time interval, suggest MAT's in the range of 12° to 7° C for southern to northern Beringia, respectively. Fossil floristic data suggest that precipitation during the growing season was substantially higher (ca. 3x) than modern precipitation in interior Beringia.

Global cooling began during the middle Miocene, soon after 15 Ma, marking the beginning of a long interval of middle Miocene to late Miocene temperature decline, interrupted by several warm temperature oscillations. The cooling trend was manifested by both declining winter and summer temperatures, but the decline in summer temperatures was more dramatic. This resulted in a rapid elimination of many broadleaf taxa from Beringian forests. Fossil evidence shows the persistence of some "temperate" broadleaf taxa such as *Pterocarya, Ulmus, Carpinus* and *Ilex.* Some of the most cold-adapted broadleaf tree and shrub genera were evolving rapidly at this time, however, and were able to adapt to the progressively cooling regional climates (e.g., *Salix, Populus, Betula, Alnus,* Ericaceae). The decline in temperatures favored expansion of conifer forests at the expense of the remnants of northern hardwood forests during late middle Miocene to early late Miocene.

Late Miocene forests of Beringia included *Pinus, Picea, Larix, Abies, Pseudotsuga, Tsuga, Glyptostrobus, Metasequoia, Betula, Corylus, Alnus, Myrica, Populus, Salix,* and Ericales. Continued cooling during the late Miocene eliminated *Metasequoia* from the forest flora by ca. 10 Ma, but *Glyptostrobus* persisted until well into the Pliocene in some areas. Small amounts of *Pterocarya* pollen occur in many late Miocene samples in Beringia and suggest a hardy form of that broadleaf tree persisted in Beringia after most "temperate" trees had disappeared from the region. During the latest Miocene, ca. 6.5-5.2 Ma, *Picea* increased in importance, at least in the forests of eastern Beringia, and this may have been the vegetation response to global cooling, manifested elsewhere by glaciation (e.g., southern coastal Alaska), and significant sea level drop. Early Pliocene forests of Beringia appear to have been compositionally little different from late late Miocene forests, including most of the same tree and shrub genera (*Pinus, Picea, Tsuga, Larix, Abies, Betula, Alnus, Salix,* Ericaceae). Pollen data suggest that *Pinus* became more abundant than *Picea* in early Pliocene time, and *Tsuga* and *Abies* were probably not abundant. The apparent expansion of *Pinus* populations at that time may have been a response to somewhat warmer climates. The rise of mountain ranges of southeastern Beringia (e.g., the Alaska Range) began in latest Miocene and early Pliocene time, and this created new, higher-elevation habitats. Rising mountains began to block the penetration of warm, moist air from the North Pacific into the interior. During the early Pliocene, herbaceous plants became more common in the landscape of Beringia, perhaps in response to cooling, drying, and the development of open forests and expanses of unforested uplands above altitudinal tree limit.

Late Pliocene vegetation of eastern Beringia was composed primarily of conifer-dominated forests of *Pinus, Picea, Larix, Abies* (uncommon), *Betula, Populus, Alnus, Myrica, Salix.* The disappearance of *Tsuga* spp. from interior Beringia was probably caused by greater aridity and colder winters as mountain ranges in southeastern Beringia continued to rise. Cold climates between ca. 2.5-2.35 Ma resulted in the start of a major glaciation in Beringia (and in other high latitude regions). The cold climates of this interval led to the development of lowland tundra, forest tundra, and lowland permafrost (with ice wedges) in northern Beringia. This represents the earliest well-documented evidence for lowland tundra vegetation in Beringia, although it is likely that tundra-like vegetation appeared in alpine habitats, and possibly some high latitude lowlands earlier, perhaps during the latest Miocene.

Glacial climates of the Pleistocene altered the vegetation of Beringia more profoundly than any climatic events of the Tertiary. After millions of years of adaptation to cooling climates, Beringian forests were essentially replaced by herb tundra, shrub tundra, and steppe-tundra during long glacial intervals. During interglacials, boreal forests recolonized from the south.

THE LATE PLEISTOCENE INTERSTADE (KARGINSKII/BOUTELLIER INTERVAL) OF BERINGIA: VARIATIONS IN PALEOENVIRONMENTS AND IMPLICATIONS FOR PALEOCLIMATIC INTERPRETATIONS

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Paleoenvironmental records from the latest Pleistocene interstade (age equivalent to marine isotope stage 3), particularly between 40 ka to 26 ka BP, indicate that this was a period of heterogeneous environments and climates. This pattern contrasts to the more homogeneous environments of the late Pleistocene stadial events. Western Beringia was more extensively reforested than eastern Beringia during warm periods within the interstade. The western Beringian *Larix* forests approximated their modern range, but the trees probably established in only the most favorable low elevation and valley sites. Although *Picea* was likely present in areas of eastern Beringia, its distribution was restricted to the eastern interior, with the trees primarily occurring in isolated stands or open woodland. Maximum forest development across Beringia occurred ca. 33 ka to 39 ka BP. In general, the eastern Beringian vegetation retained more of its stadial characteristics during the interstade, whereas near interglacial forests alternated with more glacial-like tundra in western Beringia. The “flickering” of the interstadial forests suggest great climatic variability in the west, in contrast to the more stable climatic regime of eastern Beringia. Causes of such intra-Beringian differences are not clear, but the role of vegetation feedback to the regional climatic system may have been an important factor. This work was supported by the National Science Foundation and the Russian Foundation for Fundamental Research.

AN 8100 YEAR RECORD OF VEGETATION CHANGES FROM A PEAT SITE NEAR FAIRBANKS, ALASKA

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Pollen, plant-macrofossil, radiocarbon and LOI analyses of a peat site provide new information on Holocene environmental history of Central Alaska. The investigated site (65^{O}N, 147^{O}W) is located within the modern boreal forest, near Fairbanks. Mean July temperature is about 15^{O}C, mean January temperature is about -22^{O}C, mean annual temperature is about -4^{O}C and the total annual precipitation is about 300 mm.

The peatland was drained and partially excavated for gold mining. The samples were collected from 2 peat exposures (GM-1, surface-65 cm, and GM-2, 0-210 cm) and a core (GM-3, 0-170 cm) which penetrated bottom peat layers and underlying lake sediments. 14C dates demonstrate that the sections and the core provide a high-resolution pollen and macrofossil record for the last 8100 years. A well-decomposed thin (5-10 cm) peat layer, GM-4, was found at a depth of 10 m buried in the sandy and clayey sediments in the same basin.

GM-4, buried peat was radiocarbon dated to greater than 45 000 yr. BP (IGAN-1377). *Betula*, *Picea*, *Alnus* dominated the vegetation with Ericales and *Sphagnum* on the peatland surface. The pollen content shows that the peat accumulated in rather warm conditions, probably, during an interstadial warming.

GM-3 (0-170 cm) core**.** The woody fragments and twigs from the basal layer of lake sediments (at 170-165 cm depth of the core) were AMS dated to 8120±60 yr. BP (CAMS-38445). Presence of *Nuphar, Potamogeton, Myriophyllum* and *Menyanthes* pollen and high clay content shows that clay sedimentation started in a shallow lake. Spruce and larch forest with birch dominated the site at that time. Macrofossil investigation will be done to identify the spruce species. Cyperaceae and Poaceae communities with some Rosaceae, Ericales, Compositae, Apiaceae and *Saxifraga* species were present around the lake. Significant amount of different *Lycopodium* species and Polypodiaceae spores were found in the lake sediments. Most spores are rather well preserved and may reflect abundant *Lycopodium* and fern communities growing around the site. The spores may also have a reworked origin and along with low pollen concentration in same spectra may indicate high inorganic accumulation rates in the lake.

The shallow lake changed to a wetland at 135-cm depth of the GM-3 core. *Picea* pollen shows very low percentages at this level. A comparison with other central Alaskan pollen data (Ager, 1975; Hu *et al*., 1993) can preliminarily date this episode to 7500 yr. BP, but additional AMS dating will more precisely define the age. The dramatic spruce decline was possibly due to cooler and drier conditions, if this is a regional change. The Cyperaceae communities reached maximum values on the drained lake bottom at that time. Aquatic taxa disappear from the spectra and sedge peat accumulated in the subsequent wetland.

A short episode of clay accumulation at 123-118 cm depth reflects the return back to the shallow lake conditions. Significant amount of *Menyanthes* pollen in the overlying layers (115-95 cm depth) suggests that shallow pools of continued to be present.

Picea pollen reaches 50-60 percentages at 90-55 cm. Spruce forest increased. The high sedge percentages in the pollen spectra is gradualy replaced by *Sphagnum* spores at that time

Picea pollen decreases and *Betula* pollen dramatically increases at 50-45 cm depth. Birch dominated the vegetation at this time, but was rapidly replaced by spruce. Ericales and *Sphagnum* dominated on the peatland surface. The top of this core is older than 7100 yr BP as visible from the AMS-dated *Betula nana* twigs and leaf (7080±50 yr. BP (CAMS-38444)) from the bottom of the higher situated GM-2 peat section.

Most likely a few peat layers are missing and there is a small hiatus in the records between this core and the GM-2 section. The dramatic changes in pollen content of *Picea, Betula* and *Alnus* support this suggestion. A date from the core top will show precisely the age.

GM-2 (0-210-cm) section. The spruce percentage is very low and birch percentage is high at 210-110 cm depth. This may reflect a decline in spruce in the vegetation around the site. The LOI analyses show the rather high clay content at 210-150 cm depth that may reflect unstable soil conditions at that time around the site.

Alnus pollen percentages are relatively high from the bottom of the section, showing that alder came to the area before 7100 yr ago. *Larix* pollen percentages are low in this zone, but larch pollen generally does not reflect true composition of larch in the forest. *Sphagnum* mosses and Ericales were present on the peatland surface. Additional dates are needed to provide the length of this stage. If the peat accumulation rate was constant during the Holocene it may have lasted 3000 yr.

Picea percentages increase, while *Betula* and *Alnus* percentages decrease at 110-cm depth. Significant increase of *Rubus chamaemorus* and Ericales pollen and decrease of *Sphagnum* spores at 110-65 cm depth may reflect a change in local peatland hydrology to a drier condition.

Pollen percentages are the almost the same through 110-5 cm depth. Spruce, birch and alder dominated the vegetation. The climate conditions were stable.

The top of the GM-2 section was radiocarbon dated to 1210±30 yr BP (IGAN-1375). Significant Ericales pollen percentages increase in the top 5 cm and small Cyperaceae and Poaceae percentage increases may reflect some local hydrological changes at that time.

GM-1 (surface-65 cm) peat section was situated about 30 m from the longer GM-2 section and the GM-3 core. The bottom layer of GM-1 section was radiocarbon dated to 1890±30 yr BP (IGAN-1376). The 14C dates indicate that the sections are overlapping and provide a continuous record for the last 7000 yr. Interestingly, although, the GM-1 and GM-2 sections were very close to each other the pollen records are significantly different. The *Picea* percentages reach significant values (up to 90 %) in the GM-1 section and *Betula* and *Alnus* pollen have low values. This short section was close to the peatland edge and a possible explanation for the significant difference in the same age pollen spectra can be various distances from pollen sources and different hydrological conditions. *Rubus chamaemorus* pollen percentages reaches maximum values and *Sphagnum* spores are low in the surface sample that reflect the anthropogenic hydrological disturbance during recent years.

Our high-resolution record is the first detailed peat record from this area of interior Alaska and provides a local peatland dynamic history to compare with regional lake environmental records.

REFERENCES

Ager, T.A. 1975. Late Quaternary environmental history of the Tanana valley, Alaska. Ohio State University Institute for Polar Studies, Columbus, Ohio. Report 54.

Hu F.S., Brubaker L.B., and Anderson P.M. 1993. A 12 000 record of vegetation change and soil development from Wien Lake, central Alaska. Can. J. Bot. 71: 1133-1142.

AN UPPER PLEISTOCENE ENVIRONMENT ON FADDEYEVSKIY ISLAND, EAST-SIBERIAN SEA, RUSSIA

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Pollen, plant macrofossil and radiocarbon analyses of a section from Faddeyevskiy Island, Novaya Sibir archipelago, provides new information on Upper Pleistocene environmental history of this high Arctic region. The investigated site (75°20’N, 143°50’E) is located within the modern arctic desert zone, in the central part of the island in the Khastyr River valley. Mean July temperature is about 2-4°C, mean January temperature is about -30°C, mean annual temperature is about -15°C and the total annual precipitation is about 150 mm.

The 1.4-m river section was sampled for pollen, macrofossil, ^{14}C and LOI samples. The dark gray silty clay sediments contained numerous lenses with plant macrofossils. Most likely the clay sediments are of eolian origin and more organic layers accumulated during wetter stages.

The radiocarbon analyses show that the deposits accumulated about 26,000-35 000 years ago. Plant remains from 40, 85 and 100 cm depth were dated to 25,700±1000 yr BP (GIN-8283), 32,780±500 yr BP (GIN-8281), and 35,200±650 yr BP (GIN-8283) respectively. The accumulation rate was very low at that time, because 10,000 years of time is represented by 60 cm. Poaceae pollen dominate the pollen spectra, with some Cyperaceae and Ranunculaceae. Few *Artemisia*, Caryophyllaceae, Chenopodiaceae, and Compositae pollen are also common in the spectra. Determinable macrofossil remains mostly belong to Cyperaceae and non-*Sphagnum* mosses, which grew at the site during the wetter intervals.

The pollen spectra probably reflect a steppe-like vegetation (tundra-steppe). It is important to notice the small amount of *Artemisia* in our pollen spectra. The published pollen data with similar radiocarbon age (28,640±700 yr BP (LU-1604) and 28,410±210 yr BP (LU-1751)) from Kotel’nyy Island (western part of this archipelago) shows a significant amount (up to 20-30%) of *Artemisia* in the pollen spectra (Makeev *et al*., 1989). The absence of *Artemisia* pollen in our site could be caused by wetter climate conditions on the eastern part of the archipelago or some local hydrological or edaphic differences.

Poaceae and *Artemisia* communities dominated on the expanded archipelago with lowered sea level. The productivity of these communities was high enough to feed the grass-eater herds. The numerous mammoth (*Mammuthus primigenius*) remains from Faddeyevskiy Island were radiocarbon dated to 36,700±500 yr BP (GIN-8243a), 36,000±500 (GIN-8238), 35,210±500 (GIN-8243), 34,500±500 (GIN-8247), 32,000±280 (GIN-8245), 31,400±300 (GIN-8226), 29,700±230 (GIN-8260), 28,650±350 (GIN-8225), 27,100±300 (GIN-8224), 25,540±170 (GIN-8232), 25,200±180 (GIN-8246), 25,180±150 (GIN-8227), 23,940±150 (GIN-8244), and 18,500±100 yr BP(GIN-8229). Two bison remains were found and ^{14}C dated to 32,200±600 (GIN-8228) and 33,100±320 yr BP(GIN-8231). The numerous radiocarbon dates of the bones from the Novoya Sibir archipelago previously published (Makeev *et al*., 1989; Sulerzhitsky, 1995) belong to the same time interval.

The new pollen and radiocarbon data from Fadeevsky Island again indicate that the hypothetical Panarctic Ice Sheet never existed in this area between 25,000-35,000 yr ago. We also doubt that ice covered this area after this time, because of continuous dated records from full-glacial to the Holocene (Makeev *et al*., 1989).

REFERENCES

Makeev, V.M., Arslanov, Kh.A., Baranovskaya, O.F. *et al*., 1989. Stratigraphy, geochronology and paleogeography of Late Pleistocene and Holocene of Kotel’nyy Island. *Bull. Komissii po izucheniyu chetvertichnogo perioda*, 58: 58-69. (in Russian).

Sulerzhitsky L.D., 1995. Features of radiocarbon chronology of the woolly mammoth (*Mammuthus primigenius*) in Siberia and north of Eastern Europe. *Trudy Zoologic. Instituta RAN*, 265:163-185.

CLIMATIC IMPLICATIONS OF THE BIVALVE *FORTIPECTEN HALLAE* (DALL) IN THE ALASKAN PLIOCENE

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The bivalve *Fortipecten hallae* is important for characterizing some marine Pliocene deposits of western and northern Alaska and understanding the history of Bering Strait. This species evolved in the North Pacific and migrated to Alaska during at least one episode. It is reported in Pliocene deposits around Nome (south of modern Bering Strait), and at Kivalina and along the Colville River (north of modern Bering Strait). The age of the Alaskan deposits with *F. hallae* is still uncertain. The question is whether these deposits were formed only during the Beringian transgression or whether this species also occurs in older transgressions. At its type locality of Solomon River, this species occurs in deposits that lack molluscan assemblages characteristic of the Beringian transgression. Near Kivalina, *Fortipecten hallae* is associated with some taxa characteristic of the Beringian deposits of the Nome region. However, the poorly preserved *Fortipecten* shells found there with other, well-preserved mollusks suggests their possible reworking from older deposits. Studies of Pliocene deposits on Karaginsky Island, northeastern Kamchatka, have yielded data on the stratigraphic distribution of *F.hallae*. In the Karaginsky Island section, this species is present in the middle part of the Limimtevayam Formation. Based on diatoms and paleomagnetic records, the age of this horizon is 4.05 Ma. *Fortipecten hallae* occurs with certainty only in the Limimtevayam Formation, but not in the overlying Ust-Limimtevayam Formation that contains *Astarte diversa*, *A. nortonensis*, and *Chlamys colvillensis*. This Ust-Limimtevayam assemblage, with an age of 3.6-3.5 Ma, is virtually identical to that of the Beringian transgression in Alaska. A notable climatic event accompanies the appearance of *F. hallae* in the Limimtevayam Formation. Oxygen isotope values for *Cyclocardia* and *Macoma* suggest a rise in the bottom water temperature of approximately 3.2-4.5°C. A northward incursion of relatively warm water evidently allowed *Fortipecten hallae* to live for a time along the coasts of northeastern Kamchatka and Alaska in the early Pliocene, beginning at about 4.0 Ma.

LATE QUATERNARY PALEOCLIMATIC RECONSTRUCTIONS FOR INTERIOR ALASKA BASED ON PALEOLAKE-LEVEL DATA AND HYDROLOGIC MODELS

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Hydrologic models were developed for two lakes in interior Alaska to determine quantitative estimates of precipitation over the past 12,000 years. Alaska is an important region for climate studies since general circulation models (GCMs) predict that higher latitudes will be most affected by climate change as trace green house gas emissions increase due to anthropogenic activities. Interior Alaska is semi-arid (mean annual precipitation about 30 cm) and changes in precipitation may have a significant impact on terrestrial and aquatic ecosystems. Signs that changes are already occurring in Alaska include increases in permafrost temperature (Lachenbruch et al., 1988; Walsh & Chapman, 1990; Chapman & Walsh, 1993) and changes in tree ring characteristics indicating increased moisture stress over the past 20 years or so (Jacoby & D'Arrigo, 1995; Barber et al., 1997; Juday & Marler, 1997). While it is difficult to predict how climate may change and what the effects may be on the environment, we can look at possible future climate change scenarios by studying past climates and the associated environments by using paleoenvironmental proxies.

This study utilizes hydrologic models to determine qualitative paleoclimatic information from two interior Alaskan lakes, Birch Lake (64°18'N, 146°40'W) and Jan Lake (63°34'N, 143°54'W), which formed prior to deglaciation. These low elevation lakes lie in a region that was largely unglaciated during the Wisconsin period. Sediment core transects were used to determine lake level changes over the history of the lakes. Seismic profiling also aided in lake-level reconstruction of Birch Lake (Abbott, 1996). The lake-level reconstructions are based on temporal changes in sediment paleodepths determined from the offshore transect with age control based on AMS ^{14}C dating of pollen and macrofossils (Abbott, loc. cit.). The results indicate that significant changes in lake level occurred over the past 13,000 years. Both lakes were extremely low from the beginning of the records until about 12,000 yr B.P. Birch Lake was 3 m and Jan Lake was 2 m deep prior to 12,000 yr B.P. Lake levels rapidly increased after this time with significant fluctuations. At 9,000 yr B.P., Birch Lake was 12 m and Jan Lake 3 m deep. By 6,000 yr B.P., Birch Lake was at present day level while Jan Lake was 6 m deep. Jan reached modern levels by about 4,000 yr B.P.

Modern water balance conditions were established for each lake using morphometric and climatic data. Evaporation, evapotranspiration, and precipitation were adjusted in a water balance model to determine conditions necessary to maintain the lakes at the determined paleolevels. Similar paleoclimatic solutions can be obtained for both basins during these time periods. Results indicate that precipitation was 30-60% of modern at 12,000 yr B.P., 60-90% of modern at 9,000 yr B.P. and 80-90% of modern at 6,000 yr B.P. using estimates for evaporation (E) and evapotranspiration (ET) based on modern studies in vegetation types indicated by fossil pollen assemblages. The lakes showed differing sensitivities to changing hydrologic parameters due to the ratio of lake area (LA) to drainage basin (DA) size. This ratio also changed over time as lake level and lake area increased. Smaller LA to DA ratios make a lake more sensitive to evapotranspiration, if all other factors are constant.

REFERENCES

Abbott, M. B., (1996). Holocene climatic variability for lake sites in Bolivian Andes and interior Alaska based on sedimentology and radiocarbon dating by accelerator mass spectrometry. University of Minnesota, Ph.D. dissertation.

Barber, V. A., G. A. Judy & B. P. Finney, (1997). Stable isotope and wood density evidence of upland white spruce growth in Bonanza Creek LTER in central Alaska consistent with increased climatic stress. Ecological Society of America, Albuquerque, N.M.

Chapman, W. L.& J. E. Walsh, (1993). Recent variations of sea ice and air temperature in high latitudes. Bull. Amer. Met. Soc. 74: 33-47.

Jacoby, G. C.& R. D. D'Arrigo, (1995). Tree ring width and density evidence of climatic and potential forest change in Alaska. Global Biogeochemical Cycles. 9(2): 227-234.

Juday, G. P.& S. A. Marler, (1997). Tree-ring evidence of climatic warming stress in Alaska: variation and stand history context. Ecological Society of America, Albuquerque, N.M., Lachenbruch, A. H., T. T. Cladouhos & R. W. Saltus, (1988). Permafrost temperature and the changing climate. Fifth International Conference on Permafrost, Trondheim, Norway,

Walsh, J. E.& W. L. Chapman, (1990). Short-term climatic variability of the Arctic. Arctic J. of Climate. 3: 237-250.

UPLAND WHITE SPRUCE GROWTH IN BONANZA CREEK LTER IN CENTRAL ALASKA UNDER UNPRECEDENTED DROUGHT STRESS: EVIDENCE FROM STABLE ISOTOPES AND WOOD DENSITY

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Wood sections of white spruce from Reserve West reference stand at Bonanza Creek Long-Term Ecological Research (LTER) site in central Alaska were analyzed by X-ray densitometry and stable isotope (delta ^{13}C) techniques. Fairbanks monthly temperature and precipitation were correlated with stable isotope and density values. Correlation of wood properties were made with climate in the contemporary year of growth. Maximum latewood density (1909-1981) was significantly correlated with May and August temperature (0.557 and 0.691) and August precipitation (-0.464). Normalized May plus August temperature was correlated with density (0.791, 0.912 with 5-year running mean). Isotope delta ^{13}C values were obtained from wood on a year-by-year basis (4 radii per tree, 4 trees). Isotope delta ^{13}C, itself a measure of moisture stress, was negatively correlated with growth year precipitation (-0.488, -0.656 smoothed) and positively correlated (0.610, 0.857 smoothed) with May-August temperature. A combined index of normalized May-August temperature and yearly precipitation correlated with delta ^{13}C at 0.710 (0.844 smoothed). The original delta ^{13}C values were calibrated on trees killed in the 1983 Rosie Creek Fire. Additional series were collected from survivor trees on the perimeter of the burned area and updated through 1996. The delta ^{13}C relationship with the climate index after 1983 remained generally good, although the death of competing vegetation surrounding the survivor trees appears to have relieved moisture stress to some degree for about 7 years. Delta ^{13}C enrichment continued into the mid 1990s, reaching the highest levels of the 20th century, consistent with significant climatically driven stress on the trees. Radial growth appears to be strongly controlled by the same trends in moisture stress. In interior Alaska a 10.6-year climate cycle of cool/moist alternating with warm/dry climate conditions is present. An overall trend of warming and drying is superimposed on the climate cycle throughout the 20th century. The mid 1990s were the cool/moist peak of the cycle, so even further stress to the trees appears likely into the early 2000s.

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REFERENCES

Abbott, M. B., (1996). Holocene climatic variability for lake sites in Bolivian Andes and interior Alaska based on sedimentology and radiocarbon dating by accelerator mass spectrometry. University of Minnesota, Ph.D. dissertation.

Barber, V. A., G. A. Judy & B. P. Finney, (1997). Stable isotope and wood density evidence of upland white spruce growth in Bonanza Creek LTER in central Alaska consistent with increased climatic stress. Ecological Society of America, Albuquerque, N.M.

Chapman, W. L.& J. E. Walsh, (1993). Recent variations of sea ice and air temperature in high latitudes. Bull. Amer. Met. Soc. 74: 33-47.

Jacoby, G. C.& R. D. D'Arrigo, (1995). Tree ring width and density evidence of climatic and potential forest change in Alaska. Global Biogeochemical Cycles. 9(2): 227-234.

Juday, G. P.& S. A. Marler, (1997). Tree-ring evidence of climatic warming stress in Alaska: variation and stand history context. Ecological Society of America, Albuquerque, N.M.

Lachenbruch, A. H., T. T. Cladouhos & R. W. Saltus, (1988). Permafrost temperature and the changing climate. Fifth International Conference on Permafrost, Trondheim, Norway,

Walsh, J. E.& W. L. Chapman, (1990). Short-term climatic variability of the Arctic. Arctic J. of Climate. 3: 237-250.

A TERRESTRIAL RECORD OF CLIMATIC FLUCTUATIONS DURING THE QUATERNARY: MAGNETO- AND BIO-LITHOSTRATIGRAPHIC EVIDENCE FROM BANKS ISLAND, WESTERN CANADIAN ARCTIC ARCHIPELAGO

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Sediments approximately 50 m thick from Banks Island (Western Canadian Arctic Archipelago), contain one of the longest terrestrial records of Pleistocene climate changes in North America. During the Matuyama Reversed Chron there are at least two and possibly as many as five full glaciations, two interglacial intervals, and a non-glacial interval at the beginning which is considered preglacial. Both of the normal Olduvai and Jaramillo subchrons within the reversed Matuyama appear to be present. During the Brunhes Normal Chron, three full glaciations and three interglaciations are recorded. The Brunhes-Matuyama boundary occurs within interglacial deposits, indicating that the geomagnetic field last reversed during an interglacial interval. Based on floral, faunal, stratigraphic, and paleomagnetic constraints, a normal sequence in the preglacial Worth Point Formation is assigned to the Olduvai normal polarity subchron (1.95-1.77 Ma). The Worth Point Formation records a climate milder than today, and cooler than that of the late Tertiary. The first direct evidence of glaciation on Banks Island, occurs in sediments that post-date the Worth Point Formation (< 1.77 Ma). This suggests that in the western Canadian Arctic, the first continental glaciation post-dated the first Cordilleran glaciation in North America by as much as 1.0 Ma.

THE BIVALVE *CHLAMYS COLVILLENSIS* (MACNEIL) AND CORRELATION OF PLIOCENE MARINE DEPOSITS OF NORTHEASTERN KAMCHATKA AND ALASKA

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Analysis of the stratigraphic and geographic distribution of the extinct pecten *Chlamys colvillensis* enables us to correlate Pliocene marine deposits of northeast Kamchatka with those in western and northern Alaska. On Karaginsky Island, northeastern Kamchatka, *Chlamys colvillensis* is abundant in the lower part of the Ust-Limimtevayam Formation, where it is found in association with the extinct bivalves *Astarte diversa, A.nortonensis, A.hemicymata*, and *Macoma obliqua*, among others. These beds with *C. colvillensis* have an age of 3.6-3.5 Ma, based on diatom data and paleomagnetic records. There is a hiatus between these deposits and underlying Pliocene deposits of the Limimtevayam Formation. In western Alaska, *Chlamys colvillensis* occurs with other extinct taxa and the extant warm-water species *Swiftopecten swiftii* in deposits from Intermediate Beach near Nome. Together with *Astarte diversa, A. leffingwelli, Cyclocardia crebricostata nomensis* and *Swiftopecten swiftii, Chlamys colvillensis* occurs in Anvilian deposits at California River, western Seward Peninsula, which have a potassium-argon age of about 2.8 Ma. In northern Alaska, *Chlamys colvillensis* is known in the Gubik Formation from the type-section of the Bigbendian transgression along the Colville River near Ocean Point. The type Bigbendian beds have an inferred age of 2.48 Ma, at the Gauss-Matuyama boundary, and a relatively warm-water molluscan fauna.

Chlamys colvillensis is a useful biostratigraphic marker for correlation of upper lower Pliocene to lower upper Pliocene (about 2.48-3.6 Ma) marine deposits in the region from northeastern Kamchatka to western and northern Alaska.

THE LOESS TREASUREHOUSE: LONG TERM RECORDS OF PALEOCLIMATES AND PALEOENVIRONMENTS, GLACIAL AND PERIGLACIAL HISTORY, PALEOECOLOGY AND EVOLUTION, NATIVE AMERICAN SETTLEMENT, PALEOPEDOLOGY, AND VOLCANISM ACROSS BERINGIA

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Loess deposits in some areas of Alaska and eastern Siberia contain long, semi-continuous paleoclimatic records. These high latitude loess deposits constitute a terrestrial counterpart to long paleoclimate records found in marine and lacustrine sediments. The paleoclimatic data from loess deposits are similar in detail to those from marine sediments, and reliable correlations can be made between the high latitude paleoclimate records preserved in Arctic loess and global records of climate change found in deep sea sediments. Time-series analysis of loess proxy climate data demonstrates the effects of orbital precession and obliquity on the timing of Alaskan climate change.

The sedimentology and geophysical properties of Alaskan loess changed through time in response to climatically forced changes in wind intensity, storminess, temperature, plant cover, permafrost depth, and precipitation. The loess record in central Alaska extends through the entire Quaternary, but caution is needed during geologic studies of the thickest loess sequences as major erosional unconformities are locally present.

Loess deposits contain evidence of episodic permafrost and paleosol formation, explosive volcanic eruptions, paleoecologic changes in high latitude regions, Quaternary fossils, and early man sites and artifacts. Paleoclimatic records from loess deposits provide a stratigraphic context which can be used to assign relative and sometimes absolute ages to fossils and other deposits found associated with loess.

The Old Crow tephra (ca. 140,000±10,000 BP) is the most important geochronologic datum in Alaskan loess, and lies at the transition between full-glacial conditions and the last interglaciation in loess sequences in central Alaska. Numerous other Pleistocene and Holocene tephras, regional (?) paleosols, and paleomagnetic data provide additional age control on the paleoclimatic record from loess. The radiocarbon method can be applied to well-preserved organic material found in frozen loess. Thermoluminesce dating is a powerful technique which provides absolute ages on the timeof deposition of loess itself, as well as on intercalated volcanic ash beds.

Loess is unique, in that it consists of a time-transgressive series of buried terrestrial surfaces. Loess deposits provide a unique opportunity to reconstruct the chronology and pattern of climate change in terrestrial areas. Alaskan loess deposits, which in some cases have remained continuously frozen for tens of thousands of years after deposition, contain uniquely well-preserved plant and animal fossils that reflect the paleoenvironments and paleoecology of past environments. Loess also contains abundant tephras, which have proven to be extremely useful in dating and correlation studies. Variations in the primary sedimentological and geophysical properties of Alaskan loess reflect climatic regimes at the time of deposition, and can be used to reconstruct proxy climate curves analogous to those obtained from ice sheets or marine sediments. The temporal resolution in loess records is on the order of hundreds of years, allowing the recognition of both major climatic boundaries and minor climate events.

LAST INTERGLACIATION AGE OF THE EVA FOREST BED, CENTRAL ALASKA, FROM THERMOLUMINESCENCE DATING OF BRACKETING LOESS

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The Eva Forest Bed in the Yukon-Tanana Upland of east-central Alaska represents a frozen, buried, boreal forest, consisting of well preserved peat lenses, sticks, roots, logs, as well as rooted and unrooted stumps of trees. Where preserved, the Eva Forest Bed is straddled by the overlying Goldstream Formation and the underlying Gold Hill Loess. Almost all exposures have a prominent unconformity at the top of the Gold Hill Loess, even where the forest bed is not preserved. Attempts have been made over the last 50 years to determine the age of this bed numerically.

We report here details of thermoluminescence (TL) dating of 14 samples of loess from above and below this unconformity in the Fairbanks area. Together with knowledge about the climatic indicators from the Eva Forest Bed, these TL age estimates: (1)— indicate that the most probable age of the Eva Forest Bed is 125 ka, the time of the warmest part of Oxygen Isotope Stage 5; and (2)— confirm stratigraphic inferences from tephra beds in the upper Gold Hill Loess that variable thicknesses of this loess complex have been eroded “just prior” to the development of the Eva Forest Bed.

THE BERING “BRIDGES” DURING THE PLEISTOCENE ACCORDING TO THE POINT OF VIEW OF MIGRATING INVERTEBRATES

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There is an immense group of terrestrial invertebrates that are found in both Asia and North America. Analysis of the recent ecology of these species allows us to reconstruct the environment of the Bering Land Bridges — the path of their migration between the two continents. We analyzed data concerning seven groups: Orthoptera, Hymenoptera (Formicidae), Coleoptera (Curculionidae, Carabidae), Heteroptera, and Araneae. Data about bumble bees and night moths (Noctuidae) were taken from published sources. The main question is - how significant is the steppe component in the Holarctic fauna. Only in this way we can determine whether the environment of the Bering Land Bridges was steppe, tundra-steppe, or tundra.

We divide the recent steppe insect communities of northeastern Asia into two groups, based on their thermal requirements. The first group we classify as “Warm” (relic for NE Asia). This group comprises steppe faunas that live where temperatures are at least (SDD with 0° C as a base) 25°C at the soil surface. Their thermal regime is very close to that found in mountain steppe regions of southern Siberia. Warm steppes in northeastern Asia are located on the south-facing slopes of the valleys of Yana, Indigirka, and Kolyma upstream. The second group we classify as “Cold” or crioxeric steppe faunas; these are able to exist in a very wide SDD range (900-2300±C at the soil surface). This group is limited by soil dryness in summer and bare of snow in winter. Cold steppe areas are rather often located along hill crests in the continental part of the Kolyma basin and reach the Chukotka region and Wrangell Island. Different groups of invertebrates display different aspects of former faunal exchanges between continents: Holarctic ground beetles tell us about prevailing forest and tundra environments; spiders and weevils are witnesses of forest, meadow, and to a lesser extent, tundra conditions; bugs display mainly meadow environments; grass hoppers (as typical grassland communities dwellers) show very weak exchange; ants show the prevailing of forest relationships during the Pliocene and bumble bees declare tundra environments over the Bering Land Bridges. At the same time all groups under analysis display a very weak steppe component. Among the 1000 species that were used for the analysis there are only six mutual “warm” steppe species (1.5%). They are mesoxeric meadow species that are also found in the forest zone. Thus, they were able to migrate across not only steppe but also grass communities. Among the six mutual “cold” steppe species, four species are now dwelling in the dry tundra of Chukotka, the range for one species yet is not well defined, and the last one is not quit distinct taxonomically. We need to mention that in spite of very small patches of relic steppe in our days, relatively many “warm” steppe species (a total of 75) are maintained there. The main part of their modern ranges is centered in the Central Asia.

Thus, the invertebrate data, as well as paleontological evidence in general, do not indicate either “warm” or “cold” steppe environments on the Bering Land Bridges. But S. V. Kiselev (1981) found many remains of genuine steppe weevils (*Stephanocleonus*, 10 species), ground beetles (*Carabus* and *Cyminidis*) and some others beetles in Pleistocene deposits on the coastal plains of northeastern Asia, west of Aion Island. These beetles need SDD not less than 2500° C for their development. Thus, during the Pleistocene, Aion Island was the eastern boundary of the northeastern Asian invertebrate steppe fauna, but this fauna could not cross the Bering Land Bridge, because the Pleistocene environments of “Bridges” never were steppe ones. Earlier, the same thesis was declared by K. Gorodkov (1979), and K. Mikkola et al.(1991), based on their analysis of the Holarctic fauna of some Diptera and Nucteidae species, correspondingly. The environmental reconstructions based on entomological analysis are generally supported by Beringian climate reconstructions. It is generally agreed the that main features of the atmospheric circulation over western Beringia during the Late Pleistocene were close to modern ones, thus the most important difference between the Late Pleistocene climate and the recent one is the increasing degree of continentality derived from lowered sea level.

Our estimation of the climatic continentality was based on annual and daily temperature ranges and relative humidity. Keeping in mind the possible meanings of these characteristics during the Late Pleistocene, we were able to reconstruct that climatic continentality for the arctic planes of northeastern Asia was 30-35% higher than modern in the upper reaches of Yana and Indigirka rivers. According to our reconstructions, under this very continental climate the relation of SDD of the warmest soils to thawing degree days (TDD) of the air must run up to 2 times. If the distribution of Pleistocene weevils in the arctic plains of northeastern Asia were restricted to south-facing bluffs, SDD suitable for the breeding of these beetles (more 2500° C) may be accumulated only if the mean July temperature in this region was not less than 10-11° C. In the case of weevils dwelling on dry terraces, we must assess the mean July air temperature during the Late Pleistocene as 12-13°C, or only 1-2°C less than at present in the headwaters of Yana and Indigirka rivers. In other words, during the Late Pleistocene air temperature on the arctic planes of northeastern Asia must have been about two degrees warmer than modern. The same estimation has been derived from the quantitative spore-pollen analysis of these territories.

All of the foregoing thesis concerns only the plains west of Aion Island. The climate of the Land Bridge was probably different. Due to the quantitative assessments of the main climatic characteristics over the Land Bridge during the last glacial maximum (Sergin and Scheglova, 1978) the air temperature regime of the central part of the land bridge (mean July temperature of 8-9° C) at present is registered in the upper parts of the Indigirka and the Lena deltas. But, in spite of drier conditions, the land bridge had vegetation typical of the hipoarctic tundra found in the delta regions of these rivers. Assessment of the extreme SDD for the south-facing bluffs in deltas indicates that it can not be over 1000° C. At present, identical SDD values are noted for the warmest *Carex* communities on the south-facing slope shoulders in the Amguema basin. In other words, the difference between western Beringia and the land bridge for July air temperature was 4°C, or about 30%, but for TDD of the warmest biotopes it was 1000°C or 50%. Hence, the environmental reconstruction for the Late Pleistocene of western Beringia and the land bridge based on the entomological analysis is in agreement with the quantitative estimation of the role of climatic continentality. This reconstruction suggests that in western Beringia climate was sufficiently warm and soil temperatures were satisfactory for the existence the tundra-steppe environment and even the steppe one. On the land bridge, soil temperatures were similar to those found in typical hypoarctic tundra.

RAPID (<1000 YR) DEGLACIAL VEGETATION CHANGES IN CENTRAL ALASKA

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The general pattern of late-glacial and Holocene vegetation change is well documented in central Alaska (Ager, 1983; Hu, et al., 1993; Anderson and Brubaker, 1994). Since deglaciation, the vegetation has shifted from herb tundra to *Betula*-dominated shrub tundra, then to *Picea* forest, with vegetation similar to modern developing in the latter half of the Holocene. These patterns are based on a relatively coarse sample resolution of about 200-500 yr. Recently, high resolution pollen analysis (50-100 yr) of the period 12.0 to 10.0 kyr (all ages in ^{14}C yr) suggests that, at least in some regions, there have been short-term vegetation changes that were previously unrecognized.

In general, the vegetation 12.0-10.0 kyr was *Betula* shrub tundra with a relatively minor component of herbaceous taxa, mainly Poaceae, Cyperaceae, and *Artemisia*. Two records from central Alaska (Birch Lake and Windmill Lake) show an expansion and subsequent decline of the herbaceous taxa at the expense of the *Betula* shrubs. The timing of these changes differs between the two lakes, which suggests they reflect two different climatic events.

Birch Lake is located in the Tanana valley, north of the Alaska Range. Previous analyses from this lake indicated a high sedimentation rate and a 14.0 kyr pollen record (Ager, 1975). We obtained a high-resolution AMS-dated pollen record; lake levels were also reconstructed by B. Finney and M. Abbott (Abbott et al, in prep.). Between about 11.5 and 10.5 kyr BP, *Artemisia* frequencies increase to 7% of the pollen sum, while *Betula* frequencies decrease slightly. At the same time, lake levels dropped. Hydrological studies of Birch Lake today suggests that lake levels respond strongly to precipitation changes (Barber and Finney, submitted).

At Windmill Lake in the northern foothills in the Alaska Range, about 10.6-9.8 kyr BP, *Artemisia* and Poaceae frequencies together increase from 10% to 25% of the pollen sum, while *Betula* frequencies decrease to 60%.

Interpreting the pollen data is problematic because of the ambiguous climatic signal associated with Artemisia. In Alaska today, *Artemisia* grows both in well-drained and arid sites such as floodplains and south-facing bluffs (e.g. *Artemisia frigida*), and in mesic settings at high elevations (e.g. *Artemisia arctica*) (Hultén, 1968).

At Birch lake, the decrease in water level that coincides with the increasing *Artemisia* frequencies suggests that the xerophytic species expanded. This is probable, given the lake's location at low elevation (<300 m) near both floodplains and south-facing river bluffs where *Artemisia* (i.e., species such as *A. frigida, A. alaskana, A. tilesii,* and *A. furcata*) could occupy dry or disturbed sites.

Windmill Lake lies at about 640 m (about 160 m modern below tree-line). The increase in *Artemisia* frequencies probably reflects the expansion of xerophytic and mesophytic species.

Although similar palynologically, these changes are not synchronous. The vegetation and water-level changes at Birch Lake occurred nearly 1.0 kyr before the vegetation oscillation at Windmill Lake. This suggests the changes at the two lakes reflect different climatic events.

Different geographic locations may explain the differences between the lakes. Windmill lies in the Alaska Range, which is wetter than the interior, as it is affected by weather systems in the Gulf of Alaska and systems moving east from the Bering Sea. Precipitation is also enhanced orographically. The interior lowlands are drier, and commonly experience transient water deficits; much of the annual precipitation is from eastward-tracking systems in summer (Bowling, 1979; Hare and Hay, 1974). A reduction in the summer westerly flow, for whatever reason, would greatly increase aridity in the interior, but may have had only a small effect in the Alaska Range. The same climate change, therefore, would not necessarily have the same effect at both sites.

There is little evidence for a vegetation change at Windmill Lake between 11.5-10.5 kyr BP. Whatever affected Birch Lake, it was undetectable in the Alaska Range. It seems possible that another climatic event, unrelated to the event recorded at Windmill Lake, may have affected interior Alaska. Lake-level studies at Birch

Lake show that levels were well below present throughout the late Wisconsinan, although they fluctuated markedly (Abbott *et al*., in prep.). It seems probable, therefore, that the change recorded in Birch Lake pollen and lake levels involved a reduction of precipitation, most likely caused by a weakening of the westerly flow that brings summer precipitation to northern Alaska and the Yukon.

At Windmill, the vegetation change occurred during the latter half of the Younger Dryas (YD) chronozone (Mangerud et al., 1974). Vegetation fluctuations indicating cooler and/or drier conditions during the YD chronozone have been documented in coastal regions of Alaska (Peteet and Mann, 1994; Hu et al., 1995; Hansen and Engstrom, 1996). A recently published ocean-atmosphere model simulation suggests that a colder North Atlantic would have also led to cooler SSTs in the North Pacific, an eastward shift in the Aleutian Low, and increased southerly flow into south coastal Alaska (Mikolajewicj et al., 1997). A cooler North Pacific would not only have reduced atmospheric temperatures but also lowered evaporation from the sea surface. Windmill Lake is located in a valley which transects the Alaska Range and would have been more strongly affected by these conditions than Birch Lake. During the latter half of the YD chronozone, lake levels at Birch Lake were increasing rapidly, reaching near modern levels by about 10.3 kyr BP (Abbott *et al*., in prep.). It is possible, that with increased southerly flow during the YD chronozone, precipitation was higher in the interior, but because of the increased distance from the coast, atmospheric temperatures may not have been significantly lower. This would explain the absence of a strong pollen signal at Birch Lake during the end of the YD chronozone.

From this work we conclude that high-resolution studies are worthwhile, as they reveal subtle changes that may nevertheless represent significant environmental fluctuations. Furthermore, in a region as large as eastern Beringia, we should not expect climate changes to be similar, or synchronous, across the whole region. Mock et al. (submitted) has recently shown the synoptic-scale patterns that govern the present climate of Beringia can lead to different conditions in different regions. While some trace of the Younger Dryas may be present in Pacific coastal regions, other major climate anomalies may have affected other parts of Beringia during deglaciation. In some regions these events may have interacted, creating even more complexity in the paleoecological signal.

REFERENCES

Abbott, M. B., Finney, B. P., Edwards, M. E., Kelts, K. R., Bigelow, N. H. (in prep.).
Paleohydrology of Birch Lake, central Alaska: a multiproxy approach to lake-level records.

Ager, T. A. (1975). “Late Quaternary Environmental History of the Tanana Valley, Alaska.” Ohio State University Institute for Polar Studies, Columbus.

Ager, T. A. (1983). Holocene vegetational history of Alaska. In “The Holocene” (H. E. Wright, Ed.), pp. 128-141. Late Quaternary Environments of the United States. Vol. 2. University of Minnesota Press, Minneapolis.

Anderson, P. M. and Brubaker, L. B. (1994). Vegetation history of north central Alaska: a mapped summary of Late-Quaternary pollen data. Quaternary Science Reviews 13, 71-92.

Barber, V., Finney, B. (submitted). Late Quaternary paleoclimatic reconstructions for interior Alaska based on paleo lake-level data and hydrologic models. Journal of Paleolimnology.

Bowling, S. A. (1979). Alaska’s weather and climate. In “Alaska’s Weather and Climate” (G. Weller, Ed.), pp. 1-25. Geophysical Institute, University of Alaska, Fairbanks, AK.

Hansen, B. C. S. and Engstrom, D. R. (1996). Vegetation history of Pleasant Island, southeastern Alaska, since 13,000 yr B. P. Quaternary Research 46, 161-175.

Hare, F. K. and Hay, J. E. (1974). The Climate of Canada and Alaska. In “Climates of North America” (R. A. Bryson and F. K. Hare, Ed.), pp. 49-192. World Survey of Climatology Vol. 11. Elsevier Scientific Publishing Company, Amsterdam.

Hu, F. S., Brubaker, L. B., Anderson, P. M. (1993). A 12,000 year record of vegetation change and soil development from Wien Lake, central Alaska. Canadian Journal of Botany 71, 1133-1142.

Hu, R. S., Brubaker, L. B., Anderson, P. M. (1995). Postglacial vegetation and climate change in the northern Bristol Bay region, southwestern Alaska. Quaternary Research 43, 382-392.

Hultén, E. (1968). “Flora of Alaska and Neighboring Territories.” Stanford University Press, Stanford, CA.

Mikolajewicj, U., Crowley, T. J., Schiller, A., Voss, R. (1997). Modeling teleconnections between the North Atlantic and North Pacific during the Younger Dryas. Nature 387, 384-387.

Mock, C. J, Bartlein, P. J., Anderson, P. M. (submitted). Atmospheric circulation patterns and spatial climatic variations in Beringia. International Journal of Climatology .

Peteet, D. M. and Mann, D. H. (1994). Late-glacial vegetational, tephra, and climatic history of southwestern Kodiak Island, Alaska. Ecoscience 1, 255-267.

THE AGE OF THE FISHCREEKIAN TRANSGRESSION AND THE LAST WARM PLIOCENE INTERGLACIAL

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Outline:
The Gubik Formation contains 6 transgressive units
No work on these in over 10 years but age is controversial.
Important when we discuss the climatie evolution of the arctic.
Very warm interglacial at 2.1 My or 1.2 my - impacts our view of the arctic and its role in the intiation of repeated phases of norhtern hemisphere glaciation

standard view as published in JBG and Carter
Younger view of McDougall
View of Repenning
Veiw of Hopkuns
View of the aspartic acid data

regional comparison and paleotemp reconstructions

summary.

WISCONSIN GLACIAL CHRONOLOGY OF THE WESTERN AHKLUN MOUNTAINS, SW ALASKA: ^{36}Cl AGES FROM WATTAMUSE VALLEY

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The Ahklun Mountains, southwestern Alaska, contain the highest, westernmost summits in North America, and are one of few glaciated regions in Alaska outside of the Cordilleran Ice Sheet. The timing of Wisconsin glacial advances is poorly understood due to a lack of datable material. Surface exposure dating using cosmogenic isotopes provides age control for otherwise undatable surfaces, and is increasingly being used to constrain the timing of glacier fluctuations.

This study is concentrated along the western flank of the Ahklun Mountains where valley glaciers repeatedly expanded from cirques independently from the eastern Ahklun Mountain ice cap. Parts of the area are underlain by lithologies suitable for surface exposure dating using ^{36}Cl. Wattamuse valley, a small SE facing valley located 30 km NE of Goodnews Bay, was investigated during the summer of 1996 (Figure 1). Nine boulders, each 1-2 m in diameter were sampled from two moraines, one 2 km down-valley from the cirque headwall (moraine W2) and a second smaller moraine within the cirque (moraine W1). In addition, we sampled three large (2-3 m) boulders in drift near the valley floor, 0.5-1.0 km down-valley of moraine W2. The mean age for two boulders from moraine W1 is 23,900±200 (1∂) ^{36}Cl yrs, and for five boulders from moraine W2 is 28,300±6900 (1∂) ^{36}Cl yrs. Two boulder ages, one from each moraine, were excluded from the mean calculations due to old ages (>3∂ from the mean) that suggest prior exposure. While the mean ages of the two moraines differ by ≈4000 ^{36}Cl yrs, because of the inter-sample variability, we cannot exclude the possibility that they are the same age. The exposure ages of the three boulders down-valley from moraine W2 are problematic. Ages range from 8800 to 40,900 ^{36}Cl yrs. The young age suggests that some boulders have been rotated since deposition, most likely from solifluction that is active on these slopes. Assuming unstable slope conditions, we should consider the oldest age to be a valid minimum for the surface. These boulders were deposited prior to moraine W2, most likely during an early Wisconsin advance. The absence of moraines down-valley suggests that, during the early Wisconsin, the Wattamuse glacier was confluent with an outlet lobe that extended down the Goodnews trough from the central ice cap.

Using the median altitude method for estimating paleo-ELAs, the late Wisconsin (≈28 ka) glacier in Wattamuse valley had an ELA of ≈360 m asl. The smaller cirque moraine suggests that sometime after ≈28 ka, the ELA retreated to ≈ 380 m. No ice has existed in Wattamuse valley since deposition of moraine W1, therefore, ELAs there never lowered below about 380 m after ≈24 ka. For ice to be confluent with an outlet lobe during the early Wisconsin, as the absence of a down-valley moraine indicates, the ELA needed to be as low as ≈320 m, about 40 m lower than during the late Wisconsin maximum. From Wattamuse valley, ELAs rise to the northeast. Modern glaciers in the highest part of the range, ≈130 km NE of Wattamuse valley, have ELAs of ≈900 m. Unglaciated mountains as high as 760 m near Wattamuse valley suggest that the modern local ELA is somewhere between 760 and 900 m. Therefor, during the late Wisconsin maximum, the local ELA was depressed at least 380 m, assuming a modern-like regional ELA gradient existed during the late Wisconsin. This depression is much less than for most glaciers aound the globe during the LGM.

HOLOCENE COASTAL GLACIATION OF ALASKA

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Chronologies of Holocene glacier movements and related climate change along the coast of Alaska are relevant to the migration of native Americans. Impacts include, for example, the presence/absence of physical ice barriers and changes in biological productivity of coastal regions. The cirque glaciers of the Seward Peninsula and particularly seven groups of land- and fjord-terminating glaciers that extend over 1000 km along the Gulf of Alaska between the Kenai Peninsula and Glacier Bay, are a major source of such data. New chronologies from half of these Gulf coastal sites incorporate the precision of tree-ring dating.

Early through middle Holocene climate variations may have been insufficient to generate glacial expansion beyond present positions in the low mountains of the Seward Peninsula or along the maritime Gulf of Alaska sites. Indications of some land-terminating and fjord glacier advances preceding 4000 yr BP occur only below the 3000- to 4000-m-high peaks of the Fairweather Range in Glacier Bay and at Lituya Bay on the open ocean. However, widespread but typically incomplete evidence suggests that expansions of fjord- and some land-terminating glaciers in the Gulf were underway between 3800 and 3000 yr BP. This is compatible with abundant published botanical evidence for marked cooling as well as increase in precipitation and storminess by this time.

Recessions or inactivity of land and fjord-terminating glaciers centered on 2000 yr BP is implied by the paucity of data for that interval in the Gulf and elsewhere in Alaska. Evidence of renewed fluctuation of fjord glaciers and minor expansions of land-terminating glaciers at all Gulf sites is markedly more abundant between 1700 and about 900 yr BP. The succeeding 150 years, centered on the early 12th century AD (Medieval Optimum) was an interval of recession for land-terminating glaciers in Alaska. However, many calving fjord glaciers continued advances through this interval, reaching Little Ice Age maxima between the 1600s and the turn of the 20th century.

Little Ice Age glaciation, starting about AD 1200 (750 yr BP), and extending through the 19th century, was the most marked as well as ubiquitous glacial event across the State of Alaska. During this interval, the majority of Alaskan glaciers reached their Holocene maximum expansions. Equilibrium line altitudes were depressed on average of 150 to 200 m from present values.

The group of land-terminating glaciers with the most precisely dated chronologies are based on tree-ring dating from western Prince William Sound and southern Kenai Mountains. These display three major intervals of Little Ice Age advance. Expansions were centered on the 13th or early-Middle 15th centuries respectively, the middle 17th century and the last two decades of the 19th century. While local factors must have controlled the relative strength of glaciation, the middle-17th century advances may be the most pervasive across the coastal study areas.

BERINGIAN PARADOXES - INVESTIGATING THE LATE PLEISTOCENE HUMAN BIOGEOGRAPHICAL DISPERSALS BETWEEN EURASIA AND NORTH AMERICA

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It is believed that an increasingly large series of both major and minor, true and untrue “paradoxes” make it difficult, if not impossible for many researchers, to develop a correct appreciation of various important aspects of Late Pleistocene Beringian human geography, i.e. dispersal(s) from Asia, regional Beringian colonisation and implantation, and further southern dispersal(s) in American continental latitudes and beyond.

Beginning with a discussion of the “Productivity Paradox” — which has for years served to stimulate discussions of the Beringian ecosystem, and is also an important theme of the present Workshop, this paper will attempt to examine those areas of the Late Pleistocene Beringian scientific interdisciplinary discourse that show signs of paradoxicality, contradiction, ambivalence and, even, absurdity.

Particular attention, in this regard, will be given to the “Beringian Temporal Paradox” which makes it difficult, if not impossible, to accommodate within the boundaries of a “short” inter-continental cultural chronology the immense cultural variability that must be the archaeological reflection of a chronologically lengthy and geographically extensive complex colonisation process.

MOLECULAR PHYLOGEOGRAPHY OF AMPHIBERINGIAN MAMMALS

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Several lines of evidence indicate that Beringia served as a corridor for flora and fauna between North America and Asia at various intervals in the Cenozoic. In addition, Beringia served as a major refugium for many mammals. These dual roles had a significant impact on the evolution of various mammal groups. Most research to date concerning the origins and historical biogeography of Beringian mammals has relied on their existing taxonomies. Phylogenies can often provide information beyond that available by taxonomy alone, including the sequence of branching events among taxonomic groups and, if molecular data are used, branch lengths, which can be used to infer age of divergence between selected groups (see figure). Estimating the age of invasions may help elucidate the different roles Beringia has had in shaping current relationships and distributions. By recovering the branching events (phylogenies) for several groups, we can explore common themes across geography. We describe some of the questions evolutionary biologists and mammalogists have addressed regarding Beringian mammals as we attempt to recover the phylogeographic history of mammals across Beringia, the dynamics of secondary contact with relictual populations, and the relative ages of different taxa. We discuss molecular approaches to these questions, using examples from rodents, insectivores, lagomorphs, and carnivores.

LATE PLEISTOCENE/EARLY HOLOCENE HUMAN ADAPTATIONS AND THE NORTHWEST COASTAL CORRIDOR

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The concept of the Bering Land Bridge is a cornerstone in American archeology. In addition to explaining the exchange of large terrestrial mammals between Asia and North America, it is presumed that human hunters of large terrestrial mammals first entered North America from Asia via the Land Bridge. It is further hypothesized that humans then moved south through central western Canada after the continental glaciers melted. Some researchers (Fladmark 1979, 1983, Dixon 1993, Gruhn 1994) alternatively suggest that the earliest human migration to North America may have occurred with the use of water craft along the southern margin of Beringia and then southward along the northwest coast of North America. This would have enabled humans to enter southern areas of the Americas prior to melting of the mid-continental glaciers. Some archeologists believe southward migration from Beringia into the Americas may have begun as early as 50,000 BP, or possibly earlier, while others suggest it may have been as late as 11,000 - 12,000 BP. The interior model for human colonization requires an economy based on hunting terrestrial mammals and fresh water fishing and pedestrian travel, while the coastal hypothesis suggests an economy based on marine mammal hunting, salt water fishing/shellfish gathering, and the use of water craft. It is important to address these hypotheses because each requires different types of adaptations by the New World founding population. The nature of this adaptation provided the foundation for subsequent New World cultural development.

The mid-continental colonization model postulates that humans first entered the southern areas of North America by gradually colonizing recently deglaciated terrain or through a postulated ice-free corridor. Important radiocarbon dates used to support the existence of an ice-free corridor (or which suggest early deglaciation of the central Canada during the last glacial) are incorrect (MacDonald 1987). The distribution of quartzite erratics derived near the headwaters of Alberta's Athabasca River, (Jackson et al. 1997) demonstrates the coalescence of the Cordilleran and Laurentide ice over an extensive area in southern Alberta (Jackson et al. 1997) and that the coalesced continental glaciers did not melt in southern Alberta until sometime about 11,000-12,000 RYBP (radiocarbon years before present) (Jackson et al. 1996:223). Beringia and the unglaciated areas of North America remained separated by the continental glacier until ca 11,000 RYBP when the glaciers had melted enough to enable people to move from eastern Beringia southward into the more southern areas of North America (Rutter 1984, Clague et al. 1989, Jackson et al. 1996, 1997). Following this scenario, the North American continent south of the continental glaciers could not have been colonized by humans until sometime about 11,000 RYBP.

Prior to the early 1970's it had been assumed that the Cordilleran ice extended westward to the margins of the continental shelf (Coulter et al. 1965, Nasmith 1970, Prest 1969) thus creating a barrier to human migration. More recent geologic and paleoecologic studies document deglaciation and the existence of ice-free areas throughout major coastal areas of British Columbia by ca 13,000 RYBP (Blaise et al. 1990, Bobt in recent years). The remains of large omnivores such as black and brown bears and other land animals, including caribou, have been found in Southeast Alaska dating between 12,500 and 10,000 RYBP (Heaton 1995, 1996, Heaton and Grady 1993, Heaton et al., 1996) demonstrating that sufficient subsistence resources were available to support humans (Dixon 1995).

Because of the misleading early geologic interpretations, the region has not been subject to research equivalent to that which has occurred in non-coastal eastern Beringia, but significant advances are now being made. The Northwest Coast Microblade tradition is documented as early as 10,000 BP in British Columbia and Southeast Alaska. Archeological sites ascribed to this tradition share the use of microblades, and exhibit a marine economy documented by limited faunal remains and isotopic analysis of human remains (Dixon et al 1997), and the ecological setting of the sites. Northwest Coast microblade tradition subsistence practices were adapted to an environment characterized by year round open water, rugged coast characterized by fjords, islands, and rocky headlands, calving glaciers, major salmon runs and inter tidal shell fish. It has not been determined when this tradition first appeared along the Northwest Coast. Rising sea level inundated most coastal areas older than ca 9500 RYBP. However, these sites provide a limiting date greater than 10,000 RYBP for human occupation of the Northwest coast, maritime adaptation, and the use of water craft. These complex traits were probably proceeded by long developmental process, suggesting that regional adaptation began much earlier. Increasing evidence indicates that Clovis peoples also used the coast. The Richie Roberts Clovis cache near Wenatchee, Washington is less than 150 km from the ocean. Clovis points have been reported from a coastal site in Mendocino County, California (Simons et al. 1985) and on the coast near Santa Barbara (Erlandson et al. 1987).

Archeological evidence necessary to evaluate the coastal migration hypothesis is difficult to detect because rising sea level at the close of the Pleistocene inundated much of the continental shelf. However, the coastal migration hypothesis is supported by evidence from several controversial pre-12,000 RYBP archeological sites in North and South America and from Month Verde, an archeological site in southern Chile which is securely dated to ca 12,500 RYBP (Dillehay 1984, 1997). If the coastal migrated hypothesis it to be fully evaluated, the late Pleistocene coastal archeology of western Norm America requires research efforts equivalent those which have traditionally focused on the late Pleistocene/early Holocene archeology of mid-continental North America.

REFERENCES

Clague, J. J., et al., 1989 Chapter 1. Quaternary Geology of the Canadian Cordillera. In Quaternary Geology of Canada and Greenlanmd, R. J. Fulton, ed. Geological Society of Canada, Geology of Canada no. 1.

Coulter, H. W., D. M. Hopkins, T. N. V. Karlstrom, T. L. Péwé, C. Wahrhaftig, and J. R. Williams, 1965 Map showing extent of glaciations in Alaska. In: U. S. Geological Survey Miscellaneous Geologic Investigations Map, I-415, scale 1:2,500,000.

Dillehay, T. D., 1984 A Late Ice-Age Settlement in Southern Chile. Scientific American 251(4): 100-109.

Dillehay, T.D., 1997 Monte Verde, A Late Pleistocene Settlement in Chile. Vol. 2, The Archaeological Context and Interpretation. Smithsonian Institution Press, Washington and London.

Dixon, E. James, 1993 Quest for the Origins of the First Americans. University of New Mexico Press, Albuquerque.

Dixon E. James, 1995 The Significance of Southeast Alaska Karst. The Alaskan Caver, 15(2):1-3.

Dixon, E. J., T. H. Heaton, T. E. Fifield, T. D. Hamilton, D. E. Putnam, and F. Grady, 1997 Late Quaternary Regional Geoarchaeology of Southeast Alaska Karst: A Progress Report. Geoarcheology: 61

Erlandson, Jon M., T. Cooley, and R. Carrico, 1987 A fluted projectile point fragment from the southern California coast: chronology and context at CA-SBA-1951. Journal of California and Great Basin Anthropology 9: 120-128.

Fladmark, K R., 1979 Routes: Alternative Migration Corridors for Early Man in North America. American Antiquity 44:55-69.

Fladmark, K. R., 1983 Times and Places: Environmental Correlates of Mid- to Late Wisconsin Human Population Expansion in North America. In Early Man in the New World, edited by Richard Shutler, pp. 13-42. Sage Publication, Beverly Hills.

Gruhn, Ruth 1994 The Pacific Coast Route of Entry: An Overview. Method and Theory for Investigating the Peopling of the Americas. Robson Bonnichsen and D. Gentry Steele, eds., Center for the Study of the first Americans, Oregon State University, Corvallis.

Heaton T. H. 1995 Middle Wisconsin Bear and Rodent Remains Discovered on Prince of Wales Island, Alaska. Current Research in the Pleistocene. 12:92-95.

Heaton T. H. 1996 The Late Wisconsin Vertebrate Fauna of On Your Knees Cave, Northern Prince of Wales Island, Alaska. Journal of Vertebrate Paleontology 16:40A41A.

Heaton, T. and F. Grady 1993 Fossil Grizzly Bears from Prince of Wales Island, Alaska, Offer New Insights into Animal Dispersal, Interspecific Competition, and Age of Deglaciation. Current Research in the Pleistocene 10:98-100.

Heaton, T. H., S. L. Talbot and G F. Shield 1996 An Ice Age Refugium for Large Mammals in the Alexander Archipelago, Southeastern Alaska. Quaternary Research 46(2):186-192.

Jackson, Lionel E. Jr., and Alexandra Duk-Rodkin 1996 Quaternary geology of the ice free corridor: glacial controls on the peopling of the NewWorld in Prehistoric Mongoloid Dispersals. Takeru Akazawa and Emoke J. E. Shimamaru, eds. Oxford University Press.

Jackson, Lionel E., Jr., Fred M. Phillips, Kazuhura Shimamura, and Edward C. Little 1997 Cosmogenic ^{36}CL dating of the Foothills erratics train, Alberta, Canada. Geology 25(3):195-198.

McDonald, Glen 1987 Postglacial Vegetation History of the McKenzie River Basin. Quaternary Research, 28(2):244-262.

Nasmith, Hugh W. 1970 Pleistocene geology of the Queen Charlotte islands and southern British Columbia. In: Early Man and Events in Northwestern North America, R A. Smith and J. Smith, eds., pp 5-9. Universiyt of Calgary

Prest, V. K 1969 Retreat of Wisconsin and Recent Ice in North America. Geological Survey of Canada Map 1257A

Simons, Dwight D., Thomas N. Layton, and Ruthann Kundson 1985 A Fluted Point from the Medocino County Coast, California. Journal of California and Great Basin Anthropology 7:260-269.

Rutter, N. W. 1984 Pleistocene Histery of the Western Canadian Ice-Free Corridor. In.
Quaternary Stratigraphy of Canada — A Canadian Contribution to IGCP Project 24, ed. R. J. Fulton. Geological Survey of Canada, Paper 84-10, p. 49-56.

LATE QUATERNARY GLACIAL HISTORY OF THE COLD BAY REGION OF THE ALASKA PENINSULA

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Cold Bay, at the western end of the Alaska Peninsula, opens southward to the Pacific Ocean. Till deposited during late Wisconsin time from an ice lobe draining a continental-shelf ice cap occurs throughout the Cold Bay lowlands up to 270 m elevation. This Cold Bay till forms a moraine complex consisting of four moraines. Granodiorite and red chert within the till indicate that a component of ice likely came from south of Cold Bay near Sanak and Long islands. Similar deposits form moraine complexes at the heads of Morzhovoi Bay to the west and Pavlof Bay to the east.

Major alpine advances appear to have occurred asynchronously with ice-cap advances. A late-Wisconsin ice-cap (Cold Bay II) moraine partly overlies the youngest possibly pre-late Wisconsin alpine moraine. Outwash channels are cut from the Cold Bay II moraine into flat-lying sediments on the ice-proximal side of the alpine moraine. Thus landforms indicate that alpine ice retreated by the time the ice cap was at or near its maximum position during late Wisconsin time. Absolute timing of this asynchrony is not known. Deglaciation was underway by 11,530±200 ^{14}C yr BP. Moraines in western, northern, and eastern valleys of Frosty Peak record at least two latest-Wisconsin alpine advances that occurred before 9,090±140 ^{14}C yr BP.

A numerical model suggests that alpine glaciers could have merged on the continental shelf forming a dome with a northerly flow component. Although modeling results indicate that ice may have thinned on the mountain peaks during the last glacial maximum, the model lacks the resolution to clearly distinguish the behavior of alpine glaciers.

Terminal moraines in the northern valleys of Frosty Peak preserve a record of at least four Holocene alpine advances after 1,190±120 ^{14}C yr BP. Three of these advances likely occurred during the Little Ice Age. No record of early Holocene glaciation is preserved in the valleys of Frosty Peak. Holocene sediments are dominated by wind-blown sand and volcanic ash. Wind-blown sand occurs both as sand caps over till and as dune fields. At least three extensively deposited tephra units occur in the Cold Bay area. Where sand is discontinuous over till, the tephra layers are typically also discontinuous, with at least one exception. In a beach bluff exposure along Cold Bay approximately 2 km south of Delta Point, the lowermost of these tephra units, a pumice layer directly overlies the Cold Bay till. The differences in the preserved records of alpine glaciation of three volcanic peaks immediately surrounding Cold Bay could be due to differences in volcanic history of each volcano. All three volcanoes have apparently been active since the last interglacial.

MID-PLIOCENE TO MID PLEISTOCENE GLACIATIONS IN THE TINTINA TRENCH, DAWSON AREA, YUKON TERRITORY

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Stratigraphic work following regional Quaternary mapping in the Dawson area has revealed a series of glacial and interglacial events of late Gauss to late Matuyama age. These events are represented by outwash, till and loess sequences with paleosols. Of the many sites studied two main sites are described here to which other sites are correlated, Eastfifteenmile Site and Rock Creek Site. These two sites are located along the north side of the Tintina Trench about 30km from each other. Stratigraphic work at both sites indicate that the glacial sequence overlies pre-glacial fluvial Tertiary strata. The glacial strata is conformably overlain pre-glacial Pliocene gravel deposits but is unconformably overlaying older deposits most likely Miocene in age.

Preliminary paleomagnetic determination of the glacial sequence at Eastfifteen Mile Site has revealed a normal-reverse-normal-reverse sequence. The base of the sequence has gravel and sand deposits (normal), most likely distal outwash deposits, followed by three tills (reverse-normal-reverse), each of them capped by a paleosol of one to 3 metre thick. The top of the exposure has two reverse loess deposits. This exposure has about 12 metres covered at top. The paleosols are atypical wounded moose paleosols. Preliminary paleomagnetism at Rock Creek Site shows also a normal-reverse-normal-reverse glacial sequence. The basal deposit is a normal outwash overlain by a reverse till with a paleosol which underlies another till with a paleosol of unknown age. The unknown till is overlain by a normal outwash and till with a paleosol which is subsequently overlain by a reversed outwash sequence.

A composite stratigraphy of these two sites includes a basal outwash sequence of Gauss age (normal) which is overlaying by a reversed (early Matuyama) - normal (Olduvai) - reversed (mid and late Matuyama) tills, outwash and loess deposits. The main reason for assigning these ages are based on the fact that the Olduvai subchron included cold periods for glaciers development and interglacial periods long enough to developed thick paleosols unlikely the Jaramillo subchron. Also, elsewhere in the region outwash deposits associated with the first glaciation in the region have yielded Gauss normal polarity. Furthermore, pre-glacial gravel deposits of Pliocene in age have yielded the same age associated with the first glaciation in the region. This record represents at least seven glacial events from late Pliocene to Mid Pleistocene, the oldest and longest record in Canada.

LATE-QUATERNARY PALEOHYDROLOGY AND PALEOCLIMATOLOGY OF EASTERN INTERIOR ALASKA

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Effective moisture (EM) has important effects on vegetational, geomorphic, glacial, and fluvial systems, yet is often poorly understood in the paleoclimatological record. In the northern boreal zone of interior Alaska evidence of past vegetation change, previously widespread eolian activity, and changing glacial and fluvial dynamics suggests the major landscape changes of the late Quaternary have involved large changes in moisture availability. A better knowledge of past moisture changes is important for validating simulations of past EM and precipitation by various types of climate models. Reconstructing past precipitation is particularly difficult because it is hard to separate temperature and precipitation changes in many proxy-climate records. Lake-level changes can provide a key to understanding past changes in EM, and through water-balance modelling, they can be interpreted in terms of quantitative estimates of paleoprecipitation.

Lake level is, broadly speaking, a function of inputs from precipitation (P) and groundwater minus exports via evaporation (E, including evapotranspiration (ET)) and groundwater. Where groundwater is negligible, lake-levels become a function of P-E, a system that can be modelled fairly easily. Few attempts have been made to assess lake-level histories in arctic or subarctic lakes, possibly because many regions have a strongly positive moisture balance today. However, closed-basin lakes may be highly responsive to changes in P-E and should have a record of lake-level changes. Even open-system lakes today may have been closed in times of lower EM, especially in a region such eastern interior Alaska, where water deficits are commonly experienced under modern climatic conditions, and evidence (such as widespread eolian deposits) suggests that it was even drier in past times.

In a pilot study over the past five years, we have reconstructed lake-level, effective moisture, and paleoprecipitation in eastern interior Alaska, a region of extreme continental climate defined by latitudes 67-63°N and longitudes 140-145°W. A further goal was to develop AMS chronologies and high-resolution pollen records in order to estimate the timing of vegetation changes accurately and compare them with changes in EM. Finally, we examined the paleoclimatological implications of the new data, both in terms of the broad-scale, long-term changes simulated by CGMs for Alaska, and, through the use of modern analogues, in terms of the synoptic-scale climate configurations that might have given rise to past conditions of temperature and precipition. We studied four lakes, two with closed basins (Jan and Dune) and two with marginally open systems (Birch and Sands of Time). Birch Lake was the most intensively studied; we used sediment-core transects, seismic profiling, and central-core proxies such as LOI, magnetic susceptibility, aquatic pollen, and del^{13}C to reconstruct the actual water level from ca 12,500 ^{14}C yr B.P. until present. Other lakes were studied with a sub-set of these techniques.

Prior to ca 12,000 ^{14}C yr B.P., all lakes were extremely low, intermittent or dry; lakes subsequently began to fill but over the next 3000-4000 years remained below present levels. A further rise is indicated ca. 8500 ^{14}C yrs ago. Depending upon individual hydrology, lakes reached current levels 6000-5000 ^{14}C yrs ago, with closed-basin Jan Lake reaching one or more stands higher than present in the mid or late Holocene (these are undated). At Birch Lake we can refine this lake-level chronology. The lake today has a maximum depth of ca 12 m, and about 5 m of sediment has accumulated since ca 12,500 ^{14}C yr B.P. The rise at ca 12,000 ^{14}C yr B.P. was rapid and reached 5-8 m below present level. Levels remained relatively high until ca 11,500 ^{14}C yr B.P., when they dropped to 10 m below present. A second relatively high stand that reached 5-8 m below present level occurred between 10,500 and 9800 yr B.P. Subsequently levels were lower and probably fluctuating. The final major rise began ca 8500 years ago and ended in the lake achieving overflow, but this may have accurred as late as 6000 ^{14}C yr B.P. The lake-level changes are large and indicate that major changes in effective moisture occurred during deglaciation. Eastern interior Alaska was drier than present until ca 6000 yr B.P., but some time after that there may have been one or more periods when effective moisture was higher than present.

We developed simple water-balance models for Jan and Birch Lakes for 12,000, 9000, and 6000 ^{14}C yr B.P., using precipitation, evaporation, and ET to derive solutions that maintained the reconstructed water level. We used the pollen record to define the zonal paleovegetation and used values for evaporation and ET from modern studies in those vegetation types. The solutions for both basins are very similar, despite differences in catchment area and lake morphometry. Precipitation was probably 30-60% that of modern at 12,000 ^{14}C yr B.P., 60-90% at 9000 ^{14}C yr B.P., and 80-90% at 6000 ^{14}C yr B.P.

Pollen data indicate cooler temperatures than present at 12,000 ^{14}C yr B.P.; temperatures were as high, or higher than present at 9000 and 6000 ^{14}C yr B.P. In order to understand the climatic patterns that could give rise to cooler and drier or warmer and drier conditions in eastern interior Alaska, we created averaged maps of major synoptic patterns for significantly anomalous conditions based on modern July climate data in Fairbanks. Results for cool/dry suggest the persistence of spring synoptic patterns into the summer, with the jet-stream displaced southward of its normal modern position and cold polar air affecting much of Alaska. Warm/dry conditions are generated when there is a strong ridge north of Alaska and a weakened northern edge of the eastern Pacific subtropical high (which could reflect a southerly displacement of the high); these conditions reduce westerly flow into the Alaskan interior. The patterns of temperature and precipitation associated with these specific conditions show that there are regional differences across Beringia, which may be used i) to explain different climatic responses observed in the Beringian proxy records, and ii) as hypotheses with which to explore further the paleoclimatic history of Beringia.

The lake-level data reveal some new insights into vegetation history. The birch rise, which is the first major transformation of the vegetation during deglaciation, is clearly coincident with the first major increase in EM. The AMS dates place this between 12,500 and 12,000 ^{14}C yr B.P., later than some conventionally dated records in the region. Secondly, the early-Holocene increase in white spruce, at about 8500 ^{14}C yr B.P., is coincident with the final major increase in EM, when precipitation reached 80-90% of present values; this suggests a sensitivity of white spruce to EM, and it may be that the spruce expansion in eastern Alaska was dependent upon moisture.

