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Late Tertiary origins of the Arctic beetle fauna

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Abstract

During the past 30 years, Quaternary insect paleontologists working in the Arctic have studied rare deposits of fossil insects that date back millions of years. Some of these fossils may be as old as the Late Miocene. The fossils have been preserved mostly in permafrost environments, and their state of preservation is often exceptional. The vast majority of identifiable beetle specimens appear to match modern, extant species. This morphological constancy through time appears to reflect constancy of physiological adaptations, as well. The latter aspect is demonstrated indirectly through the ecological compatibility of species found in the ancient fossil assemblages. While most of the species themselves appear to have remained constant, the biological communities in which they lived have shifted dramatically through time. Based on both insect and plant fossil data, Late Tertiary environments of the Arctic were substantially warmer than they are today, supporting the growth of coniferous forests, up to the shores of the ancient Arctic Ocean. By about 2 million years ago (my) or shortly thereafter, Arctic tundra communities came into existence in parts of Beringia. Arctic insect faunal diversity declined markedly with the onset of Quaternary cooling.

Keywords: Tertiary; Quaternary; Beetles; Arctic; Paleoecology; Evolution

1. Introduction

During the past 30 years, paleoentomologists working in the northern high latitudes have studied a small number of organic deposits containing insect fossils that date back millions of years. The fossil assemblages represent Late Tertiary environments that preceded the earliