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How Does Climate Change Influence Alaska's Vegetation? Insights from the Fossil Record

Plant fossils, such as leaves, wood, cones, pollen, and seeds, provide important evidence of how Alaska's vegetation has responded to climate changes over time periods of centuries to millions of years. Long-term trends of global temperatures have been reconstructed from oxygen isotope measurements of microscopic fossils (foraminifera) in the Pacific Ocean (fig. 1). This temperature curve can be used to compare the major changes in Alaskan vegetation with global climate changes spanning the past 20 million years.

USGS studies of the Alaskan fossil record of plants include data from many natural exposures and sediment cores (fig. 2). These data provide the basis for reconstructing the record of past vegetation changes over millions of years of Earth history. The fossil record shows that dramatic changes in high latitude vegetation have occurred many times in the past,

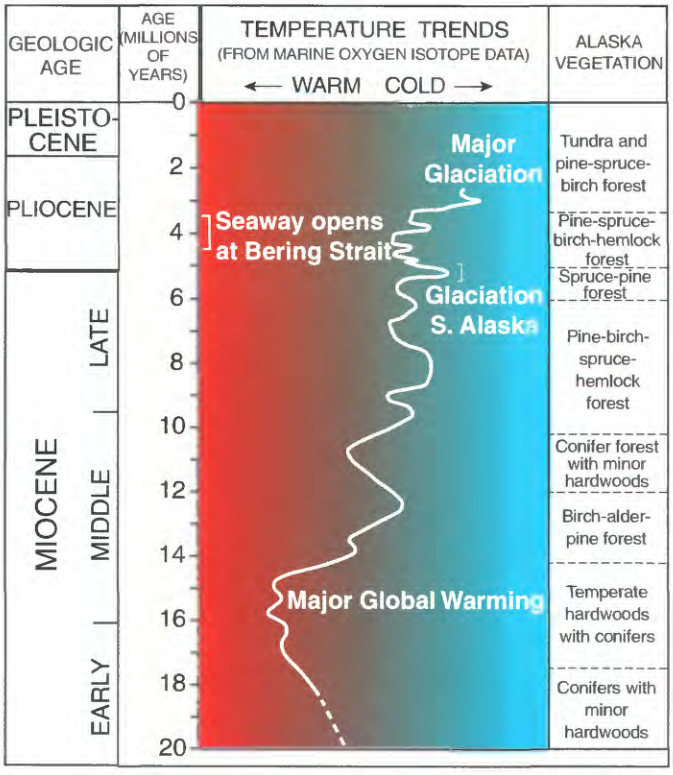

Figure 1. *Pacific Ocean seawater temperature trends derived from measurements of oxygen isotopes in fossil marine organisms provide the climatic framework for interpreting the Alaskan fossil plant record.*

Figure 2. *U.S. Geological Survey's global change drilling project at Fort Yukon, Alaska recovered a detailed record of climate and environmental change for interior Alaska spanning much of the past 16 million years.*

primarily in response to global climate changes. The record further suggests that the magnitude of ecological response to global climate change is greater at high latitudes than at low latitudes. During the Miocene, a major global warming event occurred between 17 to 14.5 Ma (million years ago). In Alaska and in other high latitude regions of the world, this warming event profoundly changed vegetation from a conifer-dominated forest with few temperate hardwoods to a temperate forest containing many tree and shrub species now found far to the south in Asia and North America, such as oak, hickory, beech, chestnut, walnut, wing-nut, elm, holly, basswood, hazelnut, and sweetgum. In order for temperate vegetation to grow at such high latitudes, the mean annual temperature of interior Alaska must have been about 25-30° F warmer than today.

Global cooling began about 14.5 Ma, and its influence on Alaskan vegetation was abrupt and dramatic. Temperate trees disappeared, leaving behind a simpler forest vegetation of hardy birch, alder, and pine species until a more complex conifer-dominated forest developed after about 12 Ma. A series of cool climate pulses during the middle and late Miocene and late Pliocene eliminated additional tree species from Alaskan forests. Minor warming events about 11, 9, and 7 Ma reversed these trends slightly for brief periods, but the overall trend during the Miocene and Pliocene was the steady reduction in tree and shrub species, leaving hardy plant types that could grow in Alaska's progressively cooler climate. By the middle Pliocene, about 3 Ma, Alaskan vegetation began to resemble modern Alaskan boreal forests. Middle Pliocene forests were composed primarily of pine, spruce, larch, birch, alder, and willow, and with the exception of pine, these compose the vegetation found today in Alaska's boreal forests.