MICROFOSSIL ANALYSIS OF DRAINED THAW LAKE BASINS IN BARROW, ALASKA: IDENTIFYING TUNDRA VEGETATION PATTERNS

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Paleoecology is a discipline which can enhance our understanding of the interactions of vegetation, climate, and carbon storage in the Arctic. However, patterns of past vegetation change derived from paleoecological data may be interpreted as a climate signal when, in fact, they are due to local effects. Plant succession and landscape evolution occur and vary independently from climate change, and a major pitfall in paleoecology is the confusion between local and regional signals.

The key to understanding paleoenvironmental change in the Arctic is understanding the spatial and temporal scale at which the most significant changes occur. The geomorphic factors which most profoundly effect modern vegetation on the North Slope of Alaska are those related to cryogenic processes. Ice-wedge development, depth of summer thaw, thaw lake evolution, and eolian deposition impact the tundra on a wide range of spatial scales. Paleoecological and ecological patterns of change and complexity are discernible at different geographic scales. At the plot scale (1 to 100 meters), tussock development, ice wedge formation, and polygon plant succession affect patterns of change in single vegetation formations. Thaw lake processes operate at the landscape scale (0.1 to 10 km). The mesoscale (10 to 100 km) and global scale (greater than 100 km) reflects the influence of climate on entire ecosystems. Patterns of vegetation change are also evident at varying time intervals: long term changes (10^3-10^4) or shorter term required for plant succession (10^2 - 10^3).

We present findings from two pollen and microfossil studies from: (1) a polygonal landscape in Atqasak, Alaska, and (2) 14 drained thaw lakes near Barrow, Alaska. We intentionally selected sites where we could identify the dominant landscape process. We then searched for patterns of change in pollen, spores, other microfossils to establish past local vegetation succession and landscape evolution based on our understanding of polygon formation and the thaw lake cycle.

The pollen stratigraphy from thaw lake sediments has been found to contain a considerable amount of "noise," (Anderson, P. M., Reconstructing the past: The synthesis of archaeological and palynological data, northern Alaska and northwestern Canada, 1982) Unpublished Ph.D. Dissertation thesis, Brown University). However, the drained thaw lake basins are relatively stable depositional environments containing extensive *in situ* peat deposits. These represent a potential major resource of paleoecological information, recording the processes of plant succession and carbon sequestration since the early Holocene began about 10,000 years ago.

Thaw lake sediments may be more prevalent in fossil form, and more valuable for vegetation reconstruction, than formerly thought (Hopkins, D. M. and Kidd, J.G. Thaw lake sediments and sedimentary environments. *In* Permafrost 5th International Conference, Tapir Publishers, Trondheim, pp. 790-795, 1988). The study of these sediments, and the comparison of ancient thaw lake sediments with modern thermokarst environments, can be applied not only to the Alaskan material, but also to similar environments. The thaw lake cycle is a probable explanation for some of the spectacular Yedoma-*alass* formations of Northeast Siberia. The reconstruction of successional thaw lake communities for the last 1000 to 3000 years will make an important contribution to our knowledge of the geomorphology of the region as well as to future interpretations of pollen profiles derived from single points in the mosaic of communities which make up the Beringian landscape.

THE REGIONAL EXTENT OF STEPPE-TUNDRA IN ALASKA

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Steppe-tundra is thought by some authors to have dominated large regions of Beringia during glacial intervals. Guthrie (1990) suggested that steppe-tundra formed an unbroken belt from the Yukon Territory to western Siberia. Other authors have discussed differences between steppe-tundra environments in eastern and western Beringia (e.g., Giterman et al., 1982), but likewise assumed that some form of steppe-tundra dominated many regions in the Pleistocene. Matthews (1982) identified a beetle fauna that typifies steppe-tundra habitats, based fossil assemblages from interior Alaska and the Yukon Territory. His *Lepidophorus-Morychus* group is indicative of the sort of cold, dry environments associated with steppe-tundra habitats. Faunal assemblages dominated by the pill beetles in the genus *Morychus,* by the weevil, *Lepidophorus lineaticollis*, and by a few other indicator taxa are common in many of the Pleistocene deposits that Matthews studied. However, my work in southwestern Alaska (summarized in Elias, 1992a), failed to yield even one assemblage dominated by these typical steppe-tundra beetles. My subsequent work on fossil beetle assemblages from the Bering Land Bridge and from the Noatak River region of the western Brooks Range also produced no steppe-tundra beetle assemblages. The paleobotanical studies done in concert with the fossil insect research in southwestern Alaska and the Bering Land Bridge also failed to find evidence of steppe-tundra vegetation (Elias et al., 1996a; Lea et al., 1991). As the work progressed, it became clear that steppe-tundra did not dominate all of Eastern Beringia, and that it was perhaps more restricted in areal extent that most workers realized.

We are still a long way from defining the extent of steppe-tundra in Eastern Beringia, but have made sufficient progress to begin to detect some geographic patterns in steppe-tundra vs. mesic tundra. Figure 1 shows Wisconsinan fossil insect assemblage sites in Eastern Beringia and the Bering Land Bridge. The white dots indicate assemblages dominated by steppe-tundra faunas. The black dots indicate assemblages dominated by mesic tundra species, including ground beetles in the *Cryobius* group of the genus *Pterostichus* and rove beetles in the omaliinae group. These groups of beetles are mostly found today in mesic and moist habitats, as opposed to the xeric habitats preferred by members of Matthews' *Lepidophorus-Morychus* group. The figure reveals as much about gaps in our knowledge as it does about regional faunal patterns, but it serves well enough as a point of departure. Based on this map, it appears likely that all of the ice-free regions of the Yukon and central Alaskan interior were dominated by steppe-tundra habitats. On the Alaskan North Slope, Nelson and Carter's (1987) full glacial assemblages were dominated by the *Lepidophorus-Morychus* group. To the south, full-glacial beetle assemblages from sites in Denali National Park also contained substantial numbers of *Lepidophorus lineaticollis*, although other elements of the steppe-tundra fauna were not found (Elias *et al*., 1996b). The southernmost fossil assemblage dominated by the steppe-tundra fauna comes from the Colorado Creek site, near McGrath (Elias, 1992b). The juxtaposition of the Colorado Creek steppe-tundra assemblage and the mesic tundra beetle assemblages from the Kuskokwim River, about 75 km southeast of the former site, suggests that mesic tundra clothed the lowlands of this region while steppe-tundra clothed the uplands between the Kuskokwim and Yukon river drainages. The most tightly-constrained boundary between steppe-tundra and mesic-tundra beetle assemblages falls on the Seward peninsula. Here, mesic-tundra assemblages have been found from Wisconsinan deposits on the Baldwin Peninsula (Hopkins *et al*., 1976) and at Cape Deceit (Matthews, 1974), while steppe-tundra assemblages have been found in deposits from Bering Land Bridge National Park (Goetcheus and Elias, unpublished data). All of these sites are near modern sea level, and would have been only a few meters higher in elevation than Wisconsinan assemblages from the Bering Sea shelf west and south of the Seward Peninsula. The Bering shelf assemblages also contained mesic-tundra fauna and flora (Elias et al., 1996a, 1997). My most recent work on late Pleistocene fossil assemblages from the Noatak River drainage has also recovered fossil beetle faunas indicative of mesic tundra habitats, with little or no fossils from the *Lepidophorus-Morychus* group.

Eastern Beringia is a vast region, and while we have made a good beginning at unraveling its Pleistocene history, much work is left to be done. Work on the steppe-tundra question needs to advance in several ways. First, sites from unstudied regions need examination. Second, we need to develop a better understanding of the Pleistocene ecosystems of Beringia. For instance, Berman (1990) studied the habitat requirements of *Morychus* pill beetles that live in relict stands of steppe-tundra habitat in eastern Siberia. This kind of research is vital to the development of our understanding of paleoecology. Third, we need a better understanding of the taphonomic processes that affect fossil beetle assemblages from arctic landscapes. For instance, Morlan and Matthews (1983) studied steppe-tundra fossil assemblages from the Old Crow region of the Yukon and suggested that the dominance of *Lepidophorus lineaticollis* in fluvial sediments may be due to taphonomic bias in such samples. They stressed the importance of geologic studies that determine whether a given sample represents autochthonous or allochthonous deposition. Armed with more fossil data, better ecological understanding of the species in question, and a clearer sense of the taphonomy of fossil sites, we may begin to unravel the complex and fascinating questions that come out of Beringian research.

REFERENCES

Berman, D. I., 1990: Ecology of *Morychus viridis* (Coleoptera, Byrrhidae), a moss beetle from Pleistocene deposits in the northeastern USSR. In Kotlyakov, V. M. and Sokolov, V. E. (eds.), Arctic Research: Advances and Prospects. Proceedings of the Conference of Arctic and Nordic Countries on Coordination of Research in the Arctic. Moscow: Nauka Press, 281-288.

Elias, S. A., 1992a: Late Quaternary beetle faunas of Southwestern Alaska: evidence of a refugium for mesic and hygrophilous species. Arctic and Alpine Research, 24: 133-144.

Elias, S. A., 1992b: Late Wisconsin insects and plant macrofossils associated with the Colorado Creek mammoth, southwestern Alaska: taphonomic and paleoenvironmental implications. 22nd Arctic Workshop, Program and Abstracts, 45-47.

Elias, S. A., Short, S. K., Nelson, C. H., and Birks, H. H., 1996a. Life and times of the Bering land bridge. Nature, 382: 60-63.

Elias, S. A., Short, S. K., and Birks, H. J. B., 1997. Late Wisconsin environments of the Bering Land Bridge. Palaeogeography, Palaeoclimatoloy, Palaeoecology, in press.

Elias, S. A., Short, S. K., and Waythomas, C. F., 1996b. Late Quaternary environments, Denali National Park and Preserve, Alaska. Arctic, 49:292-305.

Giterman, R. E., Sher, A. V., and Matthews, J. V., Jr., 1982: Comparison of the development of tundra-steppe environments in West and East Beringia: pollen and macrofossil evidence from key sections. IN: Paleoecology of Beringia, 43-73. Hopkins, D.M., Matthews, J.V., Jr, .Schweger, C. E., and Young, S. B. (Eds.), Academic Press, New York.

Guthrie, R. D., 1990: Frozen Fauna of the Mammoth Steppe. The Story of Blue Babe. University of Chicago Press, Chicago, 323 pp.

Hopkins, D. M., Giterman, R. E., and Matthews, J. V., Jr., 1976: Interstadial mammoth remains and associated pollen and insect fossils, Kotzebue Sound area, northwestern Alaska. Geology, 4: 169-172.

Lea, P. D., Elias, S. A., and Short, S. K., 1991: Stratigraphy and paleoenvironments of Pleistocene nonglacial units in the Nushagak Lowland, Southwestern Alaska. Arctic and Alpine Research, 23: 375-391.

Matthews, J. V., Jr., 1974: Quaternary environments at Cape Deceit (Seward Peninsula, Alaska): evolution of a tundra ecosystem. Geological Society of America Bulletin, 85: 1353-1384.

Matthews, J. V., Jr., 1982: East Beringia during Late Wisconsin time: a review of the biotic evidence. In: Paleoecology of Beringia, 127-150. In Hopkins, D.M., Matthews, J.V., Jr., Schweger, C. E., and Young, S. B. (Eds.), Academic Press, New York.

Morlan, R. E., and Matthews, J. V., Jr., 1983: Taphonomy and paleoecology of fossil insect assemblages from Old Crow River (CRH-15), northern Yukon Territory, Canada. Géographie physique et Quaternaire, 37: 147-157.

Nelson, R. E., and Carter, L. D., 1987: Paleoenvironmental analysis of insects and extralimital *Populus* from an early Holocene site on the Arctic Slope of Alaska. Arctic and Alpine Research, 19: 230-241.

GCM SIMULATIONS IN THE REGION OF BERINGIA SINCE THE LGM

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The model-data comparison effort of the Paleoclimates from Arctic Lakes and Estuaries (PALE) program has involved general circulation model (GCM) simulations of several time slices since the Last Glacial Maximum (LGM). The following simulations have been run: a) 0, 6, and 10 ka BP calendar years using the Global Environmental and Ecological Simulation of Interactive Systems (GENESIS) 2.0 GCM coupled with the Equilibrium Vegetation Ecology (EVE) vegetation model; and b) two 21 ka BP simulations using GENESIS 2.0 uncoupled with EVE, with and without an East Siberian ice sheet, to ascertain the climatic impact of this ice sheet. The following are the statistically significant results from these simulations.

Greater summer insolation than present at 6 and 10 ka BP produces warmer Siberian summers and a warmer coastal Alaska at 10 ka BP. The warmer temperatures correspond with wetter conditions at 10 ka BP. Less insolation than present leads to colder winters in Beringia at 10 ka BP. The colder winters, warmer summers, and increased seasonality at 10 ka BP result in more needleleaf forest and less tundra than present throughout Siberia, while the vegetation in Alaska remains similar to present. Colder Alaskan summers in the interior during 10 ka BP and warmer Siberian winters during 6 ka BP, which are opposite the forcing, are the result of circulation changes. Lower CO_2 concentrations than present at 21 ka BP result in colder conditions in Beringia during both seasons, with corresponding drier conditions in Siberia. Wetter conditions in southeastern Alaska during summer may be partly due to a weaker North Pacific high. The colder Beringia results in more tundra and polar deserts and less forests than present. The insolation and CO_2 forcing account for most of the climatic anomalies from present. Small localized circulation changes, which are probably independent from the ice sheet forcing, account for the remainder of the climate anomalies.

The existence of the East Siberian Ice Sheet creates warmer temperatures south of the ice sheet due to subsidence resulting from anticyclonic circulation over the ice sheets. Colder temperature, however, result downstream over northern Canada when the ice sheet is present. This limited climatic sensitivity in the vicinity of the ice sheet has implications for the model-predicted vegetation in Siberia, resulting in harsher tundra conditions when the East Siberian Ice Sheet is not present.

A RECONSTRUCTION OF PLIOCENE-PLEISTOCENE TECTONICS AND CLIMATE, LOWER KLONDIKE TERRACES, DAWSON AREA, YUKON

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The lower Klondike valley and its gold-bearing tributaries, Bonanza and Hunker creeks, west-central Yukon, contain some of the best preserved and exposed late Pliocene to early Pleistocene sediments in the Canadian Cordillera. In this study, sedimentologic and paleomagnetic evidence is used to present a summary of depositional environments correlated to the geomagnetic polarity time scale.

In Pliocene pre-glacial times, gold bearing tributaries of the Klondike River, Bonanza and Hunker creeks, deposited the White Channel gravel in response to active tectonics as braid river alluvial fans with repeated cycles of aggradation and incision during the late Gilbert (?) and Gauss chrons. Climatic cooling in the late Pliocene resulted in White Channel aggradation and the first evidence of periglacial conditions (ice wedge growth). Synchronous with alluvial aggradation in the unglaciated tributaries, and interfingering with distal upper White Channel gravel, the 'Klondike Wash' gravel records the first proglacial outwash in the Klondike valley during the late Gauss (magnetically normal > 2.6 Ma). This outwash can be traced southeast to the Tintina Trench and was the result of the first late Pliocene advance of the northern Cordilleran Ice Sheet, rather than local piedmont glaciers.

An intermediate terrace in the Klondike valley indicates three successive depositional environments: first, a lowermost interglacial wandering gravel bed river sequence; second, deposition of a proximal braided river assemblage, indicating aggradation during a pre-Reid glacial event followed by incision of the terrace level; and third, beginning of aeolian-colluvial deposition. Paleomagnetic results of these previously unreported loess, re-worked loess and paleosols provides a limiting chronology for the upper terrace level, and indicates deposition through much of the Matuyama (2.6-0.78 Ma) and Brunhes (<0.78 Ma) chrons, suggesting the dominance of katabatic winds in this area of Beringia during the early to middle Pleistocene. By Reid time, ca. 200 ka, the lower Klondike River and its tributaries were near their present position.

THE INFLUENCE OF THE BERING STRAIT ON THE NORTH PACIFIC-ARCTIC ECOSYSTEM DURING THE NEOGENE

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1. Dr. D. Hopkins was among the first to reveal the great significance of the Bering Strait for the Arctic and North Pacific paleogeography and evolution of sea basins. In particular, it concerns the formation and migrations of biotic assemblages in these basins. Recent data on the Arctic and Iceland, on the one hand, and Alaska and northeastern Asia, on the over hand, suggest new approaches to the problem of the Bering Strait.

2. There are some solved and unsolved problems of the Neogene history of the Pre-Bering Strait. It was revealed that the strait was opened several times, biota migrated in different directions, etc. The unsolved problems are related to the time (Miocene or Pliocene?) and extent of the first opening of the strait, main causes of its opening and closing (tectonics or eustasy), character and directions of biotic migrations, time of the extensive Arctic glaciation and others. These problems can be adequately solved only by joint efforts of scientists from different cries. We appreciate much the great contribution of Dr. D. Hopkins to this cooperation.

GEOMORPHOLOGICAL CORRELATION OF LATE PLEISTOCENE ICE COMPLEXES OF WESTERN AND EASTERN BERINGIA

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The geomorphological analysis of ice complexes continues as one of the main methods for defining the area, characteristics, and relative age of late Pleistocene glaciations. In Beringia, each of these glaciations developed under differing orographic and climatic conditions. The mapping and the morphological, morphometric, and statistical study of the depositional and erosional processes associated with ice forms have been used to examine the extent and characteristics of the most recent Pleistocene glaciation (24 to 11.5 ka BP: Sartan glaciation in northeastern Asia; Osborne Mountain glaciation on Seward Peninsula; Itkillik II in the central Brooks Range). Recently obtained results of radiocarbon and palynological analyses have helped improve these comparisons.

The available results indicate similar extent and characteristics of the most recent Pleistocene glaciation in northern and northwestern Alaska and northeastern Asia. Glaciers developed in several separate regions, but were limited primarily to mountain valleys and cirques (however, in some areas mountain valley glaciers coalesced into larger ice networks). Previous attempts to define the extent of large glacial areas in western Beringia are questionable.

THE COLONIZATION OF SIBERIA AND BERINGIA: HARD ENVIRONMENTS, LIMITING FACTORS, AND HUMAN RANGE EXPANSION IN THE LATE PLEISTOCENE

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This paper reviews the archaeological and paleoecological record of human expansion into the Siberian subarctic and arctic in the Upper Pleistocene. Although Middle Paleolithic and initial Upper Paleolithic populations occupied the more favorable, heterogeneous environments of southern Siberia 100-26 kya, it was not until after 25 kya that the first human populations (the Mal'ta culture) expanded into northern Siberia, an event coincident with the onset of glacial conditions and possibly the formation of the mammoth-steppe. Human adaptive changes at that time seem to include changes in subsistence, technologies, and settlement. The record further suggests depopulation of the north during the last glacial maximum, 20-18 kya, and it was not until the spread of late Upper Paleolithic industries after 16 kya that humans recolonized the north and finally entered Beringia.

A MOMENT IN TIME: THE LANDSCAPE OF THE FULL-GLACIAL BERING LAND BRIDGE AT 18,000 YEARS B.P.

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In 1968 David Hopkins discovered a vegetated land surface on the Seward Peninsula that had been buried by a tephra. The surface was dated to 18,000 years B.P. The existence of a full-glacial land surface provides a unique data set for environmental reconstruction of a portion of the Bering Land Bridge. Abundant macrofossils, pollen, and insect remains indicate the environment was cold and dry. The vegetation was dominated by grasses, sedges, and herbs. The only shrubs found were two different *Salix* species which occurred at few localities.

The vegetation indicates the landscape was covered by a dry, meadowy tundra with some steppe-tundra affinities. Evidence exists that caribou and numerous small animals were living in the area during the full-glacial. It is likely that other large mammals also lived in the area.

THE EXTENT AND CHRONOLOGY OF GLACIATION IN THE ANADYR REGION OF CHUKOTKA, WESTERN BERINGIA

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This research proposes the first numerically-constrained model for the extent and chronology of glaciation in the Anadyr Region of Chukotka. The reconstruction is primarily based on cosmogenic isotope-derived surface exposure ages from glacial erratics on moraines and terraces. Cosmogenic isotope analysis has not previously been used in Russia to aid in the reconstruction of glacial histories, and the technique has only recently been employed in Alaska to verify previously dated moraine sequences in the Brooks Range and Kigluaik Mountains (Brigham-Grette, Hamilton and Glushkova). Previous work on the style and timing of glaciation in Chukotka by Russian geologists includes extensive air photo interpretation of moraines, terraces, ice marginal landforms and some radiocarbon age estimates; however, a sound geochronology has yet to be established.

Fieldwork during the summers of 1995 and 1996 in the Pekulney and Koryak Mountains, the Tanyurer, Nygchekveem and Nahodka River valleys and the Lake Mainitz region included collecting samples for cosmogenic isotope analysis and radiocarbon dating. In addition, relative age dating techniques were used to supplement the cosmogenic isotope data. The relative dating techniques include moraine morphometric measurements on terminal and lateral moraines, soil development studies on terraces and crest and midslope of moraines, and amino acid analyses of fossiliferous diamicts near the coast.

Interpreted ^{36}Cl “ages” from erratics on moraines in the Pekulney Mountains range from 20.3-28.5 ka and from 70.2-89.2 ka in the Tanyurer River valley. The cosmogenic isotope ages are minimum ranges recording the amount of time that has elapsed since the boulders were exposed on the surface of the moraines, or uncovered by ice. The younger ages imply a restricted last glacial maximum (LGM), and the older ages imply that there was an earlier more extensive ice advance that possibly could be mid-Pleistocene in age. Bulk radiocarbon age estimates between 16.9 and 23.8 ka from a 10 m arl terrace further support a restricted LGM.

In the southern Anadyr Region, terminal, lateral and medial moraines, meltwater channels, dead ice topography, kettles and outwash plains mark the LGM ice limit in the Nygchekveem and Nahodka River valleys as well as the adjacent Lake Mainitz and Lake Rocamaha areas. Common to all valleys is the presence of a 13.8 m arl glaciofluvial terrace, most likely recording deglaciation of the area during the LGM. Field evidence suggests that the glaciers of the northern Koryak Mountains reached no more than 20 km beyond their present limits during the LGM. Twenty samples are currently being prepared for cosmogenic isotope analysis to further test this hypothesis. Glaciers emanating from the southern and eastern Koryak Mountains may have extended toward the Bering Sea at lower elevations. Elevations of present cirque floors on the southern side of the range are 380-400 m, and it is likely that during the last glacial maximum, and certainly during older glaciations, ELAs were depressed nearly to sea level.

This research will help to answer specific questions regarding the Bering Sea as a viable moisture source for glacier advance in western Beringia, and if necessary, serve as a testable area by which to reconcile the differences between the glacial history on both sides of the Bering Strait. Questions concerning a north-south moisture gradient and the dependence of continental shelf proximity to glacier growth will also be addressed in further research.

ORIGIN AND CAUSES OF THE MAMMOTH STEPPE: A STORY OF CLOUD COVER, WOOLLY MAMMALS, AND THE LITTLE BUCKLE

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The core of the Mammoth Steppe was in Central Asia, in the lee of the Himalayas. During the Pleistocene, in synchrony with the Milankovich cycle, this regional aridity extended westward in Western Europe and eastward to North America and northward to the Arctic, where the exposed continental shelf magnified its size. The European extension of this cold steppe was enhanced by southern deflection of the Atlantic Current and by associated atmospheric blocking of the Scandinavian Ice Sheet. The eastward extent of the Mammoth Steppe however was partially interrupted at the Bering Strait.

Even during Glacial maxima this band of intermittent maritime cloud cover, created by the narrow bite on either side of the Bering strait, produced an ecological interruption or ‘buckle’ in the extensive steppe belt. This special habitat became a minor refuge for some mesic plants and animals. While this mesic buckle did not serve as an ecological barrier to some steppe-adapted species like woolly mammoths, ferrets, saiga antelope, steppe bison, and horses, it does seem to have limited distributions of woolly rhinos, camels, American asses, short-faced bears, badgers, and some others.

The presence of this mesic buckle had important paleoecological ramifications. It was the source of endemic plant species which, at the beginning of the Holocene, expanded into northeast Asia and northwest North America. Hultén noticed the resulting floristic cross-strait pattern and called it Beringia. However, this cross-strait unity is a Holocene artifact-a recent expansion of a narrowly regional habitat. And explicitly, it should not be mistaken as the characteristic unifying flora and fauna of the Pleistocene north. On either side of this narrow mesic band or buckle, during full Glacial, was the broad belt of complex and heterogeneous, arid-adapted, communities of the Mammoth Steppe, which virtually circled the globe, from Fort Collins to London.

GLACIAL AND INTERGLACIAL RECORDS FROM GLACIAL LAKE NOATAK, NORTHWEST ALASKA

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The Noatak basin is a broad irreglar lowland about 100 km long by 30-80 km wide that is confined between two arms of the western Brooks Range—the DeLong Mountains to the north and the Baird Mountains to the south. The basin is drained by the Noatak River, which flows west into Kotzebue Sound.

During middle and late Pleistocene time, glaciers extended down the Noatak River valley, terminating within the basin. Other glaciers that originated farther west in the DeLong Mountains flowed southeastward into the basin; these dammed the Noatak River to form a succession of lakes with surface areas as large as 4400 km^2. The poorly drained beds of these lakes cover the floor of the Noatak basin, and shoreline features are common around its flanks·

Downcutting by the Noatak River and its principal tributaries has exposed thick sediment successions in bluffs up to 86 m high. Measured sections from 62 river bluffs provide a record of depositional facies across the basin floor. Sedimentary sequences in the bluffs record multiple glacial advances and corresponding lake stages; intervening organic-bearing fluvial sediments represent both interstadial and interglacial intervals.

Till, ice-contact stratified drift, and outwash are best preserved on the eastern basin floor, where lake waters were shallow and where subsequent erosion by the Noatak river was not extensive. Glaciolacustrine sediments, which are best exposed in the western part of the basin, range from till-like proximal deposits to rhythmically laminated distal facies. Some proximal deposits contain interbeds of muddy gravel that probably formed when the lake suddenly was lowered by outbursts through the confining ice dam. Slackwater and marsh deposits, which were controlled by lake-level rise in the central basin, are present in some tributary valleys. Channel gravel and finer-grained floodplain deposits alternate with glacial deposits in the bluffs. The floodplain deposits commonly include paleosols, weathering horizons, peat beds, wood fragments, and organic silt. One bluff contains organic-rich floodplain deposits that were formed during and after deposition of the Old Crow tephra about 135±5 ka.

Radiocarbon ages on glacial deposits in the eastern Noatak basin show that the youngest glacial advance is of late Wisconsin age, and that the preceding interstadial alluvial episode was well established by 35,000 ^{14}C yr B.P. Marsh and fluvial deposits in the southern part of the basin, which have corresponding radiocarbon ages, demonstrate a correlative history of base-level rise and fall. The deep stratigraphic exposures in the western part of the basin can be dated in part by radiocarbon, by a single uranium-series age on bone, and by occurrence of the Old Crow tephra; and they can also be related to four separate moraine belts that cross the western basin floor. The Cutler moraine, oldest of the four, predates the Old Crow tephra and must be middle Pleistocene in age. The subsequent Okak advance followed deposition of the Old Crow tephra, and may correlate with glacier expansions late in isotope stage 5 elsewhere in Beringia. Two younger advances formed conspicuous sets of moraines near Makpik Creek and Anisak River. Radiocarbon ages show that the youngest (Anisak) advance is of late Wisconsin age.

Organic-rich postglacial fluvial deposits show a complex history of downcutting from floodplain levels 15-25 m above present at 14,000-12,000 ^{14}C yr B.P. to late Holcoene levels close to that of the present day. Earlier interglacials may have corresponding records, as shown by initial studies of pollen (by Mary Edwards and Andrea Krumhardt, University of Alaska, Fairbanks) and insect remains (by Scott Elias, INSTAAR, University of Colorado). These data, as well as fossil wood taxa taxa, generally indicate late-glacial to early interglacial settings for floodplain deposits exposed at mid-levels in the bluffs; contrasting full-interglacial conditions predominate in sediments exhumed near modern river level. At least two sets of high- and low-level interglacial deposits, one preceding and the other immediately following deposition of the Old Crow tephra, are evident in the river bluffs of the western Noatak basin.

COASTAL PALEOGEOGRAPHY AND SEA LEVEL CHANGE IN SOUTHERN BERINGIA: POST-LGM RECORDS FROM THE LOWER ALASKA PENINSULA

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Glacial isostasy and tectonism dominate the late Quaternary trend of sea level along the Bering Sea and Pacific Ocean coasts of the lower Alaska Peninsula and eastern Aleutian Islands. Determining the relative contributions of these processes to sea level fluctuations since the last glacial maximum (LGM) is critical for examining post-glacial paleoenvironmental conditions in southern Beringia and for analyzing the regional archaeological record. Recent investigations of coastal geomorphology, glacial geology and archaeology in the USGS Cold Bay and False Pass quadrangles of the western Alaska Peninsula provide new data on sea level trends and the preservation of coastal landscapes since regional deglaciation.

Four emergent shorelines (2-3 m, 6 m, 16 m, and 25 m) are recognized in the vicinity of Cold and Morzhovoi bays, and provide evidence of the trend of regional sea level since the LGM (22 - 17 ka). Basal peat horizons from estuarine marsh platforms in Middle Lagoon (an emerging embayment at the head of Morzhovoi Bay) and Mortensen's Lagoon (an abandoned seaway along the western margin of Cold Bay) provide minimum ages for the 2-3 m stand of 610±70 (BETA-102185) and 410±110 (BETA-103344) ^{14}C yr BP, respectively. Radiocarbon determinations on the ages of higher shorelines are incomplete at present, but relative age estimates can be made based on archaeological data and tephra stratigraphy. A maximum age estimate for the 6 m stillstand is provided by a pumiceous ash that is truncated by an unconformity at this elevation in coastal bluff exposures along the head of Morzhovoi Bay. This ash probably originated from the eruption and collapse of Fisher Caldera about 9200 ^{14}C yr BP (Miller and Smith, 1987; Jordan, 1996; Dochat, 1997; Maschner *et al*. 1997). Timing of the 6 m stand may be better constrained by minimum age estimates provided the regional chronology of archaeological sites, which show two hiatuses in occupation about 1900 to 2500 ^{14}C yr BP and 3500 to 4000 ^{14}C yr BP, based on age determinations of 39 sites in the Cold Bay quadrangle (Maschner *et al*., 1997). It is possible that the 6 m stand occurred during one of these periods, persisting long enough to erode evidence of occupation of sites within the paleotide range (≈1.5 m based on modern range). Numerous younger sites occur on marine and intertidal terraces both above and below 6 m; only two older sites occur on erosional marine terraces above 6 m. The Fisher ash (c. 9200 ^{14}C yr BP) occurs in a bluff-head dune that caps the 16 m terrace southeast of Cold Bay, providing the best minimum age estimate for this terrace. It is overlain by a charcoal horizon that is equivocally associated with a lithic scatter dated to 5270_60 (AA-22422) ^{14}C yr BP; the earliest occupation ages for the 16 m terrace elsewhere are 3980±60 (CAMS-30622) and 4500±250 (CAMS-30619) ^{14}C yr BP. The marine limit is represented by a 3 km long by c. 100 m wide depositional terrace that mantles outwash at the head of Cold Bay. This feature lies at a consistent elevation of 25 m asl, except where it is crosscut by underfit stream valleys, and is composed of well-rounded pebbles and gravels. The lobate, landward edge of the terrace slopes steeply down into a narrow basin that backs the length of the feature. Inorganic mud and sandy silt recovered from a 1.3 m core on the seaward margin of this basin suggests sedimentation of fines in a lagoonal setting behind an emergent gravel barrier or nearshore bar. The lack of organic or archaeological material on this feature precludes a direct age assignment, and combined with core data, suggest that sea level occupied the local marine limit at an early stage of regional deglaciation, probably prior to 11,500 yr BP.

Determining the contributions of seismic activity and glacial isostasy to shoreline displacement is central to the problem of defining a relative sea level curve based on the data from marine terraces. Located within the Shumagin seismic gap, the lower Alaska Peninsula has not experienced a major earthquake in recent history (Sykes *et al*., 1980; Lander, 1996), although the stratigraphy of marsh peat deposits suggests that sudden tectonic displacements have occurred several times during the Holocene (Plafker, 1990; Combellick, 1991; Nelson *et al*., 1996), and that gradual subsidence or uplift may occur between seismic events. Fault traces and liquefaction features that can be indicative of seismic activity in the coastal zone (Atwater, 1992; Walsh *et al*., 1995) are rare in fine-grained deposits however, and suggest that the preservation of stacked peat sequences and emerged terraces and beach ridge complexes may relate to rapid isostatic compensation following regional deglaciation. Recent research on the glacial geology of the Cold Bay region (Dochat, 1997) provides an alternative view of the character of late Pleistocene glaciation of the lower Alaska Peninsula, suggesting that advances of alpine glaciers occurred asynchronously with glaciers originating from an ice sheet centered and grounded on the continental shelf south of the peninsula near the Sanak Islands. This work revises earlier estimates of the thickness (300 - 500 m) of a cordilleran ice sheet centered along the Pacific margin and shelf of the peninsula (Detterman, 1986; Mann and Peteet, 1994), suggesting that ice thickness near the center of the dome may have ranged from 630 to 3500 m, depending on the apparent surface slope of the ice determined from the trend of maximum till elevations measured on the Cold Bay II (15 - 13.5 ka age assignment of Detterman, 1986) moraine (Dochat, 1997: 79-81).

The modest height and number of paleoshorelines preserved above modern sea level favors a thinner rather than thicker LGM ice cover, disregarding any seismic displacement, as does the lack of terraces on islands south of Cold Bay. Support for a thicker ice cover (and subsequent rate of isostatic compensation equal to or exceeding the rate of subsidence and/or eustatic sea level rise) is indicated by the widespread preservation of peats from coastal lowland and marsh settings that date between 10,200 and 9000 ^{14}C yr BP. Geomorphic data also suggest that the removal of a thick ice cover resulted in asymmetric tilting across the axis of the peninsula (relative uplift along the Pacific coast versus subsidence along the Bering Sea coast). The net effect of long-term tectonic activity on coastal evolution along this sector of the Aleutian arc is difficult to determine from available field evidence. Because of the increasing distance of the lower Alaska Peninsula from the Aleutian trench subduction zone relative to the upper peninsula, the vertical displacement of shorelines due to seismic activity is probably overshadowed by isostatic processes (Plafker, pers. comm. 1997). It is also possible that tectonic activity and isostatic compensation work in opposite directions in the region, with long term subsidence of the Aleutian arc (Dobson et al., 1991) limiting the number and height of shorelines preserved primarily through isostatic uplift.

It is clear that the evolution of coastal environments of the lower Alaska Peninsula has been strongly influenced by extensive late Pleistocene glaciation. Geomorphic and stratigraphic data indicate a general but complex trend of coastal emergence throughout the Holocene, with terraces cut or deposited during stillstands recording attenuations in the rate of uplift. The apparent subsidence of some coastal sectors at present may be related to an asymptotic decline in the rate of isostatic uplift, or ongoing interseismic subsidence. The establishment of local vegetation cover by c. 11,500 ^{14}C yr BP (Dochat, 1997) and preservation of marine terraces dating to the early Holocene suggests that reaches of coast were habitable, at least temporarily, beginning shortly after deglaciation. Greater understanding of the dynamics and chronology of regional glaciation and coastal sedimentation and tectonics will improve models of relative sea level change and human adaptation to the lower Alaska Peninsula and eastern Aleutian Islands.

REFERENCES

Atwater, B.F., 1992. Geologic evidence for earthquakes during the past 2000 years along the Copalis River, southern coastal Oregon. *Journal of Geophysical Research,* 97:1901-1919.

Combellick, R.A., 1991. *Paleoseismicity of the Cook Inlet region, Alaska: evidence from peat stratigraphy in Turnagin and Knik Arms*. Professional Report 112, Division of Geological and Geophysical Surveys, Alaska Department of Natural Resources.

Detterman, R.L., 1986. Glaciation of the Alaska Peninsula. in: *Glaciation in Alaska: the Geologic Record*. T.D. Hamilton, K.M. Reed, and R.M. Thorson, eds., Alaska Geological Society, Anchorage.

Dobson, M.R., D.W. Scholl, and A.J. Stevenson, 1991. Interplay between arc tectonics and sea-level changes as revealed by sedimentation patterns in the Aleutians. in: *Sedimentation, Tectonics and Eustacy: Sea-Level Changes at Active Margins.* D.I.M. MacDonald, ed., Special Publication 12, International Association of Sedimentologists. Blackwell Scientific, Oxford.

Dochat, T.M., 1997. *Quaternary stratigraphy and geomorphology of the Cold Bay region of the Alaska Peninsula: a basis for paleoenvironmental reconstruction*. PhD thesis, Department of Geology, University of Wisconsin-Madison.

Jordan, J.W., 1996. Current coastal paleogeographic research on the lower Alaska Peninsula. Paper presented at the 4th Arctic Archaeology Conference, Madison, WI. 10-11 November 1996.

Lander, J.F., 1996. *Tsunamis affecting Alaska: 1737-1996*. NGDC Key to Geophysical Research, Documentation 31. U.S. Department of Commerce, National Geophysical Data Center, Boulder.
Mann, D.H., and D.M. Peteet, 1994. Extent and timing of the last glacial maximum in southwest Alaska. *Quaternary Research,* 42:136-148.

Maschner, H.D.G., J.W. Jordan, B.W. Hoffman, and T. Dochat, 1997. *The Archaeology of the Lower Alaska Peninusla.* Report 4 of the Laboratory of Arctic and North Pacific Archaeology, University of Wisconsin-Madison.

Miller, T.P. and R.L. Smith, 1987. Late Quaternary caldera-forming eruptions in the eastern Aleutian arc, Alaska. *Geology,* 15:434-438.

Nelson, A.R., I. Shennan, and A.J. Long, (1996). Identifying coseismic subsidence in tidal-wetland stratigraphic sequences at the Cascadia subduction zone of western North America. *Journal of Geophysical Research*, 101:6115-6135.

Plafker, G., 1990. Regional vertical tectonic displacement of shorelines in south-central Alaska during and between great earthquakes. *Northwest Science*, 64(5):250-258.

Sykes, L.R., J.B. Kisslinger, L. House, J.N. Davies, and K.H. Jacob, 1980. Rupture zones of great earthquakes in the Alaska-Aleutian arc, 1784 to 1980. *Science,* 210:1343-1345.

Walsh, T.J, R.A. Combellick, and G.L. Black, 1995. *Liquifaction features from a subduction zone earthquake: preserved examples from the 1964 Alaska Earthquake*. Report of Investigations 32, Washington State Department of Natural Resources.

THE SEA-LEVEL HISTORY AND DROWNED LANDSCAPES OF THE QUEEN CHARLOTTE ISLANDS/HECATE STRAIT OF BRITISH COLUMBIA, CANADA

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The continental shelf of British Columbia and the coastal fiord embayments reveal evidence of a dynamic and rapidly changing sea-level history since retreat of the last glaciers, about 14,000 years ago (Clague, 1983, Luternauer *et al*.,1989, Josenhans et al., 1995). A combination of isostatic rebound, peripheral forebulge collapse, eustatic sea-level rise and, to a limited extent, local tectonism, have left a record of paleo-shorelines at elevations which range from +200 m (Clague, 1985) at the head of Kitimat Fiord (Fig.1) to ≈153 m at the continental shelf edge; a distance of 150 km. Such extreme regional variability in shoreline elevation has prompted us to focus our study geographically in order to differentiate areas which were isostatically depressed on the inner shelf from those that were elevated at the shelf edge. Our studies center on the Queen Charlotte Island Archipelago (locally known as Haida Gwaii), and specifically Juan Perez Sound. A detailed sea-level curve (Fig.2, Josenhans et al. 1997) is presented for this shelf edge site and used to infer the paleogeography during times of lowered seas. The interpretations indicate that large offshore banks were subaerially exposed for about 4000 years between about 13,500 and 9,500 years BP. Pollen evidence (Barrie et. al., 1993) from drowned lakes indicate that these landscapes were vegetated by grasses and dwarf shrubs, and were potentially habitable. The low relief of these drowned offshore landscapes suggests that they could have served as migration routes for early human settlers. Dated artifacts, including stone tools, indicate that humans occupied this region by at least 9800 years BP (Heaton *et al*. 1996). The sea-level curve also indicates very rapid crustal adjustment following ice retreat, with evidence for substantial crustal elevation followed by crustal depression relative to the present level. A maximum rate of relative sea-level rise of 6 cm/year is indicated by the sea-level curve. Digital terrain models based on recently collected SIMRAD EM 3000 bathymetric swath data (having a vertical precision of 10 cm) illustrate the details of the drowned landscapes. DTM images reveal a complex system of incised rivers which terminate at a prominent delta in 153m water depth. Geomorphic interpretations suggest a relatively long period of fluvial downcutting after glaciation, followed by a rapid transgression which did little to modify the incised landscapes.

REFERENCES

Clague, J.J., 1983. Glacio-isostatic Effects of the Cordilleran Ice Sheet, British Columbia, Canada. In: D.E. Smith and A.G. Dawson (Editors), Shorelines and Isostacy. Institute of British Geographers, special publication number sixteen.

Luternauer, J.L., Clague, J.J., Conway, K.W., Barrie, J.V., Blaise, B., and Mathewes, R.W., 1989. Late Pleistocene terrestrial deposits on the continental shelf of western Canada: evidence for rapid sea-level change at the end of the last glaciation. Geology, 17: 357-360.

Josenhans,H.W.J, Fedje,D.W.,Conway,K.W.,Barrie,J.V., 1995. Postglacial sea levels on the Western Canadian continental shelf: evidence for rapid change, extensive subaerial exposure and early human habitation. Marine Geology, Vol. 124 pp73-94

Clague J.J., 1985. Deglaciation of the Prince Rupert- Kitimat area, British Columbia, Can. J. Earth Sci. 22, 256-265.

Josenhans, H.J., Fedje,D., Pienitz, R., Southon,J., 1997 Early Humans and Rapidly changing Holocene Sea-levels in the Queen Charlotte Islands-Hecate Strait, British Columbia Canada. SCIENCE Vol 277. pp71-74

Barrie, J.V., Conway, K.W., Mathewes, R.W., Josenhans, H.W., and Johns, J.M., 1993. Submerged Late Quaternary Terrestrial deposits and Paleoenvironment of North Hecate Strait, British Columbia Continental Shelf, Canada. Quaternary International, Vol. 20. pp 123-129.

Heaton, T. H., Talbot, S. L., Shields, G. F. 1996. An Ice Age Refugium for Large Mammals in the Alexander Archipelago, Southeast Alaska. Quaternary Research, Vol. 46, no. 2, pp. 186-192.

Figure 1. Index map of study area showing areas of continental shelf shallower than -200m that may have served as a migration corridor during time of lowered sea-levels.

PRELIMINARY REPORT ON THE AGE, EXTENT, AND PALEOCLIMATIC SIGNIFICANCE OF PLEISTOCENE GLACIATIONS, COASTAL AHKLUN MOUNTAINS, SW ALASKA

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Our recent geochronologic, geomorphic, stratigraphic, and paleontologic investigations of Pleistocene deposits of the southern Ahklun Mountains provide new information on the timing and extent of glacier advances in this data-poor region. The glacial record, in turn, provides insights into the principal controls on Pleistocene paleoclimate in western Alaska. This report presents preliminary data and interpretations based on field and laboratory work during the last two years. While our understanding of the glacial history is coming into focus, the interpretations presented here will no doubt be updated and refined as new information becomes available. Forthcoming cosmogenic isotope ages on moraine surfaces, radiometric ages, and geochemical analyses on tephra beds will improve the geochronological control. In addition, several long (6-7 m) sediment cores taken this year from lakes beyond the limit of late Wisconsin glaciers will enable more detailed reconstructions of environmental changes through the last glacial maximum, and perhaps earlier.

Glacial History

The glacial sequence of the southern Ahklun Mountains features at least four distinct middle and late Pleistocene glacial intervals: (1) an older middle Pleistocene interval represented by glacial-marine sediment on Hagemeister Island; (2) a younger middle Pleistocene advance that coincided with the eruption of the Togiak tuya; (3) a series of early Wisconsin (sensu lato) advances represented by an extensive drift sheet comprising glacially influenced intertidal sediments at Ekuk bluffs and terrestrial-based glacier deposits elsewhere; and (4) multiple fluctuations of much more restricted glaciers during the late Wisconsin.

Older middle Pleistocene. The oldest depositional record of glaciation was discovered this summer on Hagemeister Island, northwestern Bristol Bay. Bluffs >50 m high on the eastern and southern coasts of the island expose glacigenic and interglacial deposits that have been severely deformed by advancing glacier ice. Both sections include diamicton beds with erratic stones and paired molluscan shells dominated by the taxodont bivalve *Nuculana*. We interpret the shelly diamicton as glacial-marine drift deposited by an outlet glacier of the Ahklun Mountain ice cap that extended down the Togiak valley during an interval of high relative sea level. This glacier, or possibly a subsequent one, advanced over the island to deform the glacial-marine drift along with other pre-glacial deposits. The presence of nonglacially influenced marine deposits in the deformed section is indicated by *Natica janthostoma* from the east-coast exposure. This gastropod presently ranges from Japan to Kamchatka and is thought to have expanded throughout the Bering Sea during the warmest marine transgressions of the middle and late Pleistocene (Anvilian and Pelukian; Hopkins, 1967).

The age of the middle Pleistocene glacial-marine drift has been estimated using amino acid geochronology. Preliminary results of amino acid analyses on *Nuculana* suggest a correlation with the middle Pleistocene Anvilian marine transgression, which was previously dated on Seward Peninsula at about 400 ka (Kaufman and others, 1991). The south-coast exposure also includes a prominent interbed of tephra, although a correlative tephra has not yet been found.

Younger middle Pleistocene. The Togiak tuya is a glacially streamlined volcano composed of basaltic tuff and lava. Pillow lava exposed in the west flank of the volcano ~300 m above the floor of the lower Togiak valley was formed as the tuya erupted through glacier ice and melted an intraglacial lake into which the lava flowed. A new Ar/Ar date on basalt of a subaerial flow that immediately caps the pillow lava demonstrates that the valley was covered by ice 258±23 ka (average of 6 analyses). The elevation of the pillow lava indicates ice of considerable thickness in the lower Togiak valley. The maximum extent of this and other middle Pleistocene advances is unclear, however.

Early Wisconsin (sl). The broad valleys of the Ahklun Mountains, and the lowlands and continental shelf to the south, are underlain by an extensive drift sheet dominated by deformed pro- and non-glacial sediment and ice-contact stratified drift. The drift records several distinct stillsands or readvances, each represented by an ice-stagnation moraine or a glacially deformed composite ridge. The limit of the drift is clearly expressed as the upper extent of kame-kettle topography against the rolling foothills of the southern Ahklun Mountains and offshore islands. The drift delimits low, flat piedmont lobes that spread out onto the continental shelf of northern Bristol Bay, terminating more than 100 km from their source areas. In eastern Bristol Bay, Lea (1990) reported sedimentological evidence from Ekuk bluff, a composite ridge formed during the early part of the late Pleistocene, for the advance of a piedmont lobe onto the Nushagak lowland during a time when relative sea level was close to its present-day level. In western Bristol Bay, in contrast, we have not yet found evidence for glacial-marine deposition during this episode of glaciation.

The age of the drift is beyond the limit of radiocarbon dating, as is shown by new and previously published analyses. The drift is younger than the Old Crow Tephra (≈140 ka), which we recently recovered and analyzed geochemically from interglacial deposits below and within the drift. Several other tephra beds that we analyzed from nonglacial deposits below the drift do not have correlatives in the University of Toronto's database, except one with major-element chemistry similar to that of a bed near Dawson City, Yukon. The drift is also younger than the last interglaciation (<125 ka), as indicated by: (1) lack of emergent shorelines, beach deposits, and Old Crow Tephra atop the drift; (2) truncation of a possible last-interglacial shoreline by the drift near Cape Pierce; and (3) superposition of the drift in southeastern Togiak Bay over marine sediment containing pollen of interglacial character (which we correlate with oxygen-isotope substage 5e; Kaufman and Manley, 1996). The precise age of the drift might be somewhat different at the two places where it is most closely dated. In eastern Bristol Bay, luminescence and amino acid geochronology converge on an age of 80±10 ka (Kaufman and others, 1996). In western Bristol Bay, a preliminary thermoluminescence date of 60±5 ka on interglacial sediment baked by a lava flow provides a maximum age on the overlying drift. A new Ar/Ar date of 43±54 ka on the basalt does little to further constrain the age. We assign this drift to the early Wisconsin (sensu lato; i.e., oxygen-isotope stages 5d though 4), and recognize that it may include deposits of multiple pre-late Wisconsinan advances.

Late Wisconsin. The extent of glaciers that developed late during the last glacial cycle is clearly marked by prominent terminal moraines, outwash terraces, and shorelines of proglacial lakes that remain relatively unaffected by postdepositional modification. Multiple moraines and terraces record a complicated history of at least three glacier fluctuations (Manley and Kaufman, 1997). The age of the drift is constrained in a few places by cosmogenic isotope dates (Briner and others, 1997) and new radiocarbon dates that clearly place it in the late Wisconsin (i.e., LGM). The maximum extent of this drift sheet lies at least 40 km up valley from the coast, whereas previous reconnaissance-scale maps depict the LGM ice margin beyond the present-day coast.

Paleoclimatic Implications

The history of glacier-ice-volume fluctuations in the southern Ahklun Mountains reflects changing boundary conditions that control paleoclimate in southwestern Alaska. Although glacial and postglacial processes, and geographical and topographical effects preclude a simple correspondence between glacier extent and any single climatic parameter, the overall sequence of glacier advances can be evaluated in terms of a hierarchy of paleoclimate controls. The principal features of the glacial record include: (1) multiple ice-marginal fluctuations during the LGM; (2) restricted ice volume during the LGM; (3) much more extensive advances prior to the LGM.

The relatively small-scale fluctuations that took place during the LGM were too rapid to ascribe to direct orbital forcing. Instead, they must record instabilities and feedbacks within the coupled ocean/atmosphere/cyrosphere, as has been discussed for other high-frequency climatic changes recognized globally during this period. On the other hand, the in-phase coincidence of the LGM with a summer-insolation minimum implies that orbital changes were the ultimate control on this ice-volume increase. The limited extent of glacier ice in the Ahklun Mountains during the LGM shows that the correlation between orbitally driven insolation changes and glacier volume is not simple, however; it demonstrates that other processes modulate the paleoclimate conditions that control glacier mass balance. Lowered sea level of the LGM displaced maritime moisture from western Alaska; lowered sea-surface temperatures, with an attendant increase in the extent and duration of sea-ice cover, further limited atmospheric moisture; and increased zonal circulation diminished the northward advection of moisture. The idea that glacier-ice volume was limited by the availability of moisture is supported by reconstructed equilibrium-line altitudes (ELA) that were depressed by only a few hundred meters, despite other proxy climate evidence of frigid conditions. Furthermore, the steep southwestern drop of LGM ELAs across the Ahklun Mountains, in a direction that points to oncoming storm tracks, suggests that precipitation was the dominate control on glacier mass balance.

The suggestion is further supported by the discovery of glacial-marine drift, evidence that at least some, if not all, of the extensive pre-LGM ice advances took place during a time of high relative sea level. Because the ice was thin and the isostatic depression was limited (less than a few tens of meters), the high sea level is interpreted as a global eustatic high stand. The extensive glacial advances seem to occur when high sea level and lower-than-present insolation coincide, perhaps during the interval that immediately precedes the build up of continental ice sheets in the Northern Hemisphere.

Finally, the vastly expanded early Wisconsin ice of the southern Ahklun Mountains contrasts with the relatively limited expansion of presumed early Wisconsin glaciers on Seward Peninsula (Kaufman and Hopkins, 1986). Although the cause of this incongruous pattern is presently unclear, by comparing glacial records across western Alaska, where physiography and climatology are similar, larger-scale paleoclimate controls might be identified. The difference may indicate a threshold effect, perhaps through the position of sea level or the steepness of latitudinal temperature gradients.

REFERENCES

Briner, J.P., Kaufman, D.S., and Manley, W.F., 1997, Late Wisconsin glacial chronology of the western Ahklun Mountains, SW Alaska—preliminary findings from Wattamuse valley: Beringian Paleoenvironments Workshop (this volume).

Hopkins, D.M., 1967, Quaternary marine transgression in Alaska, *in* Hopkins, D.M., ed., The Bering Land Bridge: Stanford University Press, p. 121-143.

Kaufman, D.S. and Hopkins, D.M., 1986, Glacial history of the Seward Peninsula, *in* Hamilton, T.D., Reed, K.M., and Thorson, R.M., eds., Glaciation in Alaska—The geologic record: Anchorage, Alaska Geologic Society, 51-77.

Kaufman D.S. and Manley, W.F., 1996, Tentative early Wisconsin age for an extensive glacial advance into Togiak and Goodnews bays, SW Alaska: Geological Society of America Abstracts with Programs , v. 28 (7), p. 434.

Kaufman, D.S., Forman, S.L., Lea, P.D., and Wobus, C.W., 1996, Age of pre-late-Wisconsin glacial-estuarine sedimentation, Bristol Bay, Alaska: Quaternary Research, v. 45, p. 59-72.

Kaufman, D.S., Walter, R.C., Brigham-Grette, J., and Hopkins, D.M., 1991, Middle Pleistocene age of the Nome River glaciation, northwestern Alaska: Quaternary Research 36, 277-293.

Lea, P.D., 1990, Pleistocene glacial tectonism and sedimentation on a macrotidal piedmont coast, Ekuk Bluffs, southwestern Alaska: Geological Society of America Bulletin, v. 102, p. 1230-1245.

Manley, W.F., Kaufman, D.S., 1997, Radiocarbon and relative-age evidence for restricted late Wisconsin glaciation, southern and western Ahklun Mountains, southeastern Beringia: Beringian Paleoenvironments Workshop (this volume).

LATE PLEISTOCENE CLIMATE HISTORY OF THE NORTHERN N. PACIFIC

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Up until about 10 yrs ago, most of our knowledge of the Pleistocene history of the subpolar gyre in the North Pacific was based on study of siliceous microfossils. For example, the work of Morley and Hays [EPSL 66:63(1983)] showed the radiolarian species which is so common today in the Okhotsk Sea became dominant in the open sea during the last glacial maximum (LGM). That suggested the open North Pacific must have been much more stratified in the summer and ice covered in the winter. Likewise, diatom studies by Sancetta et al. [Mar. Geol. 62:55(1985)] generally revealed changes in temperature and fertility of the surface ocean. In one exceptional case, oxygen isotope ratios measured on diatom silica showed there was a puzzling event of low salinity on deglaciation in the southeastern Bering Sea. However, by and large it was difficult to integrate these results with the rapid advances made in understanding climate in the North Atlantic region because of the perception that there was too little calcium carbonate in the North Pacific for stable isotope studies on foraminifera and for radiocarbon dating.

These perceptions are now known to be false. Recently, oxygen isotope stratigraphies have been published from locations on the northern Emperor Seamounts [Keigwin *et al*., EPSL 111:425(1992)], the Okhotsk Sea [Morley et al., Paleocean. 6:121(1991)], the Bering Sea [Gorbarenko, Quat. Res. 46:230(1996)] and the Gulf of Alaska [Zahn *et al*., Paleocean.6:543(1991)]. At all these locations deposition rates are high and foraminiferal abundance is sufficient for developing detailed radiocarbon chronologies. Ocean and climate changes from the LGM to the Holocene may be generalized for the region as follows:

During the LGM, subpolar waters were uniformly cold and at least as fresh as today. No amount of cooling could increase the density of surface waters enough to convect, although brine rejection associated with sea ice formation could form dense waters. Although this is controversial and still unpublished, a set of benthic foram carbon isotope data from dozens of sediment cores supports enhanced intermediate water formation in the region but not deep water formation. Thus, during the LGM the North Pacific probably had a negative heat flux as it does today.

The most striking change during deglaciation was the deposition of highly siliceous sediments on the Emperor Seamounts. Geochemical evidence indicates this interval (centered on ~15ka (calibrated)) was caused by higher fertility, but the exact reason is unknown. Carbonate content increased at that time and remained high into the early Holocene. Associated with the deglacial interval was an episode of low oxygen isotope ratios in benthic foraminifera, which may correlate with the Bering Sea event observed in diatom silica by Sancetta *et al*.(1995) However, unpublished results on diatom silica from the northern Emperors reveal two isotopically depleted events, and these bracket the foram event. These occurrences most likely reflect times of lowered sea surface salinty, but the lack of ice rafted grains seems to rule out an iceberg origin and melting sea ice should not have an isotope effect. Modern circulation patterns would indicate Beringia as source of this fresh water.

Other “steps” in the deglacial record of oxygen isotopes, higher carbonate content during postglacial time, and the possible occurrence of Younger Dryas ice rafting make the at least some parts of the subpolar gyre look surprisingly like the North Atlantic. The last step in deglaciation occurred between 9 and 10ka (calibrated), and is coincident with a distinctive tephra layer on the northern Emperors. Although many of the paleoceanographic observations could be satisfied by the presence of substantial ice somewhere in Beringia, there is another possibility. As suggested by Gorbarenko (1996), the Arctic could be the source of both the ice rafting and the fresh water if there was a flow reversal in the Bering Strait.

Today water flows from the North Pacific through the strait to the North Atlantic because North Pacific surface waters are more buoyant (fresher) than the North Atlantic and the sea level is higher. It is known that this flow affects the mode of North Atlantic circulation. However it is also known that the North Atlantic received multiple pulses of meltwater during deglaciation (and earlier) because it was surrounded by Laurentide and Scandinavian ice sheets and melting was episodic. At those times the surface salinity of the North Atlantic may have been lower than that of the North Pacific and the flow could have reversed if the Bering Strait was flooded. This highly speculative scenario could provide a non-atmospheric mechanism for synchronizing millennial-scale climate events between the two oceans. It is testable by developing high resolution chronologies for Bering Sea cores, by developing a high-resolution sea level history for the region, and by mapping the source of fresh water events.

RADIOCARBON DATING THE EARLY HOLOCENE OCCUPATION OF WESTERN BERINGIA: REVISIONS FROM THE UPPER KOLYMA REGION

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In western Beringia the early prehistoric record is known from few archaeological sites. Building a solid cultural chronology is essential for exploring broader issues for the prehistory of this region. Problems attendant to chronology building are crucial since a small number of radiocarbon dates are used as the empirical basis for correlation dating (based on arguments of equivalence in artifact morphology) and colonization models. Unfortunately, little information accompanies published dates and the dates themselves are used uncritically. The key issue for radiocarbon dates in archaeological contexts—the relationship between the material dated and the target event (the manufacture of artifacts or "occupation")—is usually neglected. I examine the archaeological context of radiocarbon samples from four sites in the Upper Kolyma region with early Holocene age estimates. This examination illustrates possible problems with using compilations of published dates to draw chronological conclusions.

The artifact assemblage from the Uptar site provides the first evidence of a lanceolate bifacial projectile point technology in the region. Small charcoal pieces were collected from the lower extent of an early Holocene tephra, the Elikchan tephra. The charcoal pieces were combined and a single radiocarbon date of 8,260±330 yr B.P. was obtained and used to infer an early Holocene occupation (Slobodin 1990 In: Drevnie Pamiatniki Severa Dal'nego Vostoka. Academiia Nauk SSSR, Magadan, pp. 65-74). Artifacts were deposited on the surface of an alluvial deposit and were covered during a tephra fall. Stratigraphic sections at the site show that small charcoal pieces occur throughout the tephra and are not confined to the area of the site containing artifacts. Spatial proximity of charcoal to the artifacts does not provide evidence for contextual association. The radiocarbon date along with the tephra give an upper limiting date for the Uptar assemblage beyond which a more accurate age estimate is not available.

The radiocarbon record from the Maltan site consists of a suite of 13 dates. Eleven dates were from samples collected during excavation in the 1970s, of these 10 dates range between 1300 and 4450 yr B.P. A single early date (Table 1) was used to place a hypothetical lower component, the Maltan culture, chronologically in the early Holocene (Dikov 1977 Archeologicheskie Pamiatniki Kamchatki, Chukotki i Verkhnei Kolymy. Nauka, Moscow). In 1996, S.B. Slobodin and I undertook additional excavation at the site. Artifacts and charcoal were found distributed throughout the organic mineral soil horizon adjacent to the surface. The topography of the lower boundary of the soil horizon was very wavy, with abundant artifacts and charcoal within the swales. A two-dimensional plane that cross-cut the lower extent of the organic horizon would give a plan view with well-bounded areas of black sediment, perhaps similar to the hearth stains and storage pits identified in the 1970s. However, these would not necessarily represent isolated cultural features. Additional charcoal samples were collected and provided radiocarbon dates that fall within the range of most of the dates from the site (Table 1). No stratigraphic evidence is available to suggest a lower component at the Maltan site distinct from an upper component and the single early Holocene date is apparently anomalous.

In the artifact assemblage from the Ui-1 site distinctive bifacial stemmed points made on blades with triangular and trapezoidal cross-sections and conical and prismatic cores and blades are characteristic. Four radiocarbon dates are available from Ui-1 (Table 1). The dates represent multiple determinations on different fractions of a sample of small charcoal pieces collected from a 1 m^2 area, 3-12 cms below the surface. Charcoal was not ubiquitous across the site and coincides with an area where abundant artifacts were found. The concordance of three of the dates suggests that an early Holocene age estimate is accurate. However, hearths or other structural features were not identified and the early Holocene age estimate for this assemblage is provisional.

Strong evidence for an early Holocene occupation in the Upper Kolyma region is available at the Buyunda site. Excavations in 1990 and 1993 revealed stone artifacts associated with a core and blade industry similar to materials assigned to the Sumnagin culture in the Aldan basin. Artifacts were found within and surrounding a stone-lined hearth feature. Charcoal from the hearth provides an unequivocal archaeological context and analysis of the artifacts suggests a single short-term use of the site. However, the radiocarbon record spans a considerable period. Possibly, wood burned in the hearth spanned hundreds of years. Also, provenance factors may be crucial for evaluating the dates at Buyunda since the hearth feature was buried by high velocity fluvial sediments. Younger organic materials could easily have been incorporated into materials exposed at the surface. The suite of dates from Buyunda illustrates that single dates may not provide an accurate age estimate for use of a site. Fortunately, at Buyunda many artifacts contain an organic resin on the exterior surface. An

AMS date of this material may provide resolution for the existing chronology.

This examination of the radiocarbon chronology on a case-by-case basis suggests that several revisions are necessary for the early Holocene chronology of the Upper Kolyma region:

1) A bifacial lanceolate projectile point technology existed before 8,300 yrs B.P. (the age of the Elikchan tephra), but the temporal relationship of this technology to other early Holocene industries is unknown;

2) The Maltan complex cannot be shown to be early Holocene in age;

3) A distinctive technology based on the manufacture of bifacial stemmed points is part of early Holocene assemblage variability;

4) In the Upper Kolyma region a lithic industry resembling the Sumnagin complex in the Aldan basin was present during the early Holocene.

Table 1. Early Holocene radiocarbon dates from four archaeological sites in the Upper Kolyma region, western Beringia.

Site Name	^{14}C yr B.P.	Lab No.	Comments	Reference
Uptar	8260±330	MAG-1262	Wood charcoal, small pieces collected from the lower extent of Elikchan tephra.	Slobodin 1990
Maltan	7490±70	MAG-183	Wood charcoal, Maltan was excavated in 1974, 1975, and 1978. Dikov (1977) identified two cultural levels. This date is used for an age estimate for the lower level. Ten additional radiocarbon dates range between 1300 to 4450 yrs B.P. Provenance information for samples is not available.	Dikov 1977
	4012±102	DRI-3286	Wood charcoal, collected from brown sandy loam beneat the surface mineral horizon (25-28 cm below surface). Artifacts found in proximity to the charcoal.	King (unpub.)
	2514±76	DRI-3285	Wood charcoal, sample collected from swale at the lower boundary of finely divided organic level (20-22 cm below surface). Numerous lithics with thermal micro fractures in the same area as charcoal.	King (unpub.)
Ui-1	8810±235	GX-17067	Wood charcoal, sample collected from a 1 m^2 area with a high concentration of artifacts. The sample was subdivided and four dates obtained.	Slobodin 1995
	8695±100	GX-17066	Wood charcoal, see above.	Slobodin 1995
	8370±190	LE-3990	Wood charcoal, see above.	Slobodin 1995
	5950±90	LE-3900	Wood charcoal, see above.	Slobodin 1995
Buyunda	8135±220	GX-17064	Wood charcoal, sample collected from hearth feature in 1990. Exact provenance unknown.	Slobodin 1995
	7790±190	LE-3991	Wood charcoal, sample collected from hearth feature in 1990. Exact provenance is unknown. LE samples are two fractions of a large 34 g sample.	Slobodin 1995
	7510±205	GX-17065	Wood charcoal, sample collected in 1990 "near hearth." Exact provenance is unknown.	Slobodin 1995
	5610±110	LE-3898	Wood charcoal, see above comment for LE-3991.	Slobodin 1995
	8704±128	DRI-3283	Wood charcoal, small pieces including bark and twig fragments, collected from lower extent of hearth in 1993.	King (unpub)
	8146±130	DRI-3043	Wood charcoal, small pieces including bark and twig fragments, collected from hearth feature in 1993.	King (unpub)
	4728±92	DRI-3284 well-defined	Wood charcoal, small pieces collected in 1993 from a buried surface that slopes downward to hearth feature.	King (unpub)

DRI: Desert Research Institute, Las Vegas, NV.
GX: Geochron Laboratories Division, Krueger Enterprises, Cambridge, MA.
LE: Radiocarbon Laboratory, Institute of Material Culture, St. Petersburg Section of the Academy Sciences of the USSR.
MAG: Radiocarbon Laboratory, Magadan.

BIOGEOGRAPHY OF SELDOVIAN PLANT TAXA, PAST AND PRESENT, ALONG THE PACIFIC RIM

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The development and extinction of the Arctic Miocene flora were important floristic developments in Beringia occurring well before the evolution of the Arctic tundra flora during the Plio-Pleistocene. Ralph Chaney's theory of an Arctotertiary geoflora implies that temperate deciduous forest taxa of early to mid Tertiary age in the high latitudes evolved there and gradually dispersed southward during global cooling in the post Eocene interval. His chief example, the Port Graham flora of Seldovia Point Alaska, (now known to be mid-Miocene in age) had 5 species and 4 closely related species present in the Oregon Miocene Mascall flora and similar forms in the Bridge Creek flora (Olig. Ore.). Our analyses of leaf taxa occurrences show that most of the Seldovian species and their nearest relatives first appeared or evolved at mid latitudes before they occurred in Alaska, e.g. *Ulmus speciosa*, *Zelkova browni,* and *Populus kenaiana*. We call these species "old southerners"; some are mid-latitude Asian taxa that reached Alaska in the Seldovian and spread southward in W. North America (e.g. Fagus antipofi). However some "old southerner" species became locally extinct in Alaska after the Seldovian but continued in mid-latitudes (*Ulmus speciosa, Zelkova browni*.)

Many temperate genera or subgenera of the Pacific Rim have a long history in mid latitudes and in Alaska, and developed a "new" Miocene species appearing at Seldovia Point. But in several of these cases the new species do NOT "disperse southward" in post Seldovian cooling but become extinct (*Prunus* aff. *padus*, *Pterocarya nigella*) , even though the GENERA survive in mid latitudes on both sides of the Pacific. In other cases the Seldovian species appeared contemporaneously over a wide area of the Pacific Rim including Alaska (e.g. *Carya bendirei*) and then became locally extinct in Alaska in the late Miocene but survived for a while in Washington/Oregon.

In a few cases the species appeared in Alaska first and then progressively dispersed southward, as Chaney predicted; these "old northerners" are species of *Salix* and *Alnus*. *Metasequoia* cf. *glyptostroboides* may be an "old northerner" species, [though many records of near relatives are found at lower latitudes before the Miocene].

We conclude that most of the identified temperate forest genera and /or vicariad lineages that now have disjunct amphi-Pacific distributions had long fossil records at mid AND high latitudes during the mid Tertiary: *Nyssa, Acer, Prunus, Pterocarya, Carya, Ostrya, Zelkova,* etc. Many developed species that dispersed northwards to Beringia during the Oligo-Miocene. Some developed Beringian species in the Miocene that became extinct by Pliocene time. Only one or two genera developed Beringian species that dispersed southward during Neogene cooling. Hence Chaney's Arctotertiary theory of southward dispersal of temperate Arctic deciduous elements at the end of the Tertiary is not substantianted by taxonomic data; many of the "Arctic" taxa were already at mid-latitudes.

MODERN POLLEN AND LATE QUATERNARY PALEOENVIRONMENTAL DATA FROM WRANGEL ISLAND (NORTHERN CHUKOTKA): EVIDENCE FOR A "WARM-WET" YOUNGER DRYAS INTERVAL AND DWARF MAMMOTH ENVIRONMENTS

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Palynological, plant macrofossil, and cryological data from two lakes and a peat exposure on Wrangel Island indicate that climatic conditions were more moderate than present during Younger Dryas times. Pollen spectra dating to the last 10 ka BP are similar to the island's modern assemblage, implying no significant changes in vegetation or climate during the Holocene. These paleoenvironmental factors apparently did not play an important role in the ultimate demise of the dwarf mammoth population on Wrangel Island. Modern pollen data from surficial lake sediments differentiate the herb-dominated tundra of Wrangel Island from the shrub tundras of mainland Chukotka. The Wrangel Island data represent a modern spectrum that is unique when compared to spectra from other arctic regions. This work was supported by the Russian Foundation for Fundamental Research and the National Science Foundation.

DISEASE AND MAMMALIAN EXTINCTIONS IN THE LATE QUATERNARY

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In the last 30 years, the subject of Late Quaternary extinctions has been covered exhaustively in two landmark edited volumes (Martin and Wright, 1967; Martin and Klein, 1984), hundreds of articles on individual taxa, localities, and regions, and several conferences. Without intending to discount the complexity of the subject matter or the many thoughtful reviews of the issues concerned, we note that the debate remains essentially where it was decades ago. At present the debate is very nearly bipolar. One side (e.g., Martin, 1984; Diamond, 1984; Ward, 1997; see also Grayson, 1989; Stuart, 1991) posits that humans, colonizing "new" lands, directly caused extinctions by overhunting large, behaviorally naive prey species. The other side (e.g., Graham, 1990; Graham et al., in prep.; Lundelius, 1988; Guthrie, 1984, 1990) prefers to view humans as incidental to the extinction process, and argues instead that deleterious "natural" environmental change was the operative factor, particularly in the case of megafaunal species.

Over the years, these positions have been bolstered by a great variety of subsidiary arguments. Nevertheless, a comprehensive theory ought to offer a way to make sense of the particularly persuasive points that each side has made. How can the environment be dismissed as irrelevant, when it is a fundamental determinant of species distributions and species numbers? Equally, how can the role of people be denied if, in case after case, massive extinction follows their first appearance in places where they were not previously resident? What is being overlooked? It is with this context in mind that we offer an alternative argument which seeks to explain several of the unusual features of late Quaternary extinctions by reference to the biological effects of newly-introduced diseases. As we show below, this argument has potentially testable aspects.

Although rarely considered as a major proximate cause of extinction, under specific circumstances disease can cause catastrophic reductions in population size (Young, 1994). We (MacPhee and Marx, 1997) have recently argued that several fundamental features of certain late Quaternary extinctions correspond to expected effects of massive population depletions caused by highly contagious, highly lethal diseases ("hyperdiseases"). On theoretical grounds, hyperdisease is at least as plausible as its chief competitor, blitzkrieg (Martin, 1984), and satisfactorily explains (1) why extinction rates in affected areas consistently dropped off after an initial period of mass losses; (2) why larger mammals are more susceptible to extinction than smaller ones, (3) how an extinction episode can pass with dramatic rapidity through an area without regard to local topography, plant cover, or the distribution of habitat favorable to human occupation; and (4) why it need not be automatically inferred that hunting or other cultural practices of technologically unsophisticated peoples were responsible for heightened species losses in places where late Quaternary extinctions occurred.

One fundamental postulate of the hyperdisease hypothesis is that "new" diseases—ones recently emerged in naive populations—can be exceptionally lethal (Morse, 1994), and, under certain conditions, may cause extremely rapid population crashes. Another is that, during prehistoric times, diseases capable of "jumping" to new hosts may have been frequently carried into new lands by migrating humans, their commensals or synanthropics. The cardinal example of this may be the enormous losses occasioned at "first contact" between humans and naive faunas at the end of the Pleistocene in the Americas and, to a lesser degree, in northern Asia (MacPhee and Marx, 1997).

Theoretical expectations of the hyperdisease hypothesis have been modelled in a preliminary fashion (MacPhee and Marx, 1997). Epidemiologically, the model pathogen would have (1) had a reservoir from which it was able to emerge repeatedly; (2) represented a completely novel challenge to naive hosts; (3) caused fatal disease before protective immune responses developed; (4) spread, with high lethality, through all or most age groups; and (5) produced severe epizootics in numerous species quasi-simultaneously without causing serious epidemics in migrating or settled human populations. Under hyperdisease conditions, population sizes of susceptible species would have fallen to levels below sustainability so quickly that recovery was not possible. It is not necessary that the hyperdisease infect, and kill, every individual; at very low population sizes, any number of stochastic effects, including hunting and environmental change, might potentially intervene to finish off last survivors. Hyperdisease pathogens need not have been—and in all probability were not—completely new entities in an evolutionary sense. Lethality is a measure of a host's response (or lack of it) to pathogenic challenge. Diseases that are relatively benign in one species may be acutely lethal in another (e.g., myxomatosis in *Sylvilagus* vs. *Oryctolagus*).

If hyperdiseases actually occurred in nature, it should be possible to design a critical test that would, in principle, be decisive. Such a test should minimally include (1) the discovery of an identifiable pathogen in the (2) preserved remains of members of terminal populations of (3) a number of species that, on other grounds, are believed to have disappeared at the same time. However, little work has been done in the field of "ancient" molecular pathology. One reason for this is that molecular investigators are normally interested only in the host DNA of their target organism, not in what would otherwise be regarded as a contaminant. Another reason is that identifying exogenous DNA is rarely justified unless the source is already known or strongly suspected. When gross pathology gives a clear indication of the identity of the infecting microbe (e.g., lesions of tuberculosis in human mummy material; Salo et al., 1994), then detection of the microbe's genetic material by conventional molecular techniques is considerably simplified. However, most acutely lethal diseases in mammals are viral, not bacterial. Further, many extremely pathogenic viruses have RNA replication cycles, which adds greatly to the complexity of detection because of the instability of single-strand RNA molecules over time. Finally, at this time we do not know the identity of any hyperdisease pathogens.

In cooperation with Drs. A. Tikhonov and G. Baryshnikov (Zoological Institute, Russian Academy of Sciences), we are beginning our search by sampling a number of permafrost mammoth carcasses collected in eastern Siberia. Although a number of other taxa have been encountered at permafrost sites in Siberia, mammoth remains are the best reported and best collected (Lister, 1992). In addition, mammoths were geographically widespread, occupying northern Asia and North America at the end of the Pleistocene (Saunders, 1996). This provides us with the possibility of eventually being able to analyze the status of several different mammoth populations. In the paleontological context, permafrost material is likely to be the closest one can get to optimally preserved tissue, despite the fact that carcasses probably took many hours to equilibrate to ambient temperature after death, or may have thawn and refrozen on several occasions (Vereshchagin and Mikel'son, 1981; Goodman et al., 1979). We are aware that permafrost carcasses are rarely encountered. However, at this stage, soft-tissue remains are preferable to skeletal material for two reasons. First, organs that are functionally dedicated to the body's defense systems, such as the spleen, or those that are frequent sites of pathogenesis in acute infections, such as the lungs, are likely to retain evidence of pathogens after death. Secondly, soft tissues offer the possibility of processing multiple samples from different regions of the organ, which again enhances the chances of recovery of exogenous genomic material. Bones will become the crucial sampling source once candidate hyperdisease pathogens have been identified: with a definite target to aim for, our detection tools will become far more specific.