Global climate changes during the past 2.5 million years have been extreme, oscillating between relatively long periods (ca. 100,000 years) of predominantly cold, dry glacial climates and shorter intervals (ca. 10-20,000 years) of warmer, moister interglacial climates. During full glacial intervals, mean annual temperature in interior Alaska declined about 9 to 15° F below modern temperatures. During cold periods, glaciers expanded from the 5 percent of Alaska they now cover to 30 to 50 percent of the present area of the State. When glaciers expanded and temperatures declined, tundra vegetation spread to lower elevations and forests were reduced to small areas in the eastern interior, and some tree species may have been eliminated entirely from Alaska (fig. 3).

During warm interglacial periods such the one we are currently experiencing (the Holocene, spanning the past 10,000 years), boreal forests of spruce, larch, poplar, birch, alder, and willow spread throughout most of interior Alaska. During the warmest part of the previous interglacial (about 130,000 to 120,000 years ago), average growing season temperatures in Alaska appear to have been at least 5° F warmer than today. Spruce-dominated boreal forests spread north of the Brooks Range and west to the Bering Sea coast, areas where lowland tundra vegetation now grows. Warmer summer temperatures allowed trees to grow at higher altitudes than today. The expansion of forests into higher elevations greatly reduced the area covered by upland tundra communities for thousands of years.

During periods of less extreme cool climates (interstadials), Alaskan vegetation was dominated by shrub and herb-shrub tundra communities; boreal forest vegetation was restricted to a few areas in the interior lowlands of Alaska. The fossil record provides important evidence of how past climate changes influence Alaskan vegetation. Examples of both colder and warmer than modern climatic conditions of the past can be found in the geologic record, and the ecological responses to climate changes of different magnitudes can be studied. This valuable record of the past is useful for testing the results of computer simulations of climate change on global and regional scales.

Implications for future climate change

The study of past climates and ecological changes in Alaska are an important key to understanding the likely consequences of future climate changes in high latitude ecosystems. Future climate changes, whether triggered by human-induced changes in the atmosphere or by natural climate cycles will result in changes in the species composition and distribution of vegetation types. On the basis of the fossil record and climate history of Alaska, we can expect that future periods of cooler, drier climate will result in shrinkage of forest boundaries, lowering of altitudinal tree line, and expansion of tundra vegetation into lower elevations. A future change to warmer, moister climates will result in expansion of Alaska's forests into areas now occupied by tundra. The past record also shows that the magnitude of future global scale climate changes and ecological responses will be greater at high latitudes than at lower latitudes.

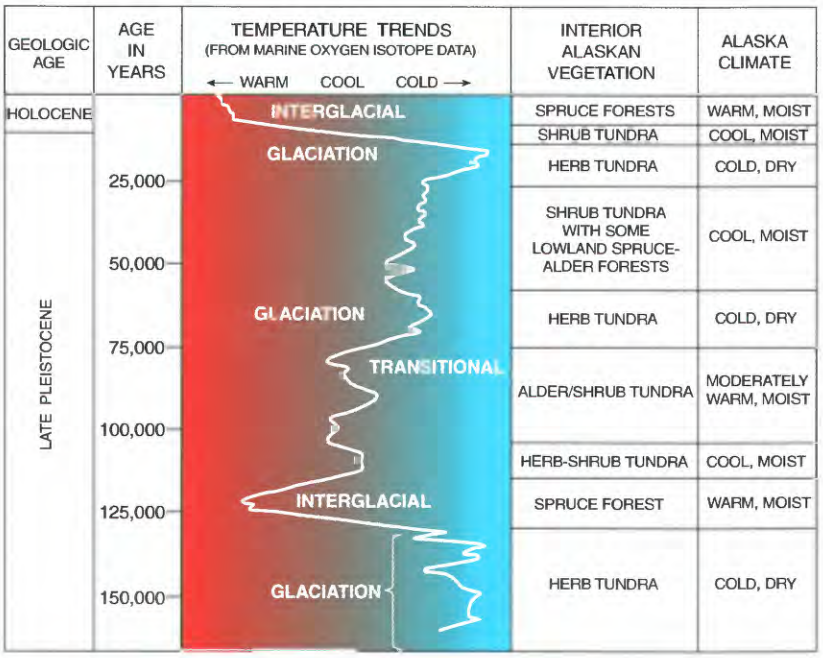

Figure 3. *Global climate trends and major vegetation changes in Alaska during the last 160,000 years.*

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