PREHISTORIC CHERT QUARRIES IN THE WESTERN BROOKS RANGE, EASTERN BERINGIA

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Determination of routes of initial migration of humans across Beringia and routes of their rapid expansion into other parts of Alaska comprise some of the most difficult questions in North American archaeology. The Seward Peninsula, the Bering and Chukchi Sea coast, and the Kobuk and Noatak River basins were the locus of major prehistoric interior routes across the westernmost part of Beringia and possibly, intra-continental east-west routes (the Seward Peninsula). Many prehistoric sites dated from 10,000 B.P. to recent occur in this region. They are mostly surficial, undated, and chert artifacts are commonly the only surviving relics of prehistoric cultures and complexes. However, no good tool quality chert sources are available on the Peninsula, nor in the Kobuk basin, whereas the Noatak basin in the western Brooks Range is rich in chert-bearing formations. Many chert chipping stations and a few large workshops in the western Brooks Range are associated with or even located on chert outcrops strongly indicating that the western Brooks Range was a prehistoric mining area.

This study focuses on the geological-geochemical sourcing of prehistoric chert artifacts from archaeological sites located in Northwest Alaska. The research is based on the idea that both the chert artifact and its geological chert source have identical mineralogy, fossils and bulk trace element chemistry that reflect their identical geologic history. Distinct geochemical signatures are specific for different geological conditions of chert formation and unique for each chert layer. The sourcing includes: 1) detailed geological sampling of chert outcrops in the western Brooks Range (including chert varieties within outcrops) based on USGS maps, 2) chert artifact sampling in prehistoric collections, 3) analysis of artifact and outcrop samples by instrumental neutron activation analysis (INAA) for detection of trace element composition and electron microprobe analysis (EMPA) combined with X-Ray diffraction (XRD) for determination of mineral inclusions, 4) construction of a database of chert outcrops consisting of the most discriminating geochemical and mineralogical characteristics for each variety in order to clearly separate chert varieties from each other, and 5) a comparison of geochemical and mineralogical signatures of each artifact with each chert outcrop variety using error bar and bivariate diagrams, as well as descriptive statistics.

Geochemical signatures such as Ce_n/Ce_n^*, Eu_n/Sm_n and Ba/Fe reflect depositional environment, provenance and diagenetic patterns respectively and are indicators for correlation of artifacts with stratigraphic units of chert deposits. Other signatures based on elements (or their ratios) that are mobile during chert formation reflect local geochemistry within the stratigraphic unit, and can also be used for correlation of artifacts with a specific outcrop belonging to the same formation.

Geochemical signatures of 289 chert artifacts from 59 prehistoric sites located in Northwest Alaska were compared with the database of geochemical and mineralogical signatures constructed for 12 chert varieties from nine outcrops sampled in the western Brooks Range. Four of these nine outcrops were determined to be prehistoric quarries from which chert material was widely distributed throughout prehistoric northwestern Alaska: 1) Wrench Creek quarry represented by black glassy chert of high tool making quality, belonging to Chert and Dolomite Unit of Kuna Formation, Lisburne Group (in the area of Hall's Tulugak quarry), 2) Upper Kelly quarry of high quality blue-gray and maroon cherts (nodules and layers) of Siksikpuk Formation (discovered by C. Mull), 3) Upper Kugururok quarry of high quality blue-gray and maroon cherts (nodules and layers) of Siksikpuk Formation (discovered by Malyk-Selivanova), and 4) Anisak quarry of blue-gray and gray-black mottled, slightly fractured chert of Otuk Formation (discovered by Malyk-Selivanova).

Of 289 artifacts analyzed: 37 artifacts found in workshops on quarries were assigned to those quarries and used for determination of realistic geochemical variability within quarries, 63 artifacts were firmly correlated with quarries at confidence of 99.7% , and 189 artifacts were not identified. Chert sourcing in the study area resulted in construction of distribution maps of each chert quarry variety in prehistoric sites that demonstrate: 1) how far and in what directions each variety was transported as prehistoric chert artifacts from their geological source in the western Brooks Range, 2) how early (by what prehistoric culture) each chert variety came to be mined and distributed, and 3) what varieties were preferred by different prehistoric groups.

The general map (Fig. 1) shows that in some local sites, the western Brooks Range chert is dominant, in regional sites it composes only a small percent of artifacts, and in some sites it is absent. The geochemically distinct cherts are probably foreign import and were not quarried at the western Brooks Range quarries even though they are visually identical. For example, of 106 black glassy chert artifacts that are all visually identical to each other by chert (color, luster, type of fracture), only 15 were correlated with Wrench Creek quarry. Five additional artifacts differ just by higher Cs concentration which probably indicates that they were mined at the same quarry, but from the layer that was not sampled for analysis and has a small compositional difference. However, 86 other artifacts differ from the Wrench Creek chert by depositional environment (Cen/Cen* values) and thus were not identified. The map shows the wide geographic distribution of the western Brooks Range cherts as a whole to the west (Chukchi Sea, Seward Peninsula) and to the south (Kobuk River basin). However, it does not extend to the east of the Onion Portage area.

The earliest tradition that utilized the western Brooks Range cherts was the American Paleo-Arctic tradition (Red Dog sites DEL-166 and-168, and possibly (?) Akmak site). In the Onion Portage, the Palisades II, Portage and Denbigh complexes all contain artifacts made of the western Brooks Range chert, whereas Choris complex does not. On the other hand, artifacts in the Choris complex on the Choris Peninsula are identical to the western Brooks Range chert possibly indicating presence of two coeval Choris groups that did not use the same chert source. Similarly, the earliest American/post-American Paleo-Arctic Tradition groups from the Red Dog sites (Del-166,-168) proximate to the quarry used black Wrench Creek chert whereas those that occupied Onion Portage did not. Black cherts from this quarry was delivered to Onion Portage just by Denbigh people.

The first geological-geochemical sourcing of prehistoric cherts in the northwestern Alaska demonstrates successful chert fingerprinting. The obtained data can lead to important archaeological conclusions and our improved understanding of the initial migration and communication routes in prehistoric Beringia.

LATE QUATERNARY PALEOENVIRONMENTS OF NORTHWESTERN NORTH AMERICA: IMPLICATIONS FOR INLAND VERSUS COASTAL MIGRATION ROUTES

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Long standing consensus that the carriers of Clovis culture were the first inhabitants of the New World who arrived in this continent on foot via an ice-free corridor through the Canadian ice sheets has led other likely migration routes - particularly the coastal one - to be less than seriously considered. The demonstration of a human presence in southern Chile at Monte Verde ca 12,500 years ago, 1) pushes human presence in the New World farther back than the 1000 years implied by the actual dates as time must be allowed for travel from Beringia to southern South America, a distance of more than 10,000 kilometers, and 2) renews the need for serious reevaluation of coastal migration routes as the ice-free corridor route through the Canadian ice sheets was not available during the millennia when the Monte Verdean ancestors would necessarily have been traveling south from Beringia.

While the Laurentide and Cordilleran ice sheets only coalesced for a brief span between approximately 21,000 and 19,000 years ago, even after ice retreat and stagnation, it was several millennia before the environment was able to support a viable human population. Levels of harvestable primary production, prey biomass, and optimum yield available to humans were below the minimal nutritional needs of a socially viable population in the linearly constricted environment of the corridor between 18,000 and 13,000 years ago, but were increasingly abundant after 12,000 years ago. If the corridor was unavailable as a migration route between 21,000 and 13,000 to 12,000 years ago, it implies that archaeological sites south of the borders of the ice sheets dating to that time are either, 1) evidence of migrations that occurred prior to the establishment of the barrier, or 2) remains left by people who arrived in the New World via some other route, e.g. the coastal or interior British Columbia routes. The reality of Monte Verde forces us to consider these possibilities.

Unlike the north Atlantic, the northern Pacific Ocean and Gulf of Alaska may have been ice free through out the glacial maximum. Additionally, there is evidence that the bulk of the Cordilleran ice sheet amassed after 20,000 BP, and extensive areas of both the coast and interior British Columbia would have been accessible prior to this time. Furthermore the Cordilleran ice retreat began earlier than the Laurentide, before 16,000 in southeastern Alaska when the climate became warmer and wetter. Thus possible windows for coastal migration appear to be open prior to 20,000 and then ca 16,000 to 14,000 years ago. New research in the Queen Charlotte Islands of British Columbia indicates sea level at the continental shelf edge was 153 meters below present 14,000 years ago with indications of extensive herb and shrub-tundra vegetation along the coast.

The oldest accepted western Beringian sites are no older than 20,000 years ago. If human groups were living on the south Beringian coast ca 25,000 to 22,000 years ago (which we as of yet lack evidence for), they theoretically could have moved east and then south along the coast prior to the deterioration in the environment and growth of ice sheets. Several theories regarding genetics, language histories and disease patterns of North America natives do suggest such a time frame. Alternatively, an ancestral maritime adapted population could have migrated around the south coast of Beringia and down the west coast during the post 16 ka climatic amelioration, moving well south of the Northwest Cost area prior to the Vashon Stade of glacial advance over southern Puget Sound.

RADIOCARBON AND RELATIVE-AGE EVIDENCE FOR RESTRICTED LATE WISCONSIN GLACIATION, SOUTHERN AND WESTERN AHKLUN MOUNTAINS, SOUTHEASTERN BERINGIA

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New ^{14}C dates and measurements of soil development and moraine morphology indicate that an ice cap over the Ahklun Mountains during the Last Glacial Maximum (LGM) was less extensive then previously believed. Previous reconstructions based on limited field data have differed greatly, depicting ice margins sheltered within range fronts (Coulter *et al*., 1965) or extended across lowlands to the present-day coast (e.g., Hamilton, 1994). The new data are from four drainages that empty into Kuskokwim Bay and northwestern Bristol Bay: the Kanektok, Goodnews, Togiak, and Kulukak River valleys. In each valley we have studied five to eight prominent morainal belts marking prolonged ice-marginal positions. We also have observations and analyses from extensive coastal-bluffs and offshore islands. Soil profiles were described at 60 sites. Moraine morphology (cf. Kaufman and Calkin, 1988) was quantified at 35 sites on 24 moraines.

Among thirteen radiocarbon determinations from the region, three are reported here for the first time, and four directly relate to the extent and timing of LGM outlet lobes draining the Ahklun Mountains ice cap. Three ^{14}C dates on peat overlying drift are >45 ka (southwest of Goodnews Bay; Porter, 1967), 39.9 ka (Crooked Island, central Togiak Bay), and >49.9 ka (central reach of the Kanektok River valley). These dates provide minimum ages for an extensive advance that appears to be early Wisconsin in age (sensu lato; Kaufman and Manley, 1996). Outlet glaciers during the LGM were necessarily more restricted in extent. The date of >49.9 ka is from a site within the limit of Late Wisconsin ice as reconstructed by Hamilton (1994). A fourth ^{14}C date of 16.9 ka is on plant macrofossils from glaciolacustrine sediment deposited in an ice-proximal, moraine-dammed lake in the upper Goodnews River valley. The date provides a minimum age for the third major moraine in the valley, constrains the age of a nearby ice margin, and is a maximum age for overlying outwash gravel that appears to grade to the second major end moraine in the valley. Together the ^{14}C data indicate that LGM ice-marginal positions were tens of kilometers inland of the present-day coast.

Soil and morphometric measurements help to define a break in age in the down-valley moraine sequences. Soil profiles generally increase in development with distance down glacier-flow. Profiles typical of the inner three or four moraines and associated drift in each valley consist of O/A/thin Bw/C horizons. B horizons average 20-23 cm in thickness. Profiles on outer moraines and drift surfaces have thicker Bw horizons, averaging 39-52 cm, and often display O/A/thin Bt/thick Bw/C horizons. The down-valley shift in soil development appears to represent a significant, correlative break in time.

Loess thicknesses also generally increase down-valley. Loess caps average 22-35 cm atop the inner three or four moraines, compared to valley averages of 41-108 cm on outer moraines and drift. The eolian silt mantle is thickest (125-240 cm) at seven sites in Togiak Bay. We hypothesize that the increase is driven by cumulative deposition during glacial events. This is supported by the common occurrence down-valley of composite soil profiles (with buried Bt and Bw horizons), indicative of at least two cycles of loess deposition and soil formation. However, loess thicknesses do not show an unequivocal step increase associated with the step increase in B horizon development.

Down-valley trends in the morphometric data in part support the relative-age differences described above. Side-slope angles for the inner three or four moraines in each valley are commonly steep, averaging 17°-20°, compared to averages of 8°-17° for the outer moraines. However, the two datasets partially overlap, and values as high as 16°-19° were observed at a few sites in southwestern Togiak Bay that are substantially down-glacier of the LGM limit, as delimited by our other data. The outermost moraine in the Kanektok River valley is markedly degraded, with an average slope angle of 3° and a crest width eight times greater than the average of all other moraines. It appears to delineate the margin of a middle Pleistocene piedmont lobe.

In sum the ^{14}C and relative-age data attest to a late Wisconsin glacier complex over the Ahklun Mountains that was more restricted than previously believed. Late Wisconsin ice limits were 15-85 km from the modern coast, similar to the reconstruction of Coulter et al. (1965). Concomitant ice volumes were lower, and equilibrium-line altitudes higher, than implied by subsequent reconstructions (e.g., Hamilton, 1994). As in much of Beringia, the late Wisconsin ice cap in the Ahklun Mountains appears to have been limited by precipitation, as moisture sources migrated south and west with falling sea level and the emergence of Bristol and Kuskokwim Bays.

REFERENCES

Coulter, H. W., Hopkins, D. M., Karlstrom, T. N. V., Péwé, T. L., Wahrhaftig, C., and Williams, J. R., 1965, Map showing extent of glaciations in Alaska. U.S.G.S. Map I-415.

Hamilton, T. D., 1994, Late Cenozoic glaciation of Alaska. In: Plafker, G., and Berg, H. C. (eds.), The Geology of Alaska. Geological Society of America, 813-844.

Kaufman, D. S., and Calkin, P. E., 1988: Morphometric analysis of Pleistocene glacial deposits in the Kigluaik Mountains, northwestern Alaska, U.S.A. Arctic and Alpine Research, 20: 273-284.

Kaufman, D. K., and Manley, W. F., 1996: Tentative Early Wisconsin age for an extensive glacial advance into Togiak and Goodnews Bays, SW Alaska. Geological Society of America Abstracts with Programs, 28(7): A434.

Porter, S. C., 1967: Glaciation of the Chagvan Bay area, southwestern Alaska. Arctic, 20: 227-246.

LATE-GLACIAL CHANGES IN AN ARCTIC LANDSCAPE: THE NORTHERN FLANK OF THE BROOKS RANGE DURING PALEOINDIAN OCCUPATION

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Paleoindian people occupied the Mesa site in the northern foothills of the Brooks Range, Alaska between 10.3 and 9.7 ka (^{14}C years) B.P. An earlier occupation may have occurred ca. 11.7 ka B.P. As part of the interdisciplinary Mesa Project, we are reconstructing the history of ecosystem changes in the region between the Killik and Nigu Rivers along the northern flank of the Brooks Range for the interval 14 to 8 ka B.P. We focus on the dynamics of four interacting systems important in structuring this tundra landscape: rivers, peatland, permafrost, and climate.

Stratigraphic sections in fluvial terraces reveal that braided, aggrading streams occupied most valleys during the Late Glacial. We infer that wide floodplains comprised large areas of disturbed soils unfavorable to peat formation but supporting disturbed-site, grass-rich plant communities. Braided floodplains were sources of loess and sand which contributed to soil disturbance on surrounding uplands. Preliminary data suggests channel forms switched from aggrading/braided to the present downcutting/wandering or meandering channel forms around 11 ka B.P. Peat sediments disturbed by mass movement evidence a widespread interval of thermokarst in the Killik-Nigu region between 10 and 11 ka. B.P. We tentatively assign this to a sudden thickening of the active layer (warming) after ca. 11 ka B.P. Peat began accumulating ca. 12.5 ka B.P. in favored locations such as stream gulleys. Around the Mesa site, peatland had expanded to near its present extent by 8.5 - 9 ka B.P. Rapid spread of tussock tundra after 10 ka B.P. may have been the proximate cause for megafauna and Paleoindians leaving the study region. Alternating aridity and moist conditions during the Late Glacial are suggested by stratigraphy at Lake of the Pleistocene (LOP), a deep thaw lake basin that was breached and drained by lateral erosion of the Etivluk River about 5 ka B.P. LOP sediments suggest the basin was dry and accumulating sand from adjacent sand sheets for an interval before 10.8 ka B.P., after which it filled to a low water level. Highest lake levels were not reached until after about 9 ka B.P.

We suspect that Paleoindians used the North Slope during warm intervals in the Late Glacial, when firewood had become available yet the modern tussock tundra was of limited extent. Rapidly changing climate and the disturbed soils caused by abundant aeolian sediments and thermokarst may have allowed herbaceous plants to dominate, including abundant grasses. Climatic and consequently geomorphic stability allowed tussock tundra to expand rapidly after 10 ka B.P., to the detriment of the Arctic Paleoindians and their subsistence strategies.

NEW PALEONTOLOGICAL INFORMATION ABOUT THE FIRST OPENING OF BERING STRAIT

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A significantly greater age than previously proposed for the initial opening of Bering Strait is based on new paleontological evidence. The opening of the strait is signaled by the appearance of the bivalve mollusk Astarte in the Bear Lake Formation of the Alaska Peninsula, southwestern Alaska. Astarte dwelled in the Arctic and North Atlantic Oceans throughout the Cenozoic, but was absent from the North Pacific until Bering Strait formed. The marine diatoms that directly occur with Astarte in the Bear Lake Formation have well-documented ages in North Pacific ODP and DSDP cores and are also present in an Astarte-bearing sequence of the Limimtevayam Formation on Karaginsky Island, northeastern Kamchatka.

A diverse marine diatom flora was recovered from fine sediment within five bivalve and gastropod shells at two *Astarte*-bearing horizons in the Bear Lake Formation. The diatoms represent Subzone b of the North Pacific *Neodenticula kamtschatica* Zone. Species from the Bear Lake Formation samples that are characteristic of this subzone include *Neodenticula kamtschatica, Thalassionema nitzschioides, Thalassiothrix robusta, Bacterosira fragilis, Detonula confervacea, Thalassiosira oestrupii, T. insigna, T. praeoestrupii, T. jouseae, T. antiqua, T. orientalis, T. gravida, T. dolmatovae, T. sheshukovae, Pyxidicula zabelinae*, the *Delphineis ovata* group, *D. simonsenii, Rhaphoneis angularis, Lithodesmium minusculum, Nitzschia cylindra,* and *Porosira glacialis*. Subzone b of the *Neodenticula kamtschatica* Zone has an age range of 5.5-5.6 Ma to 4.7-4.9 Ma, based on correlations with the geomagnetic polarity time scale of Berggren et al. (1995). *Thalassiosira oestrupii* and *T. insigna* are species of particular importance. The base of Subzone b is defined by the first appearance of *T. oestrupii* at 5.5-5.6 Ma, and the top of Subzone b is defined by the last appearance of *T. insigna* at 4.7-4.9 Ma.

These new paleontological data from Alaska are comparable to molluscan and diatom data from approximately coeval strata on Karaginsky Island, northeastern Kamchatka. On the basis of diatom dating and the presence of Astarte in the upper part of the Limimtevayam Formation it was previously inferred that Bering Strait first opened at 4.4 Ma. The first-appearance of *Astarte* sp. is in older horizons of this sequence (in the lower part of the Limimtevayam Formation) that lack diatoms. However, diatoms correlative with Subzone a of the *Neodenticula kamtchatica* Zone occur in horizons underlying the *Astarte*-bearing beds, whereas diatoms correlative with Subzones b and c of this Zone are present in overlying strata Therefore, the age of the lowermost *Astarte* on Karaginsky Island is inferred to be within the upper part of Subzone a or the lower part of Subzone b of the *Neodenticula kamtschatica* Zone. This first-appearance of *Astarte* in the Limimtevayam Formation approximately coincides with that in the Bear Lake Formation.

The Miocene-Pliocene boundary is currently placed at 5.32 Ma, so molluscan and diatom evidence suggests that Bering Strait first formed in the latest Miocene or earliest Pliocene, in the interval between 5.5-5.6 Ma and 4.7-4.9 Ma. This age range is 0.3 to 1.2 m.y. older than the previously inferred first-opening of Bering Strait at 4.4 Ma. The latest Miocene or earliest Pliocene initial opening of Bering Strait at 5.6 to 4.7 Ma significantly predates the oldest known post-strait marine deposits, about 3.5 m.y. old, in northern Alaska and Canada.

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THE EARLY HOLOCENE HYPSITHERMAL AND HUMANS: ADVERSE CONDITIONS FOR THE DENALI COMPLEX OF EASTERN BERINGIA

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Paleogeographic data records that the early Holocene witnessed large dust storms due to the openness of the spruce parkland vegetation. The calibration of ^{14}C ages has forced the revision of paleoecological relationships with the Milankovitch thermal maximum 10-9 kya (Edwards and Barker 1994). Increasing lake levels and gulley-cutting from 11 to 8 kya ago indicate that seasonally high precipitation produced dramatic impacts on the landscape. Human expansion, hypothetically, may be linked to the altitudinal and spatial spread of trees during the warmer, wetter early Holocene. The second Americans, the Denali complex, do extend across the entire eastern Beringian landscape, however, no Brooks Range sites at or beyond tree line are dated. The Denali complex is bifacial core and blade technology used as part of a weapons system of atlatl insets (alternatively, the bow and arrow) for the hunting of caribou. Although nearly ubiquitous across eastern Beringia, with >100 small surface sites, comparatively few Denali occupations are radiometrically dated. The earliest calibrated ages for the Denali complex precede both the 10 kya Milankovitch Maximum (MM) and the spread of spruce by >2,000 years. Most stratified Denali sites co-occur with weak soil horizons, assumed to represent stabilized surfaces, but are post-dated by dust falls. The Nenana valley may be witness to less than a dozen hunting parties from 12.5 to 8 k cal ya, while the equally few Tanana valley occupations are slightly younger from 11 to 7 k cal ya. Although no definite correlation can be firmly credible, due to small sample size, Denali occupations peak duing the worldwide temperature decline between 8.5-8.0 k cal ya, the "younger Younger Dryas," and were lower during the Milankovitch Maximum suggesting an inverse relationship between climate and success in caribou hunting. Holmes and Bacon (1982) argued for a Denali reliance on bison, observing only the synchronicity of the disuse of Denali tools about 2,000 years ago, when bison also (apparently) declined in abundance. The current distribution of Denali materials is skewed toward upland hunting encounters of single animals, based on data from overlook sites. Other geomorphic settings do contain sites, e.g., within alluvium (Onion Portage, Carlo Creek) and caves (Lime Hills, Trail Creek). Improbably, Denali hunters did not use dunes, lakes, surrounds, jump sites or other devices capable of obtaining a surplus. While early Holocene sea level rise precludes the easy discovery of coastal sites (except for imprecisely dated Crag Point on Kodiak Island), archaeologists need to incorporate paleogeographic data into more robust research strategies that will locate sites with a more complete household and faunal inventory.

DOES pH AFFECT POLLEN PRESERVATION IN THE LATE PLEISTOCENE BERINGIAN SEDIMENTS?

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Can the absence of certain pollen due to deterioration in high pH depositional environments obscure the climate signals and vegetation reconstruction? Pollen preservation bias has been the subject of my recent research in southern New England. The low pollen percentages of certain temperate deciduous trees recorded for the late Pleistocene has been interpreted as contamination or a result of long distance transport. However, if poor preservation of the pollen is responsible for the low percentages, then a claim for local deposition could be substantiated. The local presence of temperate deciduous trees would indicate ameliorated conditions during the post-glacial time when humans were migrating into northeastern North America. The discovery of white pine needles in southern Connecticut, dating to 12,000 BP, suggests that the temperature was amenable for an admixture of conifer and temperate deciduous trees to be growing locally. Using diatoms to determine the pH values from several post-glacial catchment basins, I have found the depositional contexts to have been alkaline compared to the Early Holocene acidic conditions. Alkaline conditions are known to be inimical to the preservation of pollen and hold the potential to degrade sensitive deciduous pollen grains more than the resilient coniferous species, thereby skewing the vegetation record. Could certain taxa be missing from the Beringian pollen spectrum? Evaluating the water chemistry of Beringian sites may help to resolve conflicts in interpreting the vegetation landscape when humans were migrating between Siberia and Alaska.

THE LAST INTERGLACIAL-GLACIAL CYCLE IN LATE QUATERNARY LOESS, CENTRAL INTERIOR ALASKA

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Interest in loess deposits has increased dramatically over the past few years because of the recognition that these sediments and their intercalated paleosols may be one of the most complete terrestrial records of Quaternary climate change. In Europe and the North American midcontinent, the stratigraphic record is straightforward because loess deposits indicate glacials or stadials while paleosols indicate interglacials or interstadials. In China, interpreting loess records is more complex, because loess is deposited during both glacials and interglacials. Therefore, thick unaltered loess deposits and paleosols represent high and low rates of loess deposition, respectively.

Loess is one of the most regionally extensive surficial sediments in Alaska (Péwé, 1975), and the oldest deposits, near Fairbanks, may be as old as ~3.0 Ma (Westgate et al., 1990). Alaskan loess stratigraphy is complex to interpret climatically because, like the Chinese records, loess deposition occurs during both glacials and interglacials (Begét, 1996). As an example, at Eva Creek in the Fairbanks area, stratigraphic studies and five AMS radiocarbon ages on wood show that in the past ~8.9 kyr, 4 m of loess were deposited, followed by development of a soil with a well-expressed O/E/Bw1/Bw2/C profile. Therefore, both thick, unaltered loess and a well-developed soil represent the present interglacial in the stratigraphic record. In contrast, the last glacial period at Eva Creek, bracketed by AMS radiocarbon ages on wood of ~30 ka and ~8.9 ka, is represented by only 1.5 m of loess. At least at this locality, apparent rates of loess sedimentation were much lower during the late Wisconsin than the Holocene. A similar stratigraphic record was reported by Hamilton et al. (1988) and Begét (1990) in the Fox permafrost tunnel. During the late Wisconsin, it is likely that silt production by expanded glaciers was greater than during the Holocene. However, loess preservation on interfluves may not have been as extensive during glacial periods because herb tundra was the dominant vegetation over most or all of the region (Ager and Brubaker, 1985) and may not have served as an efficient airborne sediment trap. In contrast, a forest cover during interglacials and interstadials may be a rather efficient airborne silt trap.

Detailed examination of four thick loess sections in the Fairbanks area (from west to east, Halfway House, Eva Creek, Gold Hill, and Birch Hill) confirms that loess stratigraphy in central Alaska is complex. Péwé et al. (1966) mapped surficial silts in the Fairbanks area, and identified two facies: (1) direct airfall loess found on uplands and (2) "perenially frozen silt, undifferentiated" in valley bottoms. The latter includes both direct airfall loess and loess reworked off hillslopes. Periods of loess deposition are marked by thick deposits of massive, tan or grey silt or silt loam. Periods of little or no loess deposition and landscape stability are marked by paleosols. Paleosols can be identified in the field by the presence of buried O or A horizons and, less commonly, Bw horizons. Field identification of paleosols is supported by laboratory analyses of: (1) organic matter concentrations, which have significantly higher values in paleosols (generally 2-20%) than in unaltered loess (generally 0.2-0.8%) and (2) P_2O_5 concentrations (normalized to TiO_2), which show a characteristic pattern of high values in upper O and A horizons, low values in lower A and B horizons, and higher values in C horizons, in contrast to unaltered loesses, which show no changes in P_2O_5 values as a function of depth. Chronology is based on geochemistry of tephras and AMS radiocarbon dating of wood, charcoal, and humic acids from soil organic matter.

Upland localities: At Halfway House, the Old Crow tephra (age estimates of ≈120 ka to ≈160 ka; Westgate *et al*., 1990; Berger et al., 1996) occurs at depth of ≈8.5 m in relatively unaltered loess. The oldest paleosol in the section occurs about 2 m above the Old Crow tephra, and humic acids from this paleosol indicate a probable minimum age of ≈42 ka. Two vertically closely-spaced paleosols above the lowermost paleosol have humic acid ages of ≈32 and ≈30 ka, respectively. The modern soil is developed in the upper part of ≈4 m of loess above the 32-30 ka paleosols. At Birch Hill, no tephras are apparent in the section studied, but humic acids from a well developed paleosol at ≈8 m depth have a probable minimum age of ≈38 ka. Three well-expressed paleosols occur above the >38 ka paleosol and have ages ranging from ≈42 ka (lowermost, on charcoal) to ≈28 ka (uppermost, on humic acids). These paleosols are in turn overlain by 3 m of loess capped by a modern soil with an O/E/Bw/C profile.

Valley bottom localities: At Eva Creek, the Sheep Creek tephra is the lowest ash exposed, and occurs ≈1 m below a thick (≈1.6 m), organic-rich paleosol. Wood (*Salix*) from the lower part of the paleosol gave a radiocarbon age of >47.8 ka; humic acids gave a probable minimum age of ≈37 ka. The upper part of the paleosol contains the Old Crow and Doma tephras in very close vertical association with one another. These tephras are overlain by relatively unaltered loess that contains spruce (*Picea*) (22-34%), birch (*Betula*) (12-50%), and alder (*Alnus*) (7-17%) pollen. The spruce-bearing pollen interval is in turn overlain by at least two more paleosols. The uppermost of these two paleosols gave humic acid radiocarbon ages of ≈35 ka. Much of the section above this is not exposed, but a stratigraphically higher upstream exposure (described above) has at least two mid-Wisconsin paleosols (wood ages for both of ≈30 ka), and three wood-bearing paleosols with ages of ≈8.8 ka that can be traced laterally to an 8.8 ka beaver dam. At Gold Hill, the upper 8 m of the section contains a well-developed paleosol with a probable minimum age on humic acids of ≈44 ka that contains the Dome tephra in its uppermost part. Loess above this paleosol contains four paleosols with humic acid ages ranging from ≈39 ka (lowermost) to ≈31 ka (uppermost); only ≈1 m of loess separates the ~31 ka paleosol from the modern soil.

Major element geochemistry of paleosols provides evidence for primary mineral alteration during the last interglacial and mid-Wisconsin periods. Values for SiO_2/Al_2O_3 and Na_2O+K_2O/TiO_2 are much lower in probable last interglacial and mid-Wisconsin paleosols relative to unaltered loess. We interpret these trends to represent significant alteration of primary loess minerals, particularly mica and plagioclase. The major element depletions are greater than those seen in modern Fairbanks area Inceptisols, but are not as great as those seen in Spodosols formed in loess in the warmer and wetter Kenai Peninsula area.

We conclude the following: (1) if the age estimates of ≈120 ka to ≈160 ka for the Old Crow tephra are correct, then at least one and possibly two paleosols representing the last interglacial complex are present; (2) pollen data are an indication that a boreal forest was present sometime shortly after deposition of the Old Crow and Dome tephras, in agreement with several other probable last interglacial localities in Alaska and Yukon (Hamilton and Brigham-Grette, 1991); (3) if our radiocarbon ages are correct, there were at least two and possibly as many as four periods of mid-Wisconsin soil formation, supporting the results of Hamilton et al. (1988) and Begét (1990); (4) the last interglacial and the Holocene may be represented by both loess deposition and soil formation; and (5) pedologic data indicate that during at least parts of both the last interglacial and mid-Wisconsin periods, climatic and vegetation conditions were such that measurable chemical weathering occurred.

REFERENCES

Ager, T.A., and Brubaker, L., 1985: Quaternary palynology and vegetational history of Alaska. In Bryant, V.M., Jr., and Holloway, R.G. (eds.), *Pollen Records of Late- Quaternary North American Sediments.* Dallas, Texas, American Association of Stratigraphic Palynologists Foundation, 353-383.

Begét, J.E., 1990: Middle Wisconsin climate fluctuations recorded in central Alaskan loess. *Géographie Physique et Quaternaire,* 44: 3-13.

Begét, J.E., 1996: Tephrochronology and paleoclimatology of the last interglacial-glacial cycle recorded in Alaskan loess deposits. *Quaternary International*, v. 34-36, p. 121-126.

Berger, G.W., Péwé, T.L., Westgate, J.A., and Preece, S.J., 1996: Age of Sheep Creek tephra (Pleistocene) in central Alaska from thermoluminescence dating of bracketing loess. *Quaternary Research*, 45: 263-270.

Hamilton, T.D., and Brigham-Grette, J., 1991: The last interglaciation in Alaska: stratigraphy and paleoecology of potential sites. *Quaternary International*, v. 10-12, p. 49-71.

Hamilton, T.D., Craig, J.L., and Sellmann, P.V., 1988: The Fox permafrost tunnel: A late Quaternary geologic record in central Alaska. *Geological Society of America Bulletin,* v. 100, p. 948-969.

Péwé, T.L., 1975a: Quaternary geology of Alaska. *U.S. Geological Survey Professional Paper 835,* 145 pp.

Péwé, T.L., Wahrhaftig, C., and Weber, F.R., 1966, Geologic map of the Fairbanks quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-455, scale 1:250,000.

Westgate, J.A., Stemper, B.A., and Pewe, T.L., 1990: A 3 m.y. record of Pliocene-Pleistocene loess in interior Alaska. *Geology,* 18: 858-861.

MID- TO LATE-WISCONSIN TRANSITION IN NORTHERN ALASKA: CONTRASTING LOESS AND FLUVIAL POLLEN RECORDS AND IMPLICATIONS FOR LAND BRIDGE ENVIRONMENTS

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Many scenarios proposed for the steppe-tundra environment call for relatively unvarying landscapes, with proposed variations being based on a more or less xeric general character. Discussions of vegetation types, sometimes leading to heated arguments, have been largely based on an assumption of broad uniformity. While it is recognized by many that this assumption is flawed, this consideration rarely enters into discussions of what is meant by “tundra-steppe” or “steppe-tundra.”

Along the Titaluk River in northern Alaska, two key exposures have allowed us to compare and contrast eolian and fluvial systems that were in part synchronous from ca. 35 ka to 30 ka. Eolian sediment accumulation was widespread in northern Alaska even in the mid-Wisconsinan; in the Titaluk River region, thick loess accumulated downwind from a sand sea. Average sedimentation rates for mid-Wisconsinan loess and fine sand at the Titaluk site accelerated from ≈0.7 mm/yr. from 35 ka to 28 ka to 1.1-1.2 mm/yr from 28 ka to 23 ka. From about 23 ka to about 20 ka, the rate doubled to 2.4 mm/yr, following which it dropped to 1.5-1.7 mm/yr through about 15 ka.

The fluvial section on the Titaluk River consists of floodplain silts and very fine sand that was deposited between about 45 ka and sometime after 30 ka. Deposits younger than 30 ka were removed by the development of a Holocene thaw lake basin. Deposition was probably episodic and highly variable; climbing ripples preserved in some parts of the section indicate pulses of rapid fluvial sedimentation.

Pollen from the fluvial section indicates that valley-bottom vegetation consisted of sedge-dominated graminoid communities throughout the depositional period, with relatively abundant willows (contributing typically 4-10% of the basic pollen sum); heaths, *Populus*, alders and dwarf birches were rare, if present at all.

This contrasts sharply to the pollen record of the loess section, although work on this is not yet complete. Pollen in the loess indicates that uplands were dominated by grasses and xeric herbs in a discontinuous vegetational assemblage, comparable to that envisioned by some proponents of the ultra-xeric steppe-tundra model. Pollen concentration in the sediments also reflects the relatively high sedimentation rate and is extremely low, with pre-Neogene: Quaternary palynomorph ratios of as much as 5:1, compared to a typical ratio of 1:2 in the lowland fluvial sediments.

These data support a scenario, as proposed by Schweger decades ago, of a mosaic of communities within the “steppe-tundra,” a mosaic in which lowlands were significantly moister than adjacent interfluves and maintained sharply contrasting vegetational communities. This conclusion may impart help to explain the so-called “productivity paradox” but also leads inevitably to cautions regarding interpretation of pollen assemblages from Beringian peats, which undoubtedly accumulated in valley bottoms and hence likely reflect the most mesic local communities within the general Beringian environment.

UPPER CENOZOIC SITES OF THE LAPTEV SEA COAST - NEW DATA AND IMPLICATIONS FOR TRANSBERINGIAN CORRELATION

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The Upper Cenozoic deposits in Beringia s.l. are mainly represented by either terrestrial, or marine sediments. Only very rarely they can occur in the same sections. This hampers direct correlations. On the contrary, at Laptev Sea coast from Cape Sviatoj Nos up to northern coast of New Siberian Islands terrestrial sediments interbed with marine ones. In few cases gradual replacement of terrestrial sediments by synchronous marine ones is recorded. The considered territory was never been glaciated. The Upper Cenozoic sediments are widespread, well exposed and contain numerous faunal and floristic remains. Upper Pleistocene mammal bones are exceptionally abundant. Several important sections were studied during the last century (Fig.1). All these make the area extremely perspective for study of late Cenozoic events in Beringia.

In the summer of 1996 the authors have begun they own study of this interesting region. We have started from Sviatoj Nos locality. This locality is situated in10 km east of Cape Sviatoj Nos (a southern coast of a Dmitrij Laptev strait). It is a steep coastal bluff up to 21 m height and 3 km long recently exposed by marine termoabrasion. A sequence of the Upper Pliocene-Holocene sediments of various genesis exposes here. It is considered of key importance in the area because all main units described in the surraunding territory occur here in one sequence.

In the base of the section presumably Upper Pliocene fluvial sands and gravels crop out (Unit 1). On New Siberian Archipelago (New Siberia Island, Dereviannie Gory site) these sediments are likely replaced with marine ones.

Silts with extensive ice wedges occur above (Unit 2) at the westernmost part of the section. Their age as based on paleomagnetic data does not exceed 0,73 Ma. Terrestrial sediments of similar age in Beringia contain exclusively pseudomorphouses (ice wedge casts) and never ice wedges. Thus, this is a unique place with ice wedges of such a significant age kept unmelted.

These sediments are uncomformably overlayed by bedded silty sands (Unit 3). Individual interbeds of these sands are traceable along hundreds of meters of the section. The sediments were generated in conditions of extensive shallow basin apparently connected to the sea. The age of Unit 3 is estimated in a range 0.73 - 0.25 Ma. It is based on both the stratigraphic distribution of *Dicrostonyx ex gr. simplicior* found in this layers and on paleomagnetic data. On Kotelnij Isl. this layers probably correspond to sands and silty sands containing shells of marine mollusks.

Unit 4 consists of fluvial and lacustrine sediments containing huge ice wedges (Edoma or Ice Complex). Many mammal bones of upper Pleistocene collected from Edoma sediments. *Equus caballus* pelvic bone derived from the top of unit has yielded a radiocarbon date of 34700±1900 y.b.p. (GIN-9043). *Mammuthus primigenius* tusk from organic silt-filled channel provided date of 48800±1400 y.b.p. (GIN- 9044).

The uppermost Unit 5 is composed of lacustrine silts and peaty material displaced while melting. It contain plant detritus and freshwater mollusks shells. The basal sediments of Unit 5 lay in deep pockets resulted by melting of Unit 4 frozen deposits. In some places autochthon peat layers up to 2 m height terminate the sequence. According to our speculative assumption Unit 5 lacustrine deposits were originated during the Holocene thaw.

Described section seems to be a very rear kind of sections known in Beringia. Layers of Upper Pliocene - Pleistocene - Holocene occur here simultaneously. Some of them can be directly correlated with marine layers. It is a good base for paleoenvironmental reconstruction. Unfortunately, because of awful weather we had not opportunity to screen micromammals' bones in the summer of 1996. Till now number of pollen, diatoms, insects and other samples had not processed. All these reduce accuracy of dating. It also does not permit us reconstruct paleoinveronmental history in details. But even obtained results make it possible to do important generalizations. Appearance of Upper Cenozoic Sviatoj Nos site is mush similar to well-studied ones in Kolima Lowland. These two areas are situated far one from another and have different tectonic. From the other hand transgressive — regressive history of the area do not conflict with known hypothesis on that in Kamchatka peninsular and some others distant regions. We suggest that global, not regional events caused similarities of distant Beringian sites. Because of that the Upper Cenozoic sites of the Laptev Sea Coast can be involved in transberingian correlations in a closest future.

EXTINCT MOOSE IN BERINGIA

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Two genera in tribe *Alcini* Simpson, 1945 are accepted. The former, *Cervalces* Scott, 1885, comprise *Cervalces gallicus* (Azzaroli, 1952), *Cervalces latifrons* (Johnson, 1874) and *Cervalces scotti* (Lidekker, 1898). The later, *Alces* Gray, 1821, includes a single species Alces alces (Linnaeus, 1758).

In Western Beringia numerous remains of Pleistocene elk-moose collected by now. About 150 bones are in Andrey Sher collection located now in Paleontological Museum, Moscow. Almost fifty more remains store in different museums of Moscow, Santpeterburg, Yakutsk and some others. The following important samples are among them: considerable part of giant early Pleistocene* moose with lacking scull, cranium of Late Pleistocene moose, fragments of mandibles and maxillas, antler beams, upper and lower teeth and various postcranial parts. Although the most fossils were collected *ex situ,* some of them can be associated with certain dated layers. This makes it possible to reconstruct in general moose evolution in Beringia.

The most aged *Cervalces* remains recovered so far in Western Beringia are presumably originated from the Lower Olyor Suite (which age is estimated in the range of 1.2-0.7 Ma). This moose was huge (largest among known), had very long, slender, slightly curved antler beams. The most important characters are poor molarization of P_3 (lack of the connection between paraconid and metaconid on lingual side) and comparatively elongated metapodial bones. Bothe, the structure of P_3 and of antler beam approach the Early Olyorian moose to *Cervalces gallicus*. Extremly big size of bones and relatively elongated metapodia differentiate them from the Gallic elk-moose and approache to both, *Alces alces* and to *Cervalse scotti*. Thus, the Early Olyorian moose consider to be a primitive *Cervalces latifrons*.

In time span of about 0.7 - 0.5 Ma moose skeleton got slightly smaller, but more robust. Lower P_3 turned more molarized (paraconid connected with metaconid by the lingual wing — the second valley became closed). Antler beams presumably associated with the Upper Olyorian deposits are little shorter and more robust than Lower Olyorian ones. This morphotype closely matches relatively advansed *Cervalces latifrons* from the Cromer deposits of Europe.

Few postcranial bones and shortened antler beams represent a moose intermediate in size between giant *Cervalces latifrons* and relatively small *Alces alces*. Among Pleistocene moose-like remains these specimens best match those of Cervalces latifrons postremus (Vangengejm et Flerov, 1965). C. latifrons postremus is recorded from the Lower Middle Pleistocene (0.4-0.3Ma) deposits of Aldan River,Central Yakutiya. Although only one fossil of that kind, the metacarpal bone from Anijuj River, can be certainly associated with the Middle Pleistocene deposits, others specimens of that size are speculatively of Middle Pleistocene age. *Alces alces* remains are poor represented. They are presumably of Upper Middle Pleistocene - Upper Pleistocene-Holocene age (no older than 0.25 Ma). No one radiocarbone date have been obtained until now.

Moose evolution in Eastern Beringia is evidently match this in Western Beringia. After study literature data and some original material it was concluded that all morphotypes described in Eastern Beringia have analogs in Western Beringia. Remains of giant moose, *Cervalces latifrons*, can be divided into two groups. The former group comprise extremely long slender antler beams and poor molarized dentitions (P_3 with lack of the connection between paraconid and metaconid on lingual side). The later represented by slightly shorter , more robust antler beams and molarized P_3 (paraconid connected with metaconid). As was stated above, the remains of the first group in Western Beringia are of about 1.2-0.7 Ma age. Thus, primitive form of giant moose, *Cervalces latifrons*, first entered in New World by at list 1 Ma.

Moose remains intermediate in size between *Cervalces latifrons* and *Alces alces* are rather common in Alaska and Yukon. But they age is as unclear as it is in Western Beringia. Also these fossils can easily be confused with *Cervalces scotti* s.l. that is much the same in size and morphology. All *C. scotti* remains are known to the South of 51 parallel. It is not known so far when *Cervalces scotti* separated from Beringian population. *C. scotti* has both primitive feature, archaic scull, and advanced one, complicated antler palmations. These suggest two hypotheses. The separation may happen before modern moose *Alces alces* originated (earlier than 0.25 Ma) and than was separated from Beringian population by ice. Or later *Cervalces latifrons* was isolated in Eastern Beringia refugium by transgression and kept unchanged for a long time. In this case the partition could happen later. It is only evidently that first *Alces alces* migrate in Eastern Beringia in earliest Holocene. In early Holocene this advanced moose displaced *Cervalsec scotti*.

Detailed study of ancient moose evolution in Beringia can source an information about transgrssive-regressive regime in Beringia and about age of glaciation that separated one Pleistocene population of ancient moose from another.

USING INDICATOR POLLEN TAXA TO INTERPRET THE LATE QUATERNARY ENVIRONMENTAL HISTORY OF THE WESTERN NORTH SLOPE, ALASKA

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Attempts to reconstruct arctic paleoenvironments with lake sediment pollen records are hindered by the prevalence of major pollen taxa with low taxonomic resolution and broad ecological tolerances (e.g. Cyperaceae, *Salix*, Poaceae, and *Artemisia*). Interpretations based on patterns of minor taxa with affinities to particular ecological settings have been made with some success, but a rigorous investigation of the methods and information gained by this approach has not been conducted. We systematically evaluate the use of indicator taxa for the interpretation of a pollen record from Tukuto Lake, a site in the western foothills of the Alaskan North Slope.

The North Slope is an expansive region of arctic tundra covering northernmost Alaska from the Brooks Range to the Arctic Ocean. While the timing and spatial variability of late Quaternary environmental changes have been fairly well documented for the boreal forest region south of the Brooks Range, the North Slope has received less study. The current understanding of North Slope paleoecology and paleoclimate is based on a variety of geologic and biotic records of marine and terrestrial environments that are geographically scattered and largely discontinuous in time. This project is a component of a PALE (Paleoclimates from Arctic Lakes and Estuaries) study of the late Quaternary vegetation and climate histories of the North Slope. We have collected sediment cores from several lakes across the North Slope in order to better document spatial and temporal changes in the regional environment since the last glacial maximum.

Tukuto Lake is currently surrounded by shrub tussock tundra, primarily composed of *Betula glandulosa-nana*, Ericaceae, Cyperaceae, and *Salix* species. This region of the North Slope was probably last glaciated during the mid-Pleistocene. The lake was cored through 2 meters of ice in April 1996 with a Livingstone square-rod sampler, using a crank-driven roll-jack to penetrate the stiff sediments. At least 300 pollen grains have been counted at each stratigraphic level. The pollen stratigraphy generally conforms to the three-zone sequence (herb, birch, alder) found in other late Quaternary sediment records from northern Alaska. Each zone is dominated by taxa with wide modern distributions and low taxonomic resolution, including *Alnus, Betula*, Poaceae, Cyperaceae, and *Salix*. In the basal herb zone, low pollen concentrations and the abundance of *Encalypta rhaptocarpa*-type moss spores suggest a harsh, sparsely vegetated landscape. Also notable are levels in the upper herb zone with high percentages of Asteraceae subf. Cichorioideae pollen, a feature that has not previously been reported in Alaskan pollen records. As the major taxa do not permit a convincing reconstruction of the past environments of the North Slope, an analysis of the less common taxa may contribute greatly to the interpretation of this pollen record.

To evaluate the potential for indicator pollen taxa to improve the current understanding of North Slope paleoenvironments, we systematically assessed the information gained through an interpretation based on rare pollen types. We used habitat descriptions from Hulten's *Flora of Alaska and Neighboring Territories* to determine the relative ecological restriction of all species within each morphological pollen type. Our assessment demonstrates that some pollen taxa are more useful than others for interpreting past ecological processes and climatic conditions. We attempted to incorporate information about the relative indicator values of different pollen taxa into a process for making decisions about the number of pollen grains that must be counted in order to strengthen the paleoenvironmental interpretation. Pollen concentrations in North Slope lake sediments are so low that many hours of counting are often required to reach even relatively small pollen sums of 300 to 400 grains. To help devise a counting strategy that is practical in terms of time required and environmental information gained, we used a series of computer simulation experiments to determine the pollen sums necessary to encounter specified indicator taxa.

The simulations were tested with actual pollen data from Squirrel Lake in the Kotzebue Sound region. High pollen counts (1400 to 2800 grains) were performed on a number of levels of the Squirrel Lake record in order to evaluate the pollen sums required to encounter rare, but valuable pollen types. The pollen percentages calculated from the high counts are assumed to represent the relative abundances of pollen types within the population of grains at three selected levels in the sediment core (representing herb zone, birch zone, and alder zone samples). We used an S-plus program in order to simulate pollen counts of 100, 300, 500, 1000, and 2000 grains at each level. The program performs 500 counting trials at the each pollen sum, and reports the proportion of trials in which at least one grain is encountered for each targeted indicator taxon. At each level and each pollen sum, we simulated counts for a series of targeted taxa. The simulated pollen counts illustrate some important points that must be considered when making sampling decisions for the Tukuto Lake and other North Slope pollen records: 1) Different parts of the pollen record require different pollen sums to encounter the same proportion of the available indicator taxa. In order to have an 80% probability of finding one half of the possible indicator taxa, it is necessary to count 300 grains in the alder zone, 500 in the birch zone, and 1000 grains in the herb zone. 2) Different parts of the pollen record require different pollen sums to encounter the same number of indicator taxa. In order to have an 80% probability of finding three indicator taxa, in is necessary to count 2000 grains in the alder zone, 500 in the birch zone, and 1000 grains in the herb zone. 3) Counting to a predetermined pollen sum may yield different amounts of paleoenvironmental information in different parts of the pollen record. When 1000 grains are counted in each of the example levels, there is an 80% probability that we will find 2 taxa in the alder zone, 5 in the birch zone, and 3 taxa in the herb zone. 4) Counting a larger number of pollen grains at a given level does not necessarily support the paleoenvironmental interpretation based on indicator taxa at a smaller pollen sum. For each of the three example levels, taxa which indicate different kinds of ecological situations were encountered as we increased the size of the simulated pollen sum.

DID LATE-GLACIAL SEA SURFACE TEMPERATURE CHANGES IN THE NORTH PACIFIC AFFECT BERINGIAN CLIMATE? - EXPLORATIONS WITH THE GISS GCM

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How sensitive is Beringian climate to changes in N. Pacific SST? Circum-Pacific marine and terrestrial records indicate a series of temperature-inferred oscillations during the late-glacial. While many previous studies have probed the role of the N. Atlantic in these oscillations, we test the sensitivity of the northern hemisphere air temperatures to N. Pacific sea surface temperature (SST) oscillation in the GISS GCM.

The effect of a colder North Pacific is to cool air temperatures over North America, as well as parts of Europe and Asia. The colder SSTs result in a large hemispheric response due to the loss of water vapor as a greenhouse gas. Snow cover at mid-latitudes increases, while at high latitudes it decreases. The large sensitivity of the northern hemisphere to a N. Pacific SST change has implications for the ice age climate as well as the late-glacial interval. The results of this experiment provide a rapid mechanism for widespread cooling which has not been previously addressed.

EVA INTERGLACIATION FOREST BED, UNGLACIATED EAST-CENTRAL ALASKA: GLOBAL WARMING 125,000 YEARS AGO

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The Eva Interglaciation Forest Bed represents a frozen, buried, ancient boreal forest in the Yukon-Tanana Upland of east-central Alaska. It consists of excellently preserved peat lenses, sticks, roots, and logs as well as rooted and unrooted stumps of trees, mainly spruce and birch. Consistent with the modern boreal forest, the largest and most common tree in the fossil forest is spruce, mainly white spruce (*Picea glauca*). Remains of birch trees are common, mostly *Betula papyrifera*. The forest remains were buried by loess that became frozen and so are well preserved. None of the wood is mineralized. Many of the fragments are black from burning, suggesting forest fires were widespread in the Yukon-Tanana Upland during the interglaciation. Also, evidence is presented for the first time of the existence of spruce bark beetles (Scolytidae) during the last interglaciation in Alaska.

Efforts to determine the age of the Eva Forest Bed in this study have covered the past 50 years. Methods applied have varied from the use of stratigraphic interpretation of sedimentological events and preserved evidence of climatic changes to the use of modern geochronometry. Several methods of dating have come to fruition in the 1990s. New radiocarbon dating by liquid scintillation (LS) detectors indicates the forest wood to be older than 70,000 years. Perhaps the greatest breakthrough is the development of the isothermal-plateau fission-track method of dating geologically young volcanic glass shards. The Old Crow tephra closely underlying the Eva Forest Bed has been dated at 140±10 ka and strongly supports the original interpretation of the forest bed as of last interglaciation. In the early 1990s, highly improved thermoluminescence (TL) sediment dating techniques were utilized for dating loess above and below the forest bed indicating the age of the Eva Forest Bed is probably 125,000 years with a duration of the Eva Interglaciation of probably only a few thousand years (Sangamon, Oxygen Isotope Substage 5e).

Stratigraphically, the Eva Forest Bed lies at the prominent unconformity between the underlying massive, green Gold Hill Loess (pre-Sangamon) and the overlying blackish, ice-wedge-rich retransported loess of the Goldstream Formation (Wisconsin). Studies of the frozen Gold Hill Loess indicate that the warm interglacial interval was characterized by deep and rapid thawing of permafrost and erosion of loess accompanied by gullying and block slumping of frozen loess. After extensive slumping, the topography became smooth and the forest became extensive. Tilting of enclosed tephra layers outline the slump blocks. Evidence for deep permafrost thawing is supported by the absence today of ice wedges, buried pingos, and mammal carcasses in the presently refrozen loess of pre-Wisconsin age. Deep thawing is also indicated by reduction of iron on loess grains from ferric to ferrous turning the traditional tan color of loess to greenish in the buried Gold Hill Loess. It is the unique sequence of refreezing in Wisconsin time that has preserved the remarkable evidence for deep thawing in earlier Sangamon time - the green color. The forest bed formed after much of the thawing, erosion, and slumping activity had ceased, and it overlies the angular unconformity. More than half-a-dozen distinct tephra layers have been identified, characterized, and correlated in the upper part of the Gold Hill Loess, aiding in the reconstruction of the sequence of events leading to the erosion, thawing, and emplacement of the Eva Forest Bed.

Dendrochronology studies of trees and $^{13}C/^{12}C$ isotopic rations of wood from the Eva Forest Bed, and comparisons with wood from the modern boreal forest, strongly suggest environmental conditions at least similar to those of today. Some plant remains and ground beetle taxa of Eva Forest time in Canada represent species that extended farther north than they do today. Also, buried spruce macrofossils suggest that the boreal forest may have extended north of the Brooks Range in Alaska.

These botanical and physical data indicate an environment warmer than the present interglaciation with the mean annual air temperature warmer that 0°C, perhaps +1 or +2°C or warmer to permit the ice to melt and permafrost to thaw from the surface downward. Supporting this concept are astronomical inferences that during the last interglacial (Oxygen Isotope Substage 5e) the July insolation anomaly at 65°N. latitude reached values of almost 50% higher than 10,000 years ago, the beginning of the Holocene Interglaciation.

SOIL MORPHOLOGICAL CLUES TO CLIMATE CHANGE IN THE BERINGIA

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Soil morphology is the key to understanding and interpreting soils and landscape relationships. Soil morphological characteristics, resulting from soil weathering processes and regulated by the factors of soil formation, provide much of the information needed to interpret site history and landscape development. Major morphological useful for this purpose include color, texture, structure, consistency, horizonation, boundary, pedogenic carbonate content, clay coating, and fine particle orientation. In permafrost-affected areas such as Beringia, cryopedogenic features such as ice-net formation, frost-churned horizons, fabric orientation provide additional clues to soil formation environment and landscape evolution. The difficulty in using soil morphology for interpreting soil genetic environment lies in integrating all of these properties.

In permafrost soils, the intermediate layer is an ice-rich layer consisting of alternate thick ice lenses and frozen soil matrix. The thickness of this layer is indicative of past climate stability. Changing climate caused the permafrost table to fluctuate periodically. The ice-rich complexknown as Yedoma, is extensive in NE Russia. Soils formed in the Yedoma deposit on the arctic coast have a thin intermediate (<25 cm) layer due to the persistently cold climate. Yet the soils formed in the same parent material in the interior taiga forest have intermediate layer as thick as one meter, indicating the fluctuating climatic condition of the early Holocene. Deposit similar to Yedoma have been observed in western Alaska. The paleosols buried 17,000 years ago by the Devil Mountain tephra on the Seward Peninsula provide an excellent example of pedological signatures of the past environment preserved by permafrost. Multiple layers of cryoturbated organic matter have been noted in more than 10 profiles of the tundra soils in the arctic foothill of the North Slope, Alaska. Radiocarbon dating yields 6000-8000 years BP in the intermediate layer and 13,000 years BP in the underlying permafrost. The existence of a paleosol is speculated based on morphological features and carbon dating.

Soils formed in loess deposit are extensive in interior Alaska. The multiple layers of A horizons, horizons with organic carbon accumulation, attest to the syngenetic nature of these soils. Buried A horizons are the result of the intermittent loess deposition during late Pleistocene and Holocene. Some of the buried A horizon are charcoal rich, as the result of past fire. The multiple sequence of buried A horizons and the underlying B horizons provide evidence of past environment. The carbonate filled root channels and undercaped gravel indicate the translocation (leaching) of secondary carbonates and the changing climate. Redoximorphic features (soil mottles) caused by reduction-oxidation of Fe and/or Mn have left permanent signatures in the soil. The pattern of these features indicates past hydrological cycles caused by permafrost table fluctuations induced by climate change or fire.

A COMPARISON OF LATE QUATERNARY VEGETATION CHANGE AT THE EASTERN AND WESTERN LIMITS OF BERINGIA

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While the nature of full-glacial vegetation in Beringia is somewhat controversial (eg. Hopkins et al., 1982; Guthrie, 1990; Ritchie, 1995), it is clear that climatic changes during the transition from the Pleistocene to the Holocene impacted upon the vegetation assemblages of the region, and led to the disassembly of full-glacial ecosystems. The nature of these changes, and their driving mechanisms, appear to have been quite different in eastern and western Beringia, however. We present herelate Quaternary paleoecological records from treeline sites at the western flank of Beringia (northeastern Siberia) (Pisaric, 1996) and the eastern limits of the region (western Northwest Territories) (Spear, 1993; Szeiczet al., 1995) (Figure 1). The pollen record from northeastern Siberia suggests that during the Pleistocene-Holocene transition (ca. 12000 yr BP to 8000 yr BP) climate warming was a two-step process, while records from northwestern Canada indicate it was a more continuous, uninterrupted process. The early to mid Holocene was characterised by warmer temperatures in both regions, a northward extension of the latitudinal treeline beyond present limits in northeastern Siberia and the Mackenzie Delta and increased densities of Picea at the alpine treeline in the Mackenzie Mountains. Modern vegetation assemblages developed after 6000 -5000 yr BP in northwestern Canada and ca. 3500 yr BP in northeastern Siberia.

Western Beringia

A 12300 ^{14}C yr paleoecological record from 71º 52.41 N, 127º 04.39 E, in the lower Lena River basin indicates that the gradual warming of the Pleistocene-Holocene transition, which characterizes the early part of the record, was interrupted between 11000 and 10000 yr BP by a rapid and brief return to near-glacial conditions. The pollen record indicates that shrub birch cover declined while the abundance of grasses, sedges and herbs increased. The rapidity and timing of this cooling event corresponds with the Younger Dryas stade in northwestern Europe. The appearance of *Alnus* following 10000 yr BP likely suggests renewed warming. The close similarity between the modern vegetation and the *Betula-Alnus* assemblage of 10000-~8000 yr BP suggests that summer temperatures were similar to today (8ºC). The pollen and stomate record suggests that significant postglacial warming continued during the mid-Holocene in this region. An advance of the Larix treeline in this region is indicated by the appearance of larch pollen and stomata in the sediment record between ≈8000 and ≈3500 yr BP. Further development of the forest vegetation took place following ≈7000 yr BP as suggested by increasing *Picea* pollen and the appearance of *Picea* stomata. Forest vegetation persisted at thenorthwestern limits of Beringia until approximately 3500 yr BP when the modern birch shrub tundra became established. Current thermal limits of Larix forest and the species limit of *Picea obovata* in the Lena River region are 10ºC and 14ºC respectively. Thus, the pollen and stomate records suggest that summer temperatures must have been 2º to 6º warmer than the current summer mean of 8ºC during the period of treeline advance.

The record from the northwestern limits of Beringia is important forseveral reasons. First, it provides unequivocal evidence that the Younger Dryas stade impacted northeastern Siberia causing a rapid and dramatic cooling and resulting in significant changes in vegetation cover. Secondly, treeline advance in this region lagged increasing summer insolation by as much as 2000 ^{14}C yr. Climate modelling experiments predict that summer insolation was greatest between 10000 and 5000 yr BP (Kutzbach, 1987). Given the lag between summer insolation and treeline extension at the western Beringia site, it does not appear that long-term treeline fluctuations in northern Asia are as clearly linked to changes in summer insolation as in western Canada.

Eastern Beringia

The late Quaternary vegetation of the Mackenzie Mountains in eastern Beringia was characterized by *Artemisia* and Salix-dominated herb-tundra from at least 12000 yr BP to ≈10200 yr BP. Pollen records from this region suggest warmer summer temperatures following 10200 yr BP as indicated by the development of *Betula glandulosa* shrub tundra, probably with groves or open stands of *Populus balsamifera* growing up to or perhaps above the current alpine treeline. Warming temperatures continued throughout the mid-Holocene with *Picea* reaching the current treeline by≈8000 yr BP. While there is no evidence suggesting that treeline occurredat higher elevations in the past in this region, the pollen record does suggest that spruce density in the forest-tundra was greater between 8000 and 5000 yr BP. The modern vegetation of the region developed by ca. 6300 yr BP.

Palynological records from the Tuktoyaktuk Peninsula (Spear, 1993) indicate that *Betula*, *Shepherdia* and *Juniperus* shrub-tundra dominated during the end of the Pleistocene. Warmer than present temperatures between about 9000 and 5000 yr BP led to a northward extension of the latitudinal treeline. The late Pleistocene-Holocene transition in eastern Beringia was therefore characterised by increasingly warmer summer temperatures. Unlike in western Beringia, the initial warming which began in the late Pleistocene does not appear to have been interrupted by a return to near-glacial conditions during the Younger Dryas stade and does not significantly lag increases in summer insolation. It appears that in eastern Beringia vegetation changes at treeline can be attributed to changes in summer insolation as predicted by the Milankovitch theory of climate forcing (Kutzbach, 1987).

REFERENCES

Guthrie, R.D. 1990. Frozen fauna of the Mammoth Steppe. The story of Blue Babe. The University of Chicago Press. Chicago.

Hopkins, D.M., Matthews Jr., J.V., Schweger, C.E. and Young, S.B. 1982. Paleoecology of Beringia. Academic Press. New York.

Kutzbach, J.E. 1987. Model simulations of the climatic patterns during the deglaciation of North America. In, Ruddiman, W.F. and Wright Jr.,H.E. (eds.). North America and adjacent oceans during the last deglaciation. (The Geology of North America, K-3). Geol. Soc. Am., Boulder, CO, p. 425-447.

Pisaric, M.F.J. 1996. The late-Quaternary vegetation history of the lower Lena River region, Siberia. Unpublished Masters Thesis. McMaster University, Hamilton, Ontario. pp. 115. Ritchie, J.C. 1995. Tansley Review No. 83. Current trends in studies of long-term plant community dynamics. New Phytol. 130:469-494.

Spear, R.W. 1993. The palynological record of late Quaternary arctic treeline in northwestern Canada. Review of Palaeobot. Palynol. 79:99-111.

Szeicz, J.M., MacDonald, G.M. and Duk-Rodkin, A. 1995. Late Quaternary vegetation history of the central Mackenzie Mountains, Northwest Territories, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology. 113:351-371.

TERMINAL PLEISTOCENE AND EARLY HOLOCENE OCCUPATION IN NORTH EAST ASIA AND THE ZHOKHOV ASSEMBLAGE

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The Zhokhov site, which was excavated during field seasons in 1989-90, is located far north, on a tiny Arctic island of the same name situated below 76° N latitude and belonging to the New Siberian island chain. This island chain constitutes the natural boundary between the Laptev and the East Siberian seas.

The results of these excavations have been reported previously (Pitul'ko 1993, Giria and Pitul'ko 1994, Pitul'ko and Kasparov 1996). Many artifacts and faunal remains characterizing ancient aboriginal culture were discovered including numerous microprismatic cores and microblades, pieces of hunting equipment (both regular bone/antler artifacts and composite tools with flint insets), and wooden artifacts including a sledge runner fragment. It was found that people visited the island about 7,800 years ago and utilized a very unusual survival strategy based on the hunting of polar bears and reindeer. Although the faunal remains belonging to each species mentioned comprise approximately 50%, the polar bear appears to have been the most important food source.

Because of the unique location, unusual hunting specialization, and excellent preservation of organics that are usually absent in contemporaneous sites, the Zhokhov assemblage is considered to be undoubtedly among the brilliant archaeological sites of the North Asia Stone Age. It could be said that the Zhokhov materials are both an easy subject for discussion and a difficult one at the same time. In general the assemblage lacks exact similarities with contemporaneous assemblages (or with north Asian relics that are approximately contemporaneous with Zhokhov). However, there are many artifacts the presence of which makes it possible to find broad analogies showing mainly general tendencies of the Late Pleistocene/Early Holocene cultural development in the region, rather than features of similarity or familiarity of the Zhokhov assemblage with neighboring sites and cultures. In my view, the latter is more important because the information contained in the Zhokhov finds is the real and important contribution to general notions on human history.

Although the north portion of East Siberia is supposed to be widely populated in the Terminal Pleistocene, there are in fact very few sites introducing the culture of that period. Early Holocene materials are much better represented. They compose the Sumnagin cultural phenomenon, but do not look to be very close to the Zhokhov industry. At the same time, there are some contemporary, radiocarbon-dated sites found in East Chukotka producing industries very similar to Zhokhov. So, making that contribution, I would like to present a general overview of the Terminal Pleistocene/Early Holocene relics coming from North East Asia, and try to place the Khokhov assemblage into the whole picture of the terminal Pleistocene/Early Holocene occupation of the area.

REFERENCES

Pitul'ko, V. V. 1993. An early Holocene site in the Siberian High Arctic. Arctic Anthropology 30:13-21.

Giria, E. Yu. and V. Pitul'ko. 1994. A high Arctic Mesolithic industry on Zhokov Island: Inset tools and knapping technology. Arctic Anthropology 31:31-44.

Pitul'ko, V. V. and A. K. Kasparov. 1996. Ancient Arctic hunters: Material culture and survival strategy. Arctic Anthropology 33:1-36.

PALEOGEOGRAPHIC AND PALEOCLIMATIC SIGNIFICANCE OF DIATOMS FROM MIDDLE PLEISTOCENE MARINE AND GLACIOMARINE DEPOSITS ON BALDWIN PENINSULA, NORTHWESTERN ALASKA

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Studies of the diatom flora of the Cape Blossom and Hotham Inlet Formations of Baldwin Peninsula, northwestern Alaska contribute new information concerning the paleoceanography of Kotzebue Sound, Alaska, during middle Pleistocene time. All subarctic North Pacific datum species are present in sediments exposed along coastal bluffs of Baldwin Peninsula. These sediments contain extinct *Rhizosolenia barboi, Rh. curvirostris, Actinocyclus ochotensis* var fossilis, *Thalassiosira nidulus* var. *nidulus, Th. jouseae, Th. gravida* var. fossilis, and *Pyxidicula dimorpha* are which are correlated with the middle part of the *Rhizosolenia barboi* Zone (0.43-0.36 Ma). Based on the distribution of the zonal diatom species and on changes in the paleoecological structure of the diatom assemblages, we conclude that the marine deposits of the Cape Blossom Formation and lower Baldwin Silt member of the Hotham Inlet Formation formed under warm, high sea level conditions associated with the marine oxygen isotope stage 11 transgression. Glaciomarine sedimentation (middle and upper Baldwin Silt and Selawik members of the Hotham Inlet Formation) was initated during the stage 11 transgression and continued into stage 10. High latitude glacier growth during a global "interglacial" period was likely facilitated by warm surface waters on flooded continental shelves and limited regional sea ice cover.

ENVIRONMENTAL CHANGES AT TREELINE IN CENTRAL ALASKA DURING THE LATE-HOLOCENE: IMPLICATIONS OF NEOGLACIAL COOLING

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The late-Holocene (≈4,000 years BP until present), also known as the Neoglacial, is characterized as a period of climate cooling. Events of climate deteriorations are recorded as sequences of glacial re-advances and vegetational adjustments (such as shifts in species range) in many regions throughout North America. Events of glacial advances are also noted from the Alaska Range and other glaciated areas in Alaska, suggesting generally cooler and/or wetter climate conditions during Neoglacial times. These records, although far from complete, show that climate fluctuations have prevailed over the last several thousand years. The most recent events are recorded between 1200 to 1900 AD during the "Little Ice-Age".

Treeline ecotones have been considered extremely sensitive to climate fluctuation and the assessment of vegetation changes at treeline has been successfully used in reconstructing climate shifts in the past. Particularly in northern regions, there is a growing interest in boreal forest dynamics in the context of global warming. Alpine and circumpolar treelines in Alaska are usually formed by *Picea glauca* (white spruce) but may be partially associated with *P. mariana* (black spruce). Although this appears to be a simple system, the response of an ecotone is dependent on the individual response of the tree species at treeline which may be fairly insensitive or react in unexpected ways to environmental changes. Little is known about the dynamics of past as well as current treeline dynamics in Alaska. In some mountain regions, treeline seems to have advanced during the late-Holocene implying that spruce is either insensitive to climate cooling or that treeline movement was controlled by other environmental variables. However, better knowledge of the behavior of spruce at treeline is important in order to properly evaluate the impact of possible future global warming on boreal forest borders.

This study investigates patterns of Neoglacial cooling and their impact on terrestrial ecosystems in a multi-proxy approach. The objective of our research is to model treeline changes in the past, e.g. from mid-Holocene to present, using fossil pollen as well as the spruce macrofossil and stomate record from sediments of two Central Alaskan lakes. We are also establishing a non-vegetational terrestrial record using stable isotope techniques. Both carbon and nitrogen stable isotope reflect lake productivity providing a powerful tool to detect climate changes independent from our treeline record.

Our study lakes are located along the Denali Highway south of the Alaska Range in Central Alaska. Nutella Lake (N63º03', W147º25'; informal name) is found at treeline at an elevation of 918 m a.s.l. It forms a smaller kettle pond enclosing two major basins with water depths of 9.35 m and 4.70 m, respectively. Shrub-heath tundra is the predominant vegetation surrounding the lake although a few scattered white spruce are found in the area. Clonal growth and asexual reproduction is common among those trees. Swampbuggy Lake (N63º41', W147º40'; 801 m a.s.l.; official name) has a medium-large but shallow basin with a water depth of 3.78 m. It is surrounded by open stands of white spruce and shrubs to the east and north which gradually expand into a denser, mixed black and white spruce forest towards the west side of the lake.

We have analyzed the Swampbuggy Lake core at 10 cm intervals for pollen, LOI and stable isotopes. The entire core is roughly 1.81 m long and is estimated to date back to the mid-Holocene. A 5 cm thick tephra layer is found at about 1 meter from the core top and serves as stratigraphic marker. We believe that the tephra layer represents the so-called Jarvis Creek Ash which has been accurately dated to 3,650 ^{14}C years. Assuming a more or less constant sedimentation rate throughout the core, the age at the bottom of the core was extrapolated from this marker and estimated to about 6,600 years.

Preliminary results from the stable isotope data reveal a major change occurring around 3,800 to 3,600 years BP. Gradually declining ^{13}C values during this period suggest a decrease in lake productivity. Carbon isotope values remain low during the early part of the late-Holocene and only slightly increase later in time. We assume that the productivity changes in Swampbuggy Lake are directly proportional to changes in summer temperature. Declining lake productivity at the mid- to late-Holocene boundary (around 3,700 years BP) therefore implies the onset cooler and presumably wetter climate conditions. A warming trend, e.g. increasing ^{13}C values, are recorded in samples near the core top reflecting a climate shift during the past century. In addition, the relatively high values in our surface sample (approximately 30 years of sediment accumulation) may represent indicators of global warming.

Because of the upslope transport of pollen in mountainous regions, percentages of abundant taxa such as spruce can be misleading and may mask local changes. Our preliminary pollen record from Swampbuggy Lake does not show any strong variations in spruce, although spruce percentages are slightly increased just below and above the Jarvis Creek tephra layer. Similar changes are noted in samples from Nutella Lake. *Betula* percentages appear to be increased near the core bottom but remain fairly stable during late-Holocene times while on the other hand, *Alnus* and Cyperaceae percentages show increased values near the core top but are lower in older samples. Estimate of pollen accumulation rates may clarify these trends. Currently, we are analyzing the sediments for stomates and macrofossils, both of which record the local presence of spruce, and determing the age structure of spruce stands at Swampbuggy Lake.

Our present data indicates Neoglacial cooling and a recent warming trend which is reflected in productivity changes in Swampbuggy Lake. Analyses to date do not show any strong response of spruce at treeline to these climate shifts, but further criticial research remains to be done.

GEOLOGIC CONTROLS ON THE FLOW OF WATER INTO AND OUT OF THE BERING SEA—THOUGHTS ABOUT PAST, PRESENT, AND FUTURE CLIMATIC EFFECTS ON BERINGIA

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Background Statement

The temperature, salinity, and volume of surface water exchanged between the Pacific and Bering Sea Basins can strongly influence the climatic regime of Beringia. Regional geological and geophysical data indicate that both the physical properties and volume of water circulating between these basins have been different in the past and may be radically different in the future. Past and future changes in the oceanographic setting of the Bering Sea are tied to changes in circulation pathways across the Aleutian Arc, and also major pathways of water entering and exiting the north Pacific at equatorial latitudes (Figure 1a and 1b). Both boreal and tropical waterways are created or destroyed as a consequence of Pacific-rim tectonism, i.e., the plate-tectonic process that vertically and horizontally moves fault-bordered blocks of Pacific ocean margin. Tectonic modulation of water movement in the north Pacific generally, and across the Aleutian Arc more specifically, have combined to affect Beringian climatology, and will continue to do so in the future.

Present North Pacific-Bering Sea Circulatory and Oceanographic Setting

Gyral circulation dominates the movement of surface water around the north Pacific and Bering Sea Basins. Circulation follows the paths of three major cells: from south to north, the CW-rotating Subtropical gyre, and, in the far northern Pacific, the co-joined and CCW-rotating Subarctic and Bering gyres (Figure 1a). These latter two gyres are separated physically by the Aleutian Arc, but they are connected oceanographically via between-island passes (Figure 1b). All of the important in-let and out-let passes are located along the central and western sector of the arc. The west-flowing Alaska Stream, which constitutes the northern side of the Subarctic gyre, transits northward across the arc to the Bering gyre via fairly deep (500-2000 m) between-island passes, Near Pass is generally thought to be the main inlet passage (Figure 1b). The cyclonic circulation of the Subarctic and Bering gyres is wind driven, primarily by the intense barometric depression of the winter-season Aleutian Low (Figure 1a). The subarctic gyre draws deep, cold, Pacific waters to the surface. These waters originate from thermohaline sinking in the north Atlantic and adjacent to Antarctica. A small volume of surface water exits the Bering Sea northward via the Bering Strait, but, at the western end of the arc, the great bulk of surface and deeper waters flows southward back to the Pacific via the 4000-m deep, 200-km-wide Kamchatka Pass (Figures 1a and 1b). The mean flow of the East Kamchatka Current through the Kamchatka Pass may be as much as 30-40 X 106m^3/sec, which is comparable to other major boundary currents, such as the Gulf Stream at Florida Strait. Surface water leaving the Bering Sea is 4-6^{o}C cooler and slightly less saline than that entering. The volume of relatively “warm” water transiting the arc is sufficient to keep the surface area of the Bering Sea Basin from winter freeze-over. Owing chiefly to foggy and overcast summer conditions, evaporation is less than precipitation and the salinity of the surface water is relatively low. As a consequence, winter chilling over the basin does not increase the density of surface water sufficiently to initiate vertical, thermohaline circulation.

Pacific-Margin Tectonism and Past and Present Beringian Climates

The width, depth, and position of passes crossing the Aleutian Arc are controlled by a tectonic environment similar to that of the San Andreas fault system of California. Along the arc, this setting involves the oblique to virtual side-swipe contact of the northwest moving Pacific plate and that of the arc (North America plate), the resulting shearing action fragments, rotates, elevates, depresses, and laterally shifts large blocks (10s to 100s of km in length, 50-100 km in width) of the arc westward at speeds of 10s of km/million years (Figures 1b and 1d). Tectonic fracturing of the arc constantly alters its effectiveness as a barrier to the exchange of water between the Pacific and Bering Sea Basins (Figures 1c and 1d). From a geological perspective, the exchange passes can be viewed as ephemeral structural lows, constantly being modified in dimension and location by the regional-scale shearing and westward transport of the arc’s rock framework. Changes in outflow and inflow volumes are thus readily effected by tectonism of the arc, a process that has been underway for at least the past 45 million years (middle Eocene), but greatly intensified during the past 5 million years (i.e., since the latest Miocene). Geologic closing, enlarging, and relocation of the Aleutian exchange passes can cool or warm Bering Sea surface waters and contribute to changes in surface water salinity. These factors influence processes that establish or turn-off thermohaline circulation and that localize and determine the vigor of the north Pacific Aleutian Low, the major atmospheric structure that spawns and steers north Pacific storms (Figures 1a and 1d).

Changes in the Beringian climatic regime can also be effected by ocean margin tectonism well south of the Aleutian-Bering Sea region. In the western equatorial Pacific, plate-boundary tectonism between 25 and 15 million years ago (Late Oligocene through early Miocene) restricted the Indonesian Seaway, the pathway that west-flowing Pacific equatorial currents used to continue westward into the Indian Ocean. Tectonic clogging of the seaway deflected warm, salty, equatorial waters northward along the western edge of the Pacific into high north Pacific latitudes, thus, commensurately, changing the temperature and salinity characteristics of both surface waters entering and leaving the Bering Sea Basin (Figure 1c). If sufficiently chilled during winter months, the presence of saltier (than now) surface waters can initiated thermohaline circulation and the production of bottom water. Evidence that bottom water was produced in the Bering Sea Basin is the large, tongue-shaped sediment mass of the Meiji Drift, which extends into the Pacific Basin southeast of the exit side (south) of Kamchatka Pass (Figures 1b and 1c). Scientific ocean drilling (Legs 19 and 145) established that the drift is composed of diatomaceous debris and fine mineral matter, much of which is derived from Bering Sea drainages. From about 30 to at least 5 million years ago (Oligocene to early Pliocene) his material was carried into the Pacific and distributed along the Meiji Drift by bottom water flowing southward out of the Bering Sea into the Pacific Basin. The outflowing bottom water impinged against the northern flank of the submerged Emperor Seamounts, depositing the drift along this flank as the current turned southeastward toward the deeper Pacific Basin (Figure 1c). The presence of warmer and saltier surface water (than now) in the Bering Sea would have established a regional oceanographic and climatic regime much different than the present, including more days of open skies that contributed to the growth of a mature coniferous forest on the Aleutian Arc (known from fossil record), which is now covered with a carpet of tundra.

About 3 million years ago (late Pliocene), the Central American Seaway (i.e., the Panama connection) on the eastern side of the equatorial Pacific was finally sealed, thus ending the westward flow of Caribbean water into the Pacific. The loss of the influx of tropical Atlantic water allowed north Pacific water along the northern side of the Subtropical gyre (Westwind Drift, Figure 1a) to penetrate southward along the eastern rim of the Pacific. Southward deflection of subtropical waters combined with the surfacing of deep bottom waters inside the Subarctic gyre presumably contributed importantly to the thermal isolation and cooling of the surface waters of the Subarctic and Bering Sea gyres. Cooling of the waters of the Alaska Stream and Bering gyre added to the effects of the late Pliocene deterioration of atmospheric temperatures that, about 2.6 million years ago, lead to cyclic Northern Hemisphere glaciation. The presence of cold surface water and the consequent prevalence of foggy and overcast summer days and decreased surface-water evaporation presumably combined to stop thermohaline circulation. This in turn would have decreased the drawing of Pacific water into the Bering Sea to support vertical turnover and the depositional growth of the Meiji Drift. A commensurate drop in summer-time degree days presumably contributed to the late Pliocene replacement of the Aleutian forest with tundra.

Continuing Arc Tectonism, a Scenario for the Future Climatic Regime of Beringia

Except in a general way, geologic information is too sparse to reconstruct how ocean-margin tectonism formed, closed, and migrated Aleutian exchange passes during most of the past 40-50 million years. However, it is appealing (and fun) to speculate about what the oceanographic and climatic consequences might be if the on-going style of regional arc fragmentation continues. East of Near Pass, this style involves the clockwise rotation and westward translation of large blocks of arc crust. West of Near Pass (Komandorsky Island sector, Figure 1b) lengthwise shearing splinters the arc into lengthy crustal blocks that are shuttled westward at speeds as high as ≈80 km/million years (Figure 1d). Within about 2 million years the westward movement of the Komandorsky block will close the deep-water outlet channel of Kamchatka Pass. It is possible that Near Pass, the present major inlet waterway at the eastern side of the block, will have to accommodate outflow as well. If this happens, then the rate of exchange of water between the north Pacific and the Bering Sea could decreased below present rates. One impact might be winter freeze-over of the surface of the Bering Sea Basin. Surface ice presently only extends as far south as the southern edge of the Beringian shelf (Figure 1a). Freeze-over of most of the area of the Bering Sea (Bering Sea Basin + shelf = ≈2 million km^2) would effectively continentialize all of Beringia for the winter months, a circumstance that would require the atmospheric depression of the Aleutian Low to move away from the Bering Sea Basin, whose open winter waters presently nourish and localize the low over the Aleutian Arc (Figure 1a). Movement of the low elsewhere, most probably eastward to the Gulf of Alaska (Figure 1d), would likely further weaken the exchange of water across the arc between the Subarctic and Bering gyres. The scenario of a weakened Bering gyre could allow warmer Pacific water to drift into the Bering Sea, in particular during spring and summer months, a circumstance that would favor open skies, increased surface water evaporation, warmer degree-days, and the return of redwoods to the Aleutian Islands.

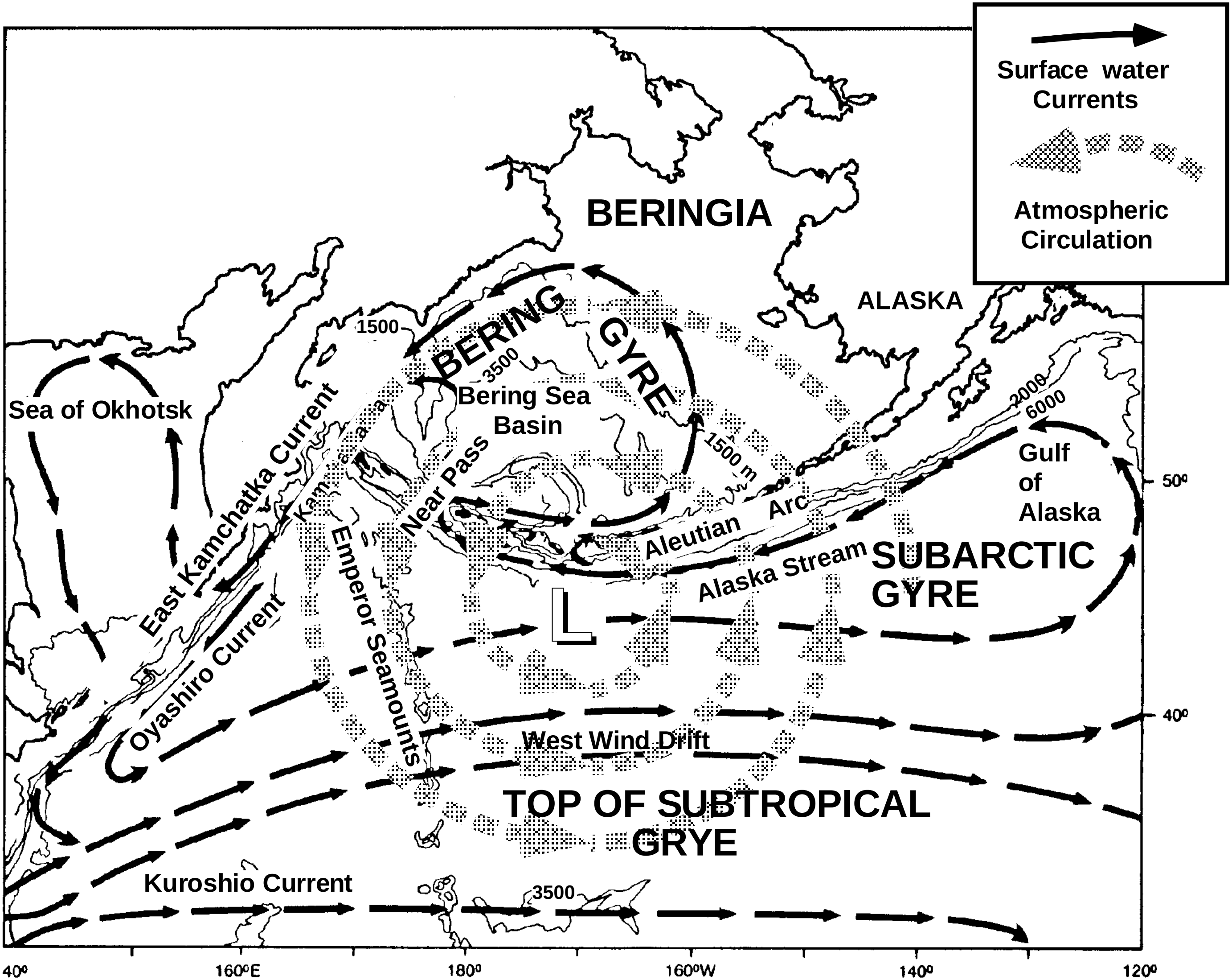

FIGURE 1a: Generalize surface water currentsand atmospheric circulation of winter Aleutian Low (L), north Pacific-Bering Sea, Region.

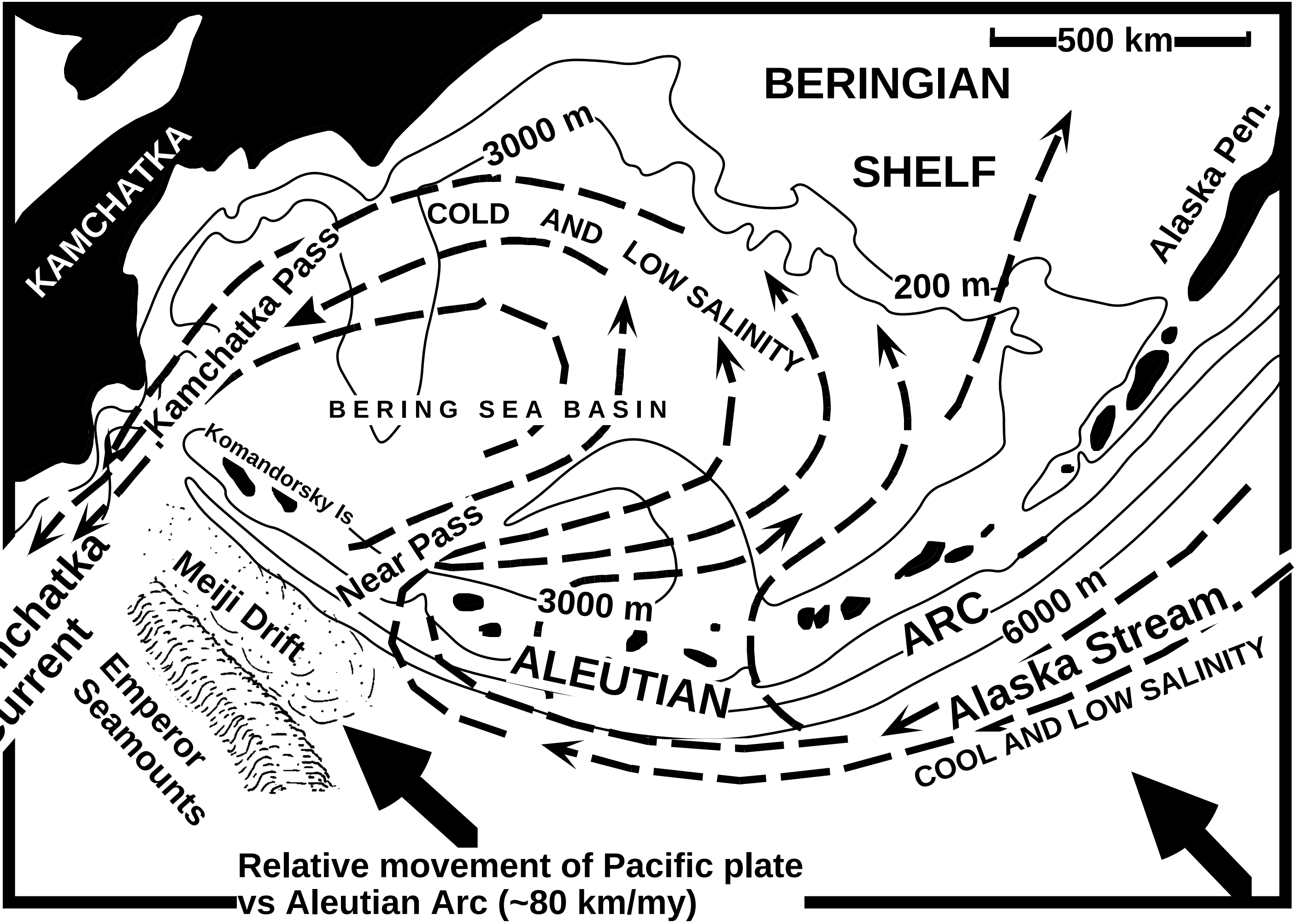

FIGURE 1b: Surface water currents of the Bering gyre, fed via inter-island passes from the Alaska Stream. No vertical or thermal-haline circulation occurs.

YEDOMA AS A STORE OF PALEOENVIRONMENTAL RECORDS IN BERINGIDA

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Definition, properties, distribution

At least three different meanings of the term "*yedoma*" can be encountered in the Russian literature: geomorphic ("yedoma surface"), stratigraphic ("the Yedoma Suite"), and sedimentological. The latter implies a peculiar kind of frozen sediment, widely distributed in West Beringida - ice-rich silts with very large ice wedges. The notion of YEDOMA as a product of syncryogenic sedimentation, driven by certain climatic and environmental conditions in the Pleistocene, is the focus of the present paper. The term "Ice Complex" is often used as a synonym of "Yedoma" in this sense. Most commonly, YEDOMA is characterised as an extremely ice-rich silty (loess-like) sediment of varying thickness (5-7 to 50 m). It includes the largest polygonal systems of syngenetic ice wedges (up to 5-8 m wide and up to 30-40 m high) and abundant texture ice in intrapolygonal ground blocks; total amount of ice may reach 80% of the sediment volume. Homogeneous grain size (up to 60% of 0.05-0.01 mm particles), complete sorting of silt sediment, and its mineralogical uniformity, advocated by some authors, have been reasonably disputed by others. In fact, YEDOMA represents a rather complicated sedimentary formation, made up of various facies, sometimes including coarser deposits. Perfect preservation of various organic remains is typical for YEDOMA. They range from worm coprolites, autochthonous grass roots permeating some YEDOMA facies, micro plant detritus, peat lenses, plant and insect macrofossils and numerous mammal bones to the buried dwelling holes, soft tissues and complete carcasses of Pleistocene animals. Although the main distribution area of YEDOMA sediments is on the coastal lowlands and surrounding low mountains of north-eastern Yakutia, and on the shelf islands, quite similar deposits are known from other permafrost regions as well (Central Yakutia, the Kolyma Highlands, the north of Middle Siberia, the Taimyr, and even West Siberia). Similar deposits are known in Alaska, where they are interpreted as eolian loess. Occurrence of YEDOMA-like sediments at various hypsometric levels (20-80 and up to 100-150 m a.s.l.) gave rise to an idea of blanket distribution of YEDOMA, of its excessively large thickness and the absence of clearly distinguished geomorphic levels built by YEDOMA. "Creeping" of YEDOMA sediments up the gentle slopes of bedrock hills is a well established fact; on the other hand, certain terrace-like levels, built up by YEDOMA of different ages, have been traced on the lowlands.

Origin

Long-term debate on the origin of the YEDOMA sediments was clearly polarised between fluvial and eolian concepts. Each imagined itself to be exclusive, but both actually failed to offer non-conflicting explanations to some of the observed features. A few less popular but more exotic hypotheses included sedimentation in vast basins, dammed by marine-based ice sheet over the Arctic Ocean, or large-scale catastrophic flood, caused by the resonance tide of the Ocean. In the 70's, a theory of cryogenic weathering was successfully developed, providing a link between Pleistocene climate and the abundance of the silt fraction in different sedimentary facies in the cryolithozone. The study of slope and proluvial deposits in the north-east Siberian permafrost area demonstrated their rather close affinities to YEDOMA on the lowlands. In the latter, it became possible to recognise not only different flood-plain facies, but channel sediments of coarser grain size, local slope deposits, deposits of thermokarst (alass) origin; local occurrence of eolian facies is also assumed. As a result, by the end of the 70's, a concept of polygenetic origin of YEDOMA became more and more widely accepted. It has been shown that the structure, composition, and properties of YEDOMA were essentially independent of depositional agents. Cryogenic weathering equalised the influence of particular sedimentation environments. Thus, YEDOMA is not considered to be a facies but a climatic formation. This broad concept helps to explain such peculiarities of YEDOMA, as its predominantly silty composition, occurrence of sediments of the same age at various hypsometric levels, its blanket distribution, etc. Long-distance profiles through the low mountain to lowland areas actually show paragenetic sequences of these cryogenic sediments across various sedimentary environments.

Age

Originally referred to the Late Pleistocene (Zyryanian), or even to the Middle Pleistocene, YEDOMA sediments have been almost entirely pushed into the range of radiocarbon dating (Karginian-Sartanian) when its wide application started in the 70's. Subsequent dating of some key sections such as Duvannyy Yar showed that only their top parts had a Sartanian age (24-10 ka), and the main part of the high YEDOMA sequence was beyond the range of the method. The existence of lower YEDOMA terraces (up to 20-25 m) of Sartanian age became increasingly evident. On the other hand, some sections produced a late Middle Pleistocene mammal fauna from the lower part of the 20-25 m YEDOMA sequence, while new infinite ^{14}C dates demolished the earlier finite dates from the same and underlying members. Thus, at least in some areas the ice-rich YEDOMA sediments had started to accumulate as early as the Middle Pleistocene and have never been completely thawed since that time. The preservation of some unthawed ice wedges of even earlier age has been reported from some other sites. With recent evidence, it seems quite possible that environmental conditions in West Beringida allowed cryogenic sedimentation of YEDOMA type as long ago as the Early Pleistocene, and some fragments of ice-rich bodies of these sediments may be preserved unthawed since the late Matuyama Chron, i.e. about 1 m.y. ago. The age range of YEDOMA-type sedimentation should not be confused with the age of the Yedoma Suite and the Yedoma Superhorizon in the official Stratigraphic Chart.

Paleoecology

Mammals were historically the first and most spectacular group of YEDOMA fossils to be known and discussed. The main controversy was in matching a severe paleoenvironmental image of the ice-rich YEDOMA with the abundance of bones of large grazing mammals, which are extinct now (mammoth, woolly rhino) or live much further south (horse, saiga). There were three main approaches to solve this puzzle: to deny the natural character of this combination; to argue that all grazers were able to live in an environment very similar to modern Siberian tundra or taiga; or to assume former existence of a hypothetical environment that equally satisfied the "life requirements of both northern and southern inhabitants" (Tugarinov, 1929) and the conditions under which YEDOMA was deposited. The latter, essentially non-uniformitarian approach, was behind the tundra-steppe concept and the focus of hot debate for almost 30 years. This concept is closely related to the problem of YEDOMA and its depositional conditions, in particular, how wet or how dry they could be. Naturally, the discussion involved all kinds of organic fossils preserved in YEDOMA.

Most spore and pollen spectra of YEDOMA sediments have only minute content of tree and shrub pollen and are dominated by grass and herb pollen. A very high content of *Selaginella sibirica* spores, in combination with a rich and various herb component, or with grasses and *Artemisia,* is remarkable in most YEDOMA sequences. The persistence of minor quantities of larch pollen in some grass dominated YEDOMA spectra, confirmed by macrofossils, also suggests an unusual vegetation. Although all recognised taxa can be found in modern pollen samples from the Arctic, the fossil spectra are quite different from the modern in relative abundance of pollen and spore taxa. Thus, the herb dominated YEDOMA spectra are interpreted as the evidence of non-analog relatively dry arctic grassland, or tundra-steppe. Some pollen zones in YEDOMA show a higher amount (10-40%) of shrub and tree pollen. These spectra certainly document some environmental changes during YEDOMA accumulation (expansion of tree birch and some shrubs over still dominating grassland, probably reflecting somewhat more mesic conditions), but they also have no complete analogs in modern samples. On the whole, the pollen spectra of YEDOMA sediments portray predominantly treeless vegetation, rather xeric than mesic, that cannot be completely identified with any kind of modern one.

The best confirmation of this inference comes from the abundant insect fossils buried in YEDOMA. Most typical are fossil assemblages that include the species common to various tundra habitats (mesic to xeric) in combination with large amounts of steppe and open ground species. Most of the steppe species now have a clearly more southern distribution, and do not occur together with the tundra ones. As strange as the unusually high amounts of *Selaginella sibirica* spores in the YEDOMA spectra, a non-flying pill-beetle, *Morychus viridis,* is often a superdominant of insect assemblages from the same sediments. Currently it is restricted to extremely dry and almost bare-ground habitats in the Kolyma Highlands, with an enormous soil temperature range. The YEDOMA insect faunas have no modern counterparts, and clearly indicate a non-analog xeric grassland environment. Quite different are the conclusions based on the study of plant macrofossils, even when they have been collected from the same section where pollen and insects portray a xeric environment. This discrepancy can be partly explained by taphonomic arguments, partly by the problems of seed and fruit taxonomy, but also by a strictly uniformitarian approach to the interpretation of plant macrofossils. At present, the carpological arguments against a xeric environment during YEDOMA deposition should be taken very cautiously. The diatom flora of the YEDOMA sediments includes mostly cold-adapted species of various freshwater or soil habitats. Although diatoms can be indicative of some fluvial or bog environments, they do not provide crucial evidence for the resolution of the most disputed problems of YEDOMA. Among other microscopic fossils in YEDOMA are oribatid mites, a very promising group in the initial stage of study. The oribatid fauna of YEDOMA has much in common with that of modern tundra, but still does not have complete modern analogs. Other organic fossils, found in the frozen sediments of YEDOMA, are either rare (freshwater shells), or still poorly studied. Quite promising is the study of buried soils in YEDOMA, though their interpretation is still controversial. A summary of paleoecological information obtained from YEDOMA allows us to outline some general features of the extinct tundra-steppe biome: 1.High tolerance of most organisms to very low winter temperatures.2.Essential role of xeric rather than mesic associations, and xeric affinities of many species. 3.Mosaic distribution of plant and invertebrate associations. 4.Higher species diversity within a given area, and, conversely, less pronounced regional variation (e.g., latitudinal zonality) than observed at present.

Inferred climate

Recent attempts to reconstruct past climate from various physical parameters of YEDOMA sediments (the spacing of frost cracks, oxygen isotopic composition of ground ice) definitely agree that the winter temperature during the time of YEDOMA deposition was much lower than now. The estimates of January air temperature are -46 - -48ºC or even lower. Summer climatic features can be reconstructed from proxy paleoecological evidence only. This evidence suggests that in generally much colder climate, summer heat influx to the ground must have been higher, which could be possible if we assume clearer skies (less frequent complete cloud cover). Increased summer insolation resulted in better evaporation, and drier and warmer upper soil layer. The active layer became deeper, with much sharper temperature and moisture gradients. Soil aeration and transformation of organic litter improved. To the winter characteristics the proxy data add very low snow cover. The inferred climate must have been of extremely continental type, presumably under almost round-the-year high baric conditions. This could exist only if the summer influence of arctic seas was minimized. This climatic model actually has no modern analog, since at present such huge land masses do not exist at these high latitudes.

Conclusion

It seems that the most debated problems of YEDOMA (origin, environment, etc) can be solved provided that two conditions are followed. First, if it is considered as a climatically driven formation, a specific type of syncryogenic sedimentation, peculiar for certain environmental conditions in the Pleistocene. Second, if all seemingly controversial paleoecological information, held within YEDOMA, is estimated and synthesised from the platform of a non-uniformitarian approach. At least in the late Pleistocene, YEDOMA sediments covered practically the whole of West Beringida, so the information on past environments obtained from YEDOMA is very important**.** Fossil mammal evidence from the shelf islands indicates that even at the highest latitudes the environment was not a kind of lifeless arctic desert, since it was inhabited with the same grazers. This biome definitely played the primary role in the story of Beringida, providing permanent source of cold-resistant continental species that were able to disperse onto the surrounding territories by appropriate climatic conditions. Some of these species were able to cross the more mesic zone of the modern Bering Strait and disperse to East Beringida. That kind of influence could have started much earlier, if the early Pleistocene deposition of YEDOMA in the modern shelf area is proven. Certainly, YEDOMA still conceals many unsolved problems. Potentially, it can provide a long continuous record of climate and environment, but this is hampered by the dating problems. The main current tasks are to improve chronology significantly, and to conduct effective and compatible multidisciplinary research in the northern part of the YEDOMA distribution area, i.e. on the shelf islands.

BERINGIDA: LAND, SEA, AND THE EVOLUTION OF CRYOXERIC ENVIRONMENTS AND FAUNAS

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The concept of Beringida was formulated to emphasise the former faunal entity of the exposed shelf and coastal lowlands of north-east Siberia and Alaska (Sher, 1976). The basic idea behind it was to abandon the earlier notion of Beringia as a land bridge, periodically connecting two different continents and allowing occasional migration of species. Similarity between the Pleistocene mammals of the Yana-Kolyma Lowland and Alaska turned out to be so close (and much closer than between each of these regions and the lower latitudes of their own continents), that it seemed more appropriate to consider those areas as belonging to a single paleofaunistic unit, that had a long and rather peculiar history of its own. From the perspective of Beringida as a whole, the area of the modern Bering Strait with its dynamic history of sea level change, was viewed rather as a periodically emerging water and climatic barrier, separating that unitary land into western and eastern parts. The unique character of the history of this relatively narrow zone has been emphasised (Yurtsev, 1970; Sher, 1976), and it has been proposed to reserve the name "Beringia" for it; in this paper we describe it as Central Beringida (CB).

West Beringida (WB), i.e. the Siberian part of the ancient land beyond the limits of CB, seems to have had the most stable history in the Late Cenozoic. The currently inundated part of WB is considered to correspond to the shelves of the East Siberian and Laptev Seas, thus extending from about Wrangel Island to the Taimyr Peninsula. That area was not subjected to glaciations (except the highest ranges); instead, sediments of a peculiar syncryogenic formation (Yedoma) were widely deposited there (Sher, this volume). Evidence of marine transgressions in WB is very limited and restricted mostly to its northernmost part.

The fossil environmental record in the coastal lowlands of WB, though far from being complete and continuous, provided some important landmarks for the late Cenozoic. It documents that permafrost and tundra-type plant and insect communities had already developed by 2.5 Ma at the latest (the Kutuyakh Beds, Sher et al., 1979). Repenning and Brouwers (1992) believe that the Kutuyakh rodent fauna is quite close to Fish Creek fauna on the arctic coast of Alaska, but the Siberian counterpart may indicate "greater aridity and a steppe-forest mosaic in the more continental environment of Yakutia". In fact, the first steppe insects have been recorded in WB a little later, possibly around 2.0 Ma (Sher et al, 1979). Later increase in continentality resulted in the development of xeric grassland, further permafrost aggradation, and the evolution of a diverse fauna of arctic grazers by approximately 1.5 Ma (the Olyorian Mammal Age). Some phases during the Olyorian supported vegetation almost inseparable from the typical tundra-steppe of the later Pleistocene, while the well-established "Chenopod" horizon, straddling the Matuyama-Brunhes boundary, is possibly one of the most arid episodes in the history of arctic environment.

Thus, the fossil record indicates that tundra-steppe plant and insect communities, and a fauna of arctic grazing mammals, coevolved in WB throughout the Pleistocene. It seems quite likely that these very peculiar types of communities originated in WB, from where many Beringidan mammals dispersed to the temperate latitudes of Eurasia and North America in the course of subsequent climate cooling and the spread of periglacial conditions during glacial ages (Sher, 1986, 1992; Repenning, Brouwers (1992). It has also been suggested that the cold and arid plains of WB could have served as a shelter (or refugium) for those tundra-steppe mammals intolerant of the interglacial environments in lower latitudes (Sher, 1997).

All of these considerations imply that WB must have retained a quite continental climate during most of the Pleistocene. In the context of this assumption it is interesting to consider, in a broader chronological scale, two hypotheses, recently forwarded in connection with the Pleistocene-Holocene transition in the Arctic (Sher, 1997).

The first suggests that modern "zonal" lowland tundra is not so much a zonal, as a coastal phenomenon. It follows from the fact that most peculiarities of the present climate of tundra (cool summer, reduced insolation because of frequent dense clouds, strongly decreased evaporation, overhumification in spite of very low precipitation, etc.) are directly related to the influence of the cold water mass of the arctic shelf seas. (It should be noted that these features are almost all antagonistic to the climate inferred for tundra steppe, cf. Sher: this volume). So, it is quite possible that the position of the tundra "zone" is directly tied to the position of the shoreline, and shifted with changes in the latter.

The second hypothesis concerns the position of the shoreline during regression phases. Because of the shallowness of the WB shelf, the sea coast ran much farther north than the southern limit of the pack ice under present conditions which are considered as "interglacial". It is hard to envisage that this limit was essentially farther north during glacial phases. Hence, it seems quite likely that when the shoreline retreated to much higher latitudes, the land could immediately contact pack ice through most of the year, including summer. Certainly, the formation of perennial ice cover in the Arctic Ocean is and was a very complicated process, which depends not only on global temperature, but on the sea and land distribution, river run-off, etc. For example, at present the main volume of new ice contributing to the Transpolar Drift is formed just within the shallow shelves of the WB seas; in the absence of these seas the whole situation of the ice regime in the Arctic Ocean could be very different from that of the present day. The possibility of a very sharp reduction in summer open water areas during regression phases in the WB sector should be examined by paleoceanographers (some of whom have themselves suggested this - Dunaev, Pavlidis, 1990). We only wish to draw attention to the possible consequences of this hypothetical situation for the land biota. The huge land mass (approx. 2.500x500 km) protruding far into high latitudes was a significant factor in increased continentality by itself. If it was not bordered by large areas of cold open waters in summer, but by ice instead, that should have resulted in even higher desiccation of the environment in WB. It should be stressed that, unlike the Panarctic Ice Sheet model, this hypothetical model does not imply the "sealing up" of the whole Arctic Basin and the isolation of its central part from water exchange. However, the supposed existence of the vast WB land mass should have had an immense effect on air, water, and ice circulation in the Arctic, and we believe that it should be taken into account, at least, as a possible option, by climate modelling and other kinds of reconstruction of past environments in Beringida.

If this situation was possible during the late Pleistocene regression, it seems just as likely to have happened during earlier low sea level phases. This could explain the early evolution of cryoxeric conditions in WB. At present, there is not much direct evidence to verify this hypotheses, but some data are rather suggestive. An extremely xeric environment on the Kolyma Lowland during the Matuyama/Brunhes transition clearly implies that the shoreline ran much further north at that time. About 700 km to the north, on Faddeevskiy Island (76°N), the Kanarchak Suite, referred to the Late Pliocene - Early Pleistocene (probable equivalent of the Olyorian, but possibly older) was deposited on a very flat coastal plain (tidal flat) under permafrost conditions and includes ice layers and ice-wedge casts (Chamov, 1990). Pollen spectra portray tundra vegetation with "distinctive coenoses of tundra-steppe type" (Zyryanov, 1989). Syncryogenic Yedoma-type sediments referred to the late Matuyama Chron have been reported (Arkhangelov et al., 1996) from Lyakhov Island (cf. Sher, this volume). The age correlations need to be verified, but these data generally agree with the assumption of a vast land with cryoxeric environment in WB in the Early Pleistocene. The same assumption could be equally reasonable for the earlier appearances of xeric assemblages in the lowlands (see above for Repenning and Brouwers' opinion).

Very rare and poorly documented evidence of marine deposits within the present mainland in WB has already been mentioned. In some coastal sections referred to the Late Pliocene - Early Pleistocene a few species of brackish-water and marine diatoms have been found in admixture to the complex of freshwater forms, but the sediment environment is still debatable. The same is true for Middle Pleistocene sediments of apparently marine or lagoon origin. Findings of marine shells in Pleistocene sediments are known from the shelf islands only, mostly in the northern group. Age assignment of these sediments is often far from being clear. For instance, dating of a marine section on Kotelniy Island (with marine shells and forams) to the Kazantsevo (Eemian) transgression is rather doubtful. ESR dating of marine shells from this island revealed a much older age of all samples (385-550 Ka, Bol'shiyanov et al., 1996).

Although our knowledge of the Pleistocene history of the WB shelf is still quite poor, and further research is urgently required, at least some evidence indicates that the idea of stability of continental development, allowing early origin and long evolution of cryoxeric environments in this area is quite plausible. In the framework of the whole Beringida, the WB area could have served as a source of species peculiar to the tundra-steppe biome. It is suggested that the dispersal of particular cryoxeric species and communities was regulated not only by the presence or absence of the Bering Strait as a physical barrier, but also by the distribution of sea and land at the time, which controlled climatic and environmental situation in the generally more mesic area of CB. The idea of mesic control by CB over the dispersal of cryoxeric elements was discussed by Yurtsev (1982), Guthrie (1990), and others; recently, it has been splendidly developed by the research of Berman (this volume) and by bottom cores studies in the Bering Strait (Elias et al., 1996). We may only hope that similar multidisciplinary work will be done some day on the Laptev or East-Siberian shelf, to examine tundra-steppe assemblages hidden below the present cold sea. Recent international research activities in this area, such as The Laptev Sea -2000 Project, and others, allow some hope.

IMPACT OF ACTIVE LOESS DEPOSITION ON NATIVE FORAGE PRODUCTIVTY: CASE STUDIES FROM YUKON AND ALASKA

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The Beringian "Production Paradox" is posed by abundant evidence that large ungulates populated Beringia during the late Pleistocene yet botanical data form the same period suggest a poorly productive tundra environment. In order to test the hypothesis that sites in receipt of loess may have played a significant role in the vegetative productivity of the Beringian ecosystem data from two sites actively receiving loess were evaluated. The first site was a continental, dry, parkland environment (MAAT -2.7ºC, MAP 225 mm) at Kluane Lake, Yukon and the second was the moist, modified maritime environment (MAAT +2.0ºC, MAP 460 mm) of the Matanuska Valley , Alaska.

Earlier work in range assessment in the Kluane Lake area had indicated that parkland vegetation communities receiving active loess deposit were dominated by *Festuca saximontana* and were estimated to as much as 350 kg/ha of forage production annually in comparison to <100 kg/ha in communities not receiving loess. Subsequent field studies at Kluane Lake indicated a positive correlation between the presence of eolian silt in the A horizon of grassland soils and the biomass of the associated surface vegetation cover. This was especially evident at sites with active loess deposition where relatively unweathered (calcareous) loess dominates the surface horizon. Once loess deposition ceases, total carbon, nitrogen and ammonium increase over time (few hundred years) to produce the most nutrient-rich soils of the region today. Soils with active deposition had mean and median biomass values of 210 and 120 kg/ha, while those stabilized surfaces has respective values of 280 and 220 kg/ha. The number of plant species on both types of sites was similar. In both cases organic matter level are high, >5% in hoizons formed from active deposition and >7% in stabilized and humified loess. Soil pH are alkaline in this system, all parent materials are calcareous and pH (H_2O) ranged from 7.2 to 7.4. The productivity gains from loess deposition within this semi-arid calcareous environment stem from increased nutrient availability as a result of enhanced biological activity, turnover and diversity, and the physical suppression of moss growth by burial from mineral soil input.

Loess materials generated from braided floodplains of the Matanuska and Knik rivers have accumulated as a silty veneer of variable thickness over glacial soil parent material throughout the Matanuska Valley in south-central Alaska. Soil series were evaluated in terms of their chemistry and associated vegetation communities relative to the degree of active loess deposition in the valley. Soils formed closest to the braided floodplains have non-leached, organic matter-rich surface horizons (Ah) with pH values >6.0, base saturation values >70%, high cover (40%) of graminoid cover and low moss cover. The soils support an open forest dominated by *Betula papyrifera* with lesser amounts of *Picea glauca* with an understory dominated by *Calamagrostis canadensis*. Soils in the valley not in receipt of active deposition have surface mineral horizons that are strongly leached (E horizons), are acidic (pH <5.5), and have base saturation <50% and as low as (10%). The ground vegetation cover is dominated by feather mosses, Sphagnum moss and lichens. These soils support a forest cover dominated by *Picea mariana* with minor amounts of *Betula papyrifera*. The productivity gains from loess deposition within this moist, leaching environment appear to stem from the rejuvenation of leached surface soils through increased base saturation of the upper solum.

While enhanced productivity of graminoids can be documented in a range of temperate loessal environments, some workers report no visible impacts of loess deposition on vegetation cover in other areas of Alaska (i.e. north side of the Alaska Range). The extrapolation of these soil responses to glacial paleoenvironments should proceed with caution.

THE NEO-TECTONIC SETTING OF BERINGIA

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In terms of the conventional global plate tectonic models, Beringia and the surrounding regions do not lie on plate boundaries. However, it has been known for a long time that significant earthquake activity is associated with the Seward Peninsula and the adjacent parts of Chukotka, as well as a series of large shallow events that trend WNW from the leading edge of the Pacific Plate beneath the Alaska Range. Following the major geothermal studies of the Seward Peninsula it became clear that the Seward Peninsula is part of an active extensional environment.

Various hypotheses were put forward to explain this, one of which was that the extension was the result of back-arc spreading behind the Aleutian subduction zone. Although generally plausible, the large distance between the area of active subduction and the presumed back-arc extension was worrisome. More recent work involving detailed studies of the earthquake records from both Alaskan and Russian sources, and the elimination of spurious events (mainly large explosions generated by Russian mining operations) has led to a new model. The new model invokes an independent Bering Sea plate which is slowly rotating in response to the stresses applied by the collision of the Yakutat block in south Central Alaska, and the general northward motion of the Pacific Plate. Evidence for this motion back through time can perhaps be sought in young terraces, uplifts and other fault-generated geomorphic features.

LATE HOLOCENE TREELINE DYNAMICS IN NORTHWESTERN CANADA

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Changes in the northern and altitudinal limits of the boreal forest in northwestern Canada are known to have occurred at various times during the Quaternary (Ritchie, 1984), and may also occur in the near future in response to anthropogenic climate forcing (Rizzo and Wiken, 1992). Relationships between climate change and treeline response are complex, however, and we need a good understanding of these relationships in order to interpret past and possible future dynamics of northern environments. Changes in the extent of the boreal forest may have feedback effects on further warming due to changes in surface albedo and carbon sequestration, for example (Bonan et al., 1992; Foley et al., 1994), and so knowledge of the potential rates of forest spread are important. In this study we combine dendrochronological and paleoecological records to examine the interactions between climate change and spruce dynamics at the subarctic alpine treeline of northwestern Canada during the late Holocene.

Using temperature-sensitive white spruce ring width chronologies from five sites in the Yukon and western N.W.T., a dendroclimatic record of June-July temperatures extending back to AD 1638 has been developed (Szeicz and MacDonald, 1995a). Summer conditions were particularly cool in the mid-19th century - the final phase of the so-called 'Little Ice Age' - and have since increased substantially. Late 20th century summer temperatures are greater than at any time in the last 350 years, except for the period 1760-1775. These trends compare well with larger-scale proxy climatic records for northern North America (eg. D'Arrigo and Jacoby, 1992). A moisture-sensitive white spruce chronology from the Inuvik area of N.W.T. suggests that the mid-19th century may have been dry as well as exceptionally cool (Szeicz and MacDonald, 1996).

To investigate the impact that these climate changes may have had on forest-tundra dynamics, the establishment dates of 1043 white spruce individuals from eleven treeline sites in the Mackenzie, Richardson and Ogilvie Mountains have been determined (Szeicz and MacDonald, 1995b). Data on mortality were also obtained by cross-dating dead spruce. These analyses have led to several findings. Firstly, the establishment of white spruce at or near treeline has been episodic, and these establishment trends compare well with the proxy temperature record. In particular, there has been a trend of increasing population density since the mid to late 1800's, coincident with the increasing trend in summer temperatures. The response of these populations to climate, however, appears to have been dampened somewhat by the ability of white spruce to reproduce vegetatively during periods of unfavourable climate. Secondly, despite the increases in establishment at or near treeline during the past 100 to 150 years, there is evidence for only minor increases in treeline elevation during this time. Thirdly, a mass mortality of white spruce in the early to mid 1800's, coincident with the pronounced cooling, occurred at a site currently above treeline. Despite increasing temperatures since that mortality event, spruce have been unable to become re-established at this site. These results suggest that the establishment and mortality of white spruce at the subarctic alpine treeline is controlled to some degree by temperatures, but the response of treeline position to climate change has been limited by a degree of inertia inherent in the marginal populations. The continued survival of marginal white spruce populations during periods of fluctuating climate is facilitated by vegetative reproduction, shifts in growth form, and local microclimatic modification. Establishment beyond the limits of the stands, however, may be limited by a lack of suitable protected microenvironments for seed germination and survival. Treeline response in this region appears to be similar to post-Little Ice Age responses in the forest-tundra of northern Quebec (Payette and Filion, 1985) and central Canada (Scott *et al*., 1987).

Dendroecological records of alpine treeline dynamics for northwestern Canada currently extend back only three to four centuries. Fossil pollen analyses indicate that spruce population densities in the forest-tundra of the Mackenzie Mountains (western N.W.T.) were greater than present between about 8000 and 5000 yr BP, and have since declined (Szeicz et al., 1995). As with the dendroecological data, there is no evidence for major changes in the position of treeline, but the coarse resolution of these analyses makes direct comparison with dendroecological records difficult. High-resolution pollen records have therefore been developed at two small treeline lakes in the Mackenzie Mountains, in order to bridge the temporal gap between paleoecological and dendroecological records. Changes in spruce pollen percentages and spruce/shrub birch pollen ratios compare well with stand establishement data from treeline sites in the region, which suggests paleoecological analyses can help extend back records of treeline vegetation dynamics several millennia. Distinguishing between changes in forest-tundra density and changes in the elevation of treeline is difficult using pollen records alone, however, and highlights the need for multi-proxy paleoecological investigations of treeline dynamics during the late Holocene.

REFERENCES

Bonan, G.B., Pollard, D. and Thompson, S.L. (1992) - Nature, 359: 716-718.

D'Arrigo, R.D. and Jacoby, G.C. Jr. (1992) - in Bradley, R.S. and Jones, P.D. (eds.) - Climate Since AD 1500, Routledge, pp. 296-311.

Foley, J.A., J.E. Kutzbach, M.T. Coe, and S. Levis (1994) - Nature, 371: 52-54.
Payette, S. and Filion, L. (1985) - Can. J. For. Res., 15: 241-251.

Ritchie, J.C. (1984) - Past and Present Vegetation of the Far Northwest of Canada. University of Toronto Press.
Rizzo, B. and Wiken, E. (1992) - Clim. Change, 21: 37-55.

Scott, P.A., R.I.C. Hansell, and D.C.F. Fayle (1987) - Arct. Alp. Res., 19: 45-51.

Szeicz, J.M. and MacDonald, G.M. (1995a) - Quat. Res., 44: 257-266.

Szeicz, J.M. and MacDonald, G.M. (1995b) - J. Ecol., 83: 873-885.

Szeicz, J.M. and MacDonald, G.M. (1996) - Holocene, 6: 345-351.

Szeicz, J.M., G.M. MacDonald, and Duk-Rodkin, A. (1995) - Paleogeog., Paleoclim., Paleoecol. 113: 351-371.

THE LAST BERINGIAN SURVIVORS: INTERDISCIPLINARY PALEOGEOGRAPHICAL STUDIES ON WRANGEL ISLAND, EAST SIBERIA

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Wrangel Island is located on the border of the East Siberian and Chukchi seas, between 70º and 72º N and 176ºE and 177ºW. Because of the particular geographical position and peculiarities of the topography and microclimate of the area, studies of the late Quaternary and Holocene natural history of the island are of the greatest importance for paleogeographical and biogeographical research in the Beringian section of the East Arctic. The territory of the island is unique, representing the only part of the northern (shelf) portion of West Beringia currently available for exploration, due to the remainder having been submerged or destroyed by the Postglacial transgression of the Polar Ocean.

Specific natural conditions of Wrangel Island promoted a survival of some periglacial flora and fauna species in the Holocene, i.e., this isolated territory became a natural phenomenon, a kind of refuge for the latter. Interdisciplinary studies covering the palegeographical problems of the area are conducted on the territory of the "Wrangel Island" State Nature Preserve (Russia). During the past 7 years these paleogeographical investigations have included a sampling program for studies of the most recent deposits, the collecting of bone remains of Pleistocene and Holocene animals, and laboratory studies. The data available make it possible to present important conclusions, even if some of them are of a preliminary nature:

1. The territory of the island lacked extensive glacial cover during the late Pleistocene. Small glaciers, more or less stable, or stagnant, occurred during that time in the mountainous areas of the island.

2. Some climatic fluctuations are recognized to have taken place during the period after the last Pleistocene interstadial, which corresponds in general to those found in other regions of the northern hemisphere. According to the paleobotanical record, the late Pleistocene cold intervals (Zyryan and Sartan glaciation in Siberia) were of rigorous climate, with grass vegetation predominating, while sediments belonging to the interstadial (Karga deposits) are characterized by increases in the pollen content of bush and shrub vegetation. Most probably the latter shows the rise in summer temperature, which took place during that time.

3. The greatest portion of the island was affected by thermokarst processes, contemporary with the spreading northward of sub-arctic vegetation near the Pleistocene/Holocene boundary. Peat bog sediments and thermokarst lake deposits radiocarbon dated from 12.5 to 7.7 kyr ago, are very typical for plains and intermontane depressions. The very short interval from 10 to 9 kyr ago was found to be the warmest time in the whole Holocene.

4. Climatic conditions very close to the modern type occurred on Wrangel Island about 3 kyr ago.

5. Mammoths and other megafaunal species such as reindeer, bison, muskoxen, horses, and woolly rhinoceros, usual for the late Pleistocene faunal complex of North Asia, populated that area including Wrangel Island at least in the last third of the Late Pleistocene as well as other territories of West Beringia. They were not numerous but occupied extensive areas. Supposedly some of the High Arctic regions were not visited at all (or visited sporadically) by large mammals. Regarding the woolly rhinoceros it should be mentioned that all the data available show that this species inhabited the island in the Karga interstadial only.

6. Wrangel Island became unaccessible for the large mammals about 8 kyr ago. At that time the dwarf mammoth population appeared on the island and survived in isolation up to 4 kyr ago. It is found that they were relatively more numerous than ever in the late Pleistocene.

7. There is no evidence that any other species of the Mammoth Complex except the mammoth itself survived on Wrangel Island in the mid-Holocene.

MOIST NONACIDIC TUNDRA: POSSIBLE CAUSES AND SIGNIFICANCE TO BERINGIAN PALEOENVIRONMENTS

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Landscape evolution during the post glacial period has resulted in remarkable changes in the ecosystems of northern Alaska, so much so that there appears to be few analogs of systems that existed during the glacial intervals. One of the most remarkable changes has been the almost total conversion of the region from a dry minertorophic system to a peaty oligotrophic one with extensive wetlands. Recent mapping studies reveal an important boundary that separates tussock tundra landscapes (moist acidic tundra, MAT) from mineral-rich moist nonacidic tundra (MNT) to the north. This boundary appears to stretch across all of northern Alaska and is evident in many other parts of the circumpolar region. The causes of the boundary are not entirely clear. One current hypothesis currently being tested is that windier conditions on the coastal plain result in thinner, more dense winter snowpacks, causing colder winter soil surface temperature that result in greater amounts of cryoturbation, which continually brings calcareous eolian and alluvial materials to the surface, which are colonized by nonacidic plant communities. The resulting nonacidic tundra appears to have great significance for a wide variety of organisms, including small mammals, caribou, grizzly bear, fish and shorebirds. Here, some of the important ecosystem differences between acidic and nonacidic tundra are illustrated along with the possible significance to the Beringian paleoenvironments and early man in the region. A "tundra late-succession avoidance hypothesis" can be summarized as follows: Over millenial time scales low arctic ecosystems evolve toward tundras that have the following characteristics:

* Deep moss carpets dominated by *Sphagnum*.
* Organic-rich, fine-grained, low pH soils.
* Shallow active layers and ice-rich permafrost.
* Tussock tundra with low vascular-plant diversity, dominated by shrubs that are high in secondary protective compounds and low in minerals, especially calcium.
* Generally high-microrelief caused by tussocks (*Eriophorum vaginatum*).

The implications for wildlife are:

* Poor forage for herbivores because of secondary compounds and low Ca for bone development, antlers, and lactation.
* Few denning sites for small mammals because of shallow active layers.
* Poor footing for migratory species because of high microrelief, soft moss carpet, and deeper more variable snow cover.
* Poor hunting for predators.
* Few insects for birds.

The implications for indigenous people are:

* Gradual restriction through the Holocene of good hunting areas to the riparian corridors and areas of nonacidic tundra.
* Location of villages and hunting camps in areas of nonacidic tundra.

HUMAN DISPERSAL INTO INTERIOR ALASKA: ANTECEDENT CONDITIONS, MODE OF COLONIZATION, AND ADAPTATIONS

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In spite of more than a half-century of exploration of interior and northern Alaska, no definitive evidence has yet come to light for human occupation preceding ca. 12 KA BP. In unglaciated areas with deep loessic stratigraphy, as in the Tanana River valley, no evidence of earlier occupations has been found entrained in these deposits. Cave sites offering possibly older dates (Lime Hills, Trail Creek, Bluefish Cave sites in the adjacent Yukon Territory), in common with those south of the ice sheets, are plagued with stratigraphic and taphonomic problems that are not easily resolved.

The region east of the Lena River basin in western Beringia appears to have been a major barrier to human migration during the time of the glacial maximum, just as it was in northern Europe. Recent summaries of dates from western Beringia by Kuzmin and Tankersley (1996) reflect a wave pattern of human migration that places the earliest humans in the Bering Strait region around 13 KA BP, coincident with glacial recession and a significantly warming environment east of the Lena basin. Human population growth and the encroachment of peoples from the west and south may have been an additional factor underlying these migrations. The gradual drowning of the land bridge, completed a couple of thousand years later, presented a relatively narrow window of opportunity for early Alaskan colonists.

The earliest colonization of interior Alaska appears to have been a "push-pull" phenomenon. In this context, the "push" involved the disappearance of key areas of the land bridge acceleration of faunal extinctions associated with major shifts in weather systems, temperature, precipitation, and vegetation; and the limitation of remnant stands of megafauna, both latitudinally and altitudinally. The "pull" involved the cessation of catabatic winds and major sandstorms in interior Alaska, the development of stable land surfaces, and opportunities for accessing both animal populations and lithic resources.

Sedimentological and radiocarbon data from the deeply stratified Broken Mammoth, Mead, and Swan Point sites in the central Tanana River valley (Fig. 1) help to confirm this process. They suggest that human occupation began around 12 KA BP, soon after the cessation of late Pleistocene dune formation and widespread sand deposition. The well-preserved fauna associated with these sites suggests relatively dry, open parkland conditions with Arctic taxa (Arctic fox, snowshoe hare, Arctic ground squirrel, pika, lemming, etc.) continuing until as late as 9300 yr BP. Wetlands were locally important, particularly in the earliest phase of occupation of the Broken Mammoth site (11,800 to 11,000 yr BP), representing a source of waterfowl and fish. The major portion of the biomass was provided by two taxa, *Bison* cf . *priscus* and *Cervus elaphus*, which were extensively butchered for meat, marrow, and possible tool production. Mammoth utilization was limited to tusk material for tool production, for which there is considerable evidence. Dates on mammoth ivory at these sites range from 18,000 to 12,050 yr BP, with the last date suggesting that mammoth extinction, if it occurred before human occupation of the region, did not precede it by much.

Sedimentological and faunal data from the Broken Mammoth site provide relatively little evidence of a Younger Dryas climatic reversal. Faunal taxa show few differences between the earliest occupation (11,800 to 11,000 yr BP) and the second occupation (10,500 to 9300 yr BP). Most of the differences between these units, reflected in the species diversity data, are related to reduction in the use of wetland taxa, possibly a function of different seasons of site utilization.

In contrast to the above, there is strong sedimentological and faunal evidence at the Broken Mammoth, Mead, and Swan Point sites for a thermal maximum dated from ca. 9300 to ca. 7600 yr BP. Increasing aridity appears to be associated with accelerated wind velocity and human abandonment of this area of interior Alaska. After that tine, and more so after 4 KA BP, there is evidence for more wetland as well as boreal taxa, and the disappearance of the Arctic forms found in the earlier (late Pleistocene/early Holocene deposits). At the same time, however, there is evidence from Broken Mammoth, as well as from nearby sites (Gerstle Quarry, Fort Greeley) that bison and elk persisted into at least mid-Holocene times.

Given that the early phase of human occupation of interior Alaska was relatively brief, lasting no more than ca. 2500 years, the intensity of occupation is surprising. The earliest phase of occupation (11,800 to 11,000 yr BP) at Broken Mammoth and other sites does appear to represent initial colonists who were more transient occupants of the site, and had relatively little knowledge of more distant lithic resources, thus needing to maximize their use of resources such as scavenged mammoth tusk. However, within 1000 years after initial colonization, the local inhabitants had developed more intensive, semi-sedentary occupations with extensive hearths and a wider array of activities, including catching and secondary transport of game, hide preparation and clothing manufacture, and lithic manufacture and reutilization. They also demonstrated greater access to distant lithic sources, indicative of widespread trade networks.

The early bifacial lithic traditions of interior Alaska, whether defined as a so-called "Nenana Complex" that excludes microblade industries, or a broader "Beringian Tradition" that includes them, is clearly linked to the late Pleistocene Dyuktai culture of eastern Siberia as broadly defined. At the same time, West, Goebel, and others have demonstrated links to the Paleoindian complexes of western North America south of the ice sheets. The fluted point complexes of the North Slope and western interior Alaska, as described by Clark, Reanier, Ackerman, and others, seem to represent slightly younger, derivative Paleoindian assemblages, rather than the initial transitional industry between antecedent Siberian and later Paleoindian ones. At present, the "Nenana Complex" remains our best candidate for such a transitional industry, containing elements of both.

The search for early occupations in coastal Alaska has yielded to date none earlier than 10 KA BP. The oldest dates are in the region from southeastern Alaska to central British Columbia, where conditions allowed early migrations along the coast. These dates are associated with microblade and biface industries that may be derivative from interior Alaska. To the west, the oldest industries of the Aleutian/Kodiak region are no older than ca. 9 KA BP, where they are preserved in tectonically uplifted areas. The coastline in this region was less penetrable during late glacial times, and basal peat dates suggesting fully deglaciated surfaces are earliest Holocene in date. The affinities of these industries are more clearly with the maritime region of Primorie Province (Russian Far East) and neighboring Japan, which range in age from ca. 14 to 10 KA BP. Current evidence suggests that they may also be ancestral to proto-Eskimo industries in both south central Alaska ("Ocean Bay" tradition) and northern Alaska ("Arctic Small Tool" tradition).

THE PLEISTOCENE "TUNDRA-STEPPE" AND THE PRODUCTIVITY PARADOX

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1. In the Pleistocene Beringia the Tundra-Steppe stages alternated with mesic-hygric Tundra ones successively and not once. The modern flora and vegetation (especially in Mega-Beringia) contain rich material both for the paleo-reconstruction of the tundra-steppe vegetation and for the re-establishment of the latter in the case of the new exposure of shelf under cryo-xeric conditions. Though the ability of species to combine with others can drastically change with major climatic changes, and we should not mechanically extrapolate the modern composition of relic communities to the past vegetations and landscapes.

2. Tundra-Steppe"(like terms "Tundra","Taiga","Steppe") means both a certain sort of plant communities (and the respective ecosystems) and a type of landscape. As type of communities it represents the ecotone and the intermediate formation between the tundra and the steppe as the two contrasting zonal types of communities and ecosystems (the comparison is to be given). A specific feature of the cryo-xeric epochs of the Pleistocene was the appearance of cryophytic steppe as zonal types of communities and ecosystems on the northern plains. The proximity in the composition of the dominant herbaceous species of steppes (zonal or relic) is traced now on the huge area from Central Asia (Mongolian Altai, Khangai) up to the northern arctic islands (Wrangel I.) with mean July temperature down to 2.4 degree C. The maximum diversity of northern relic cryophyte steppes is recorded from Beringia. The main ecological factor determining the distribution of steppe and its interrelations with tundra or taiga is aridity of climate. Even at the present epoch, the herbaceous xerophyte vegetation locally dominates landscape at the certain threshold in precipitation/summer warmth relation ("Indigirka forest-steppe" in the Subarctic; the inner parts of Ellesmere Island in the High Arctic). For the definitions see the chapter by B. A. Yurtsev in "Paleoecology of Beringia, N.-Y.,1982.

3. More important is the concept of "tundra-steppe" (or "Steppe Tundra") as a type of landscape co-dominated by both steppe and tundra (with certain part played by the tundra-steppe communities, too), the cryophyte steppes being among the zonal formations, whereas the mesic and hygric tundra ecosystems occupy the subordinated positions beyond the watersheds. Evidence from the fossil assemblages of mammals and insects, as well as from the pollen spectra testify to the tundra-steppe landscape with the drastically increased role of herbs (versus trees, low to dwarf shrubs, bryophytes and lichenes), and increased diversity of the xerophytes and cryo-xerophytes. "Productivity paradox" also testifies to the type of landscape that supported an increased diversity of herbivorous mammals. It included a mosaic of communities and ecosystems, dominated mostly by herbs, with unleached, base-saturated soils, and a humus horizon involving saturation with plant roots decomposed rather then accumulation of surficial peat. Herbivorous animals were the important components of those herb-dominated ecosystems (as are they in the modern steppes) which could benefit also from eolic sedimentation and fires. Of maximum forage value for herbivorous animals could be not the cryophyte steppes themselves that occupied the driest sites, but other, more mesic, ecosystems in valleys, lower parts of slopes, gullies etc.

4. Analysis of the modern distribution of the probable relics of the Pleistocene tundra-steppe permits to suggest the following paleo-reconstruction of the vegetation of the tundra-steppe landscapes of Beringia in Pleistocene.

A. Eluvial and transitive-eluvial positions (watersheds etc.). 1) Cryophyte steppes with co-dominance of steppe plants and cryo-xerophytes (i.e. xerophytes of the arctic or alpine zones), very often with increased role of steppe sedges [characteristic species: *Festuca lenensis*, *Calamagrostis purpurascens, Carex obtusata, C.supina* subsp. *spaniocarpa*]; 2) cryoxerophyte herbaceous vegetation (steppe-like vegetation of the Arctic or alpine areas) [*Kobresia myosuroides, Carex rupestris*], and (3) its calcicolous variants [*Kobresia filifolia* subsp. *subfilifolia*, *Carex petricosa* s.l.]; 4)dry herb-prostrate shrub tundras with slightly-leached debris soils [prostrate summer-green shrubs: *Dryas* spp., *Salix* spp.]; the tundra-steppe associations formed at the contact zones between the 1 and 4 or 2 and 4 types of vegetation.

B. Transitive-accumulative and accumulative positions (valleys, pediments etc.). 5)mesic-xeric meadows enriched by steppe elements [grasses of *Bromus, Agropyron* s.l., *Helictitrichon*, legumes etc.], sometimes with shrub layer [*Salix glauca, Rosa acicularis* etc.]; along with mesic meadows of moister sites [*Arctagrostis* spp.etc.]; 6) solonetz (brackish-water) meadows of the drying-out mires, shores of lakes, valleys [*Hierochloe glabra* s.l., *Arctopoa subfastigiata, Triglochin maritimum*, *Carex* spp.]; 7)cryo-xeric-halophyte vegetation of "arctic takkyrs"(the sites wet in spring, later drying-out, with salt-crusts etc.) [*Braya thorildwulffii, Poa hartzii, Melandrium triflorum, Potentilla pulchella, Puccinellia* sp. in the High Arctic; *Thel-*

lungiella salsuginea etc. in the Southern Arctic]; 8) sparse groupings of ruderal annuals-zoochors [*Hedinia czukotica, Arabidopsis bursifolia* s.l. etc.]; 9) sparse vegetation of eolic “seas” of Beringia [*Carex sabulosa, Plantago canescens* s.l.]. Most productive, in terms of forage value for herbivores, were the vegetation types 2, 3, 5, and 6.

5. The plant cover of the Pleistocene tundra-steppe landscapes was not quite homogenous throughout Beringia, but revealed a certain provincial differentiation like do the modern steppe regions of the inner Eurasia and North America. Most productive and botanically diverse could have been the landscapes of the zones of the joint of mountainous glaciers and the adjacent arid plains where comparatively warm, though short, summer combined with adequate water supply from glaciers. In this way some Beringian mesophytes could spread up to the northern Ellesmere Land and the northernmost Greenland [*Acomastylis rossii*] and some Central-Asian subalpine grasses - up to Frontier Range of the Rockies in Colorado. Here many relics of the mesic to moist tundra could have persisted the cryo-arid intervals of the Pleistocene.

6. The area of the exposed shelf of Bering Strait and some adjacent areas with their monotonous topography and, possibly, increased precipitation from the Pacific could function as a filter for the migration of many steppe and montane plants and xerophilous invertebrates. But more than 40 xerophyte species that presently occur on every side of Bering Strait, crossed the area, providing the sufficient material for the formation of various cryophyte steppe, tundra-steppe and cryoxerophyte herbaceous associations. Though in the composition of these biocoenoses eurytopic (including nearly ubiquitous) species could played an increased part.

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BERINGIAN PALEOENVIRONMENTS: SESSIONS and PROGRAM, 20-23 September, 1997

SATURDAY, 20 SEPTEMBER

Welcome statements and goals Brigham-Grette and Elias

Session 1: EARLY BERINGIA: its nature and origins
Chair: Julie Brigham-Grette

The Neo-Tectonic Setting Of Beringia
David B. Stone Kazuya Fujita and Kevin Mackey

The History Of Late Tertiary Floras And Vegetation Change In Beringia Based On The Fossil Records Of Northwestern Canada, Alaska, And Northeastern Asia
Thomas Ager and James White

The Influence Of The Bering Strait On The North Pacific-Arctic Ecosystem During The Neogene
Yuri B. Gladenkov

Geologic Controls On The Flow Of Water Into And Out Of the Bering Sea—Thoughts About Past And Future Climatic Effects On Beringia
David W. Scholl and Andrew J. Stevenson

Open discussion and synthesis

Session 2: Plio/Pleistocene Environments & the Age of Warm/Cold Events
Chair: Julie Brigham-Grette

New Paleontological Information On The First Opening Of Bering Strait
Louie Marincovich and Andrey Yu. Gladenkov

Mid Pliocene To Mid Pleistocene Record Of Glaciations In The Tintina Trench, West Central Yukon Territory
A. Duk-Rodkin and R. Barendregt

The Age of the Fishcreekian Transgression and the last warm Pliocene Interglacial
J. Brigham Grette

Origin and Environment Of The 2 My Old Dawson Cut Interglaciation Forest Bed
Troy Péwé

Discussant comments:
Charles Repenning, Bob Nelson, Pavel Nikolskiy, Duane Froese, Boris Yurtsev

Open discussion and synthesis

SUNDAY, 21 SEPTEMBER

Session 3: Long term glacial/paleoclimate record in Beringia :Why do we have out-of-phase glaciations in Beringia? What is the nature of Arctic interglaciations and Arctic Glacials?
Chair: Tom Hamilton

Geomorphological Correlation Of Late Pleistocene Ice Complexes Of Western And Eastern Beringia
Olga Yu. Glushkova

Diatom Stratigraphy And High-Resolution Paleogeography Of Baldwin Peninsula Deposits, Seward Peninsula, Alaska
Vladimir S. Pushkar, Steven R. Roof, Marina V. Cherepanova, David M. Hopkins, Victor F. Ivanov, and Julie Brigham-Grette

Glacial And Interglacial Records From Glacial Lake Noatak, Northwest Alaska
Thomas Hamilton

A Terrestrial Record Of Climatic Fluctuations During The Quaternary: Magneto- And Bio-Lithostratigraphic Evidence From Banks Island, WesternCanadian Arctic Archipelago
Rene W. Barendregt, Jean-Serge Vincent, Edward Irving, And Judith Baker

Preliminary Report On The Age, Extent, And Paleoclimatic Significance of Pleistocene Glaciations, Coastal Ahklun Mountains, SW Alaska
Darrell Kaufman, William Manley, Shari Preece,

Discussant comments
Louie Marincovich, Steve Forman, and Paul Layer

Late Quaternary Glacial History Of The Cold Bay Region Of The Alaska Peninsula
Tina M. Dochat

Upper Cenozoic Sites Of The Laptev Sea Coast - New Data And Implications For Transberingian Correlation
Pavel Nikolskiy and Alexander Basilyan

Discussant comments
Charlie Schweger, David Hopkins, A. Duk-Rodkin, Olga Glushkova, Scott Smith

Open Discussion and Morning synthesis

Session 4: What can we extract from the Loess Record? What can we extract from Yedoma?
Chair: Jim Beget

The Loess Treasurehouse: Long Term Records Of Paleoclimates and Paleoenvironments, Glacial And Periglacial History, Paleoecology and Evolution, Native American Settlement, Paleopedology, And Volcanism Across Beringia
James E. Begét

Yedoma as a Storage of Paleoenvironmental Record in Beringia
Andrei Sher

The Last Interglacial-Glacial Cycle In Late Quaternary Loess, Central Interior Alaska
Daniel R. Muhs, Thomas Ager, Thomas W. Stafford, Jr., Milan Pavich, James E. Begét, and John P. McGeehin

Eva Interglacial Forest Bed, unglaciated east-central Alaska: Global Warming 125,000 years ago
Troy Péwé, Glenn Berger, John Westgate, Peter Brown, And Steven Leavitt

Open Discussion:

MONDAY, 22 SEPTEMBER

Session 5: The “Productivity ParadoxÓ revisited and What is steppe tundra?
Chair: Scott Elias

The Pleistocene “Tundra-Steppe” and the productivity paradox
Boris Yurtsev

Nature of ancient and modern steppe tundra
Daniil Berman

Regional extent of steppe tundra in Alaska
Scott Elias

A Moment In Time: The Landscape Of The Full-Glacial Bering Land Bridge At 18,000 Years B.P.
Victoria G. Goetcheus and David M. Hopkins

Impact of Active Loess Deposition on Native Forage Productivity: Case Studies from Yukon and Alaska
Scott Smith

Origin And Causes Of The Mammoth Steppe: A Story Of Cloud Cover, Woolly Mammals, And The Little Buckle
R. Dale Guthrie

Microfossil Analysis Of Drained Thaw Lake Basins In Barrow, Alaska: Identifying Tundra Vegetation Patterns
Wendy R. Eisner and Kim M. Peterson

Discussant Comments
Andrei Sher, Charlie Schweger, Bob Nelson, Russell Graham, Mary Edwards, David Yesner, Pat Anderson, Linda Brubaker, Sergey Vartanyan

Discussion and synthesis: future directions

Session 6: What are the implications of a late persistence of an intercontinental land bridge for human dispersals? For faunal dispersals:? For floral dispersals? And Beringia as a center for development in its own right.
Chair: David Yesner

Human Colonization of Northern Asia and Beringia: Hard Environments,Limiting Factors, and Range Expansion in the Late Pleistocene
Ted Goebel

Terminal Pleistocene And Early Holocene Occupation In North East Asia And The Zhokhov Assemblage
Vladimir Pitul'ko

The Early Holocene Hypsithermal And Humans: Adverse Conditions For The Denali Complex Of Eastern Beringia
Owen K. Mason

Beringian paradoxes: investigating late Pleistocene human biogeographical dispersals between Eurasia and North America
Jacques Cinq-Mars and Nicolas Rolland

Beringia: Land, Sea, And The Evolution Of Cryoxeric Environments And Faunas
Andrei Sher

Discussant Comments
Maureen King, E. James Dixon; Charlie Schweger,Boris Yurtsev

Open Discussion and Synthesis

Session 7: What are the merits of interior vs coastal routes as dispersal path of earliest humans into North America?
Chair: Carol Mandryk

Human Dispersals into interior Alaska: Antecedent conditions, mode of colonization, and adaptions
David R. Yesner

Late Pleistocene/Early Holocene Human Adaptions and the Northwest corridor
E. James Dixon

Late Quaternary Paleoenvironments Of Northwestern North America:Implications For Inland Versus Coastal Migration Routes
Carole Mandryk

The Sea-Level History And Drowned Landscapes Of The Queen Charlotte Islands/Hecate Strait Of British Columbia, Canada
Heiner Josenhans

Open Discussion and Synthesis

FINAL DINNER Followed By Talk From David Hopkins

TUESDAY, 23 SEPTEMBER

Session 8: Can we develop a more accurate and detailed record of Late Quaternary climate and vegetation in Beringia ?
Chair: Pat Anderson

The Late Pleistocene Interstade (Karginskii/Boutellier Interval) Of Beringia: Variations In Paleoenvironments And Implications For Paleoclimatic Interpretations
Patricia M. Anderson And Anatoly V. Lozhkin

Mid-to Late Wisconsin Transition in Northern Alaska:Contrasting Loess and Fluvial pollen records and implications for Land Bridge environments
Bob Nelson and L. David Carter

Beringian Paleovegetation Maps and Trends
Pat Anderson and Linda Brubaker

Seasonal temperature records from Alaska based on fossil beetle data
Scott Elias

Late-Glacial Changes In An Arctic Landscape: The Northern Flank Of The Brooks Range During Paleoindian Occupation
Dan Mann, Dorothy Peteet, Rick Reanier, Mike Kunz, And Steve Durand

Controls And Spatial Variations Of Late Quaternary Paleoclimates In Beringia
Cary J. Mock, Patrick J. Bartlein, and Patricia M. Anderson

Late Pleistocene Climate History Of The Northern N. Pacific
Lloyd D.Keigwin

Did Late-Glacial Sea Surface Temperate Changes In The North PacificAffect Beringian Climate? - Explorations With The GISS GCM
Dorothy Peteet*, Anthony Del Genio1, and K.-W. Lo

Open Discussion and Synthesis

Session 9: What was the character of Holocene climate across Beringia?
Chair: Mary Edwards

Holocene Coastal Glaciation Of Alaska
Parker E. Calkin, Gregory C. Wiles, And David J. Barclay

Late-Quaternary Paleohydrology And Paleoclimatology Of Eastern Interior Alaska
Mary Edwards, Bruce Finney, Cary Mock, Mark Abbott, Nancy Bigelow, Val Barber, Patrick Bartlein, And Kerry Kelts

The Last Beringian Survivors: Interdisciplinary Paleogeographical Studies On Wrangel Island, East Siberia
Sergey Vartanyan

Modern Pollen And Late Quaternary Paleoenvironmental Data From Wrangel Island Northern Chukotka): Evidence For A "Warm-Wet" Younger Dryas Interval And Dwarf Mammoth Environments
A.V. Lozhkin*, P.M. Anderson, S.L. Vartanyan B.V. Belaya, T.A. Brown, And A.N. Kotov

GCM simulations in the region of Beringia since the last glacial maximum
Ben Felzer

Open Discussion and Synthesis:

POSTER SESSION

(titles alphabetical order by first author)

An 8100 Year Record Of Vegetation Changes From A Peat Site Near Fairbanks,Alaska
Andrei A. Andreev, And Dorothy M. Peteet

An Upper Pleistocene Environment On Faddeyevskiy Island, Laptev Sea, Russia
Andrei A. Andreev, Fedor A. Romanenko, Leopold D. Sulerzhitsky, Dorothy M. Peteet, And Pavel E. Tarasov

Late Quaternary Paleoclimatic Reconstructions For Interior Alaska Based On Paleolake-Level Data And Hydrologic Models
Valerie Barber

Upland White Spruce Growth In Bonanza Creek LTER In Central Alaska Under Unprecedented Drought Stress: Evidence From Stable Isotopes And Wood Density
Valerie A. Barber And Glenn P. Juday

Climatic Implications Of The Bivalve Fortipecten Hallae (Dall) In The Alaskan Pliocene
Konstantin B. Barinov and Sergei I. Kiyashko

The Bivalve Chlamys Colvillensis (Macneil) And Correlation Of Pliocene Marine Deposits Of Northeastern Kamchatka And Alaska
Konstantin B. Barinov, Valentina N. Sinelnikova, And Louie Marincovich, Jr.

Last Interglaciation Age Of The Eva Forest Bed, Central Alaska, From Thermoluminescence Dating Of Bracketing Loess
Glenn W. Berger And Troy L. Péwé

Rapid (<1000 Yr) Deglacial Vegetation Changes In Central Alaska
Nancy Bigelow And Mary Edwards

Wisconsin Glacial Chronology Of The Western Ahklun Mountains, SW Alaska: 36Cl Ages From Wattamuse Valley
Jason P. Briner, Darrell S. Kaufman, And William F. Manley

Molecular Phylogeography Of Amphiberingian Mammals
Chris Conroy, Joe Cook, John Demboski, And Karen Stone

A Reconstruction Of Pliocene-Pleistocene Tectonics And Climate, Lower Klondike Terraces, Dawson Area, Yukon
Duane G. Froese, R.W. Barendregt, A. Duk-Rodkin, R. Enkin, F.J. Hein, D.G. Smith

The Extent And Chronology Of Glaciation In The Anadyr Region Of Chukotka, Western Beringia
Lyn Gualtieri

Coastal Paleogeography And Sea Level Change In Southern Beringia: Post-Lgm Records From The Lower Alaska Peninsula
James W. Jordan

Radiocarbon Dating The Early Holocene Occupation Of Western Beringia: Revisions From The Upper Kolyma Region
Maureen L. King

Biogeography Of Seldovian Plant Taxa, Past And Present, Along The Pacific Rim
Estella Leopold, Alan Yen, Cindy Updegrave, Katie Maier,

Disease And Mammalian Extinctions In The Late Quaternary
Ross D. E. Macphee And Preston A. Marx

Prehistoric Chert Quarries In The Western Brooks Range, Eastern Beringia
Natalia Malyk-Selivanova, Gail M. Ashley, Michael D. Glascock And Robert Gal.

Radiocarbon And Relative-Age Evidence For Restricted Late Wisconsin Glaciation, Southern And Western Ahklun Mountains, Southeastern Beringia
William F. Manley And Darrell S. Kaufman

Does Ph Affect Pollen Preservation In The Late Pleistocene Beringian Sediments?
Lucina Mcweeney

Using Indicator Pollen Taxa To Interpret The Late Quaternary Environmental History Of The Western North Slope, Alaska
W. Wyatt Oswald, Linda B. Brubaker, And Patricia M. Anderson

Soil Morphological Clues To Climate Change In The Beringia
Chien-Lu Ping and John Kimble

A Comparison Of Late Quaternary Vegetation Change At The Eastern And Western Limits Of Beringia
Michael F.J. Pisaric, Julian M. Szeicz And Glen M. Macdonald

Environmental Changes At Treeline In Central Alaska During The Late-Holocene: Implications Of Neoglacial Cooling
Melanie Rohr, Mary E. Edwards, Bruce P. Finney

Late Holocene Treeline Dynamics In Northwestern Canada
Julian M. Szeicz And Glen M. Macdonald

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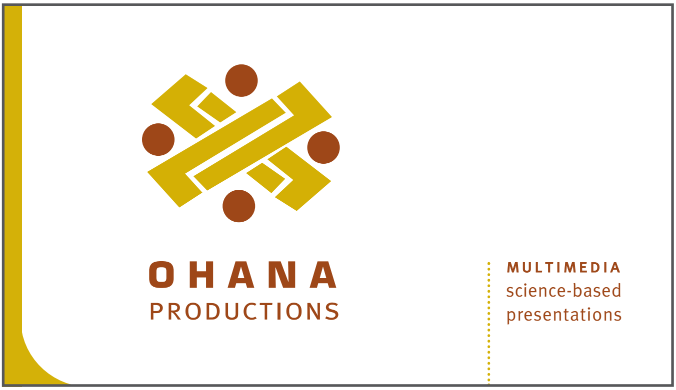

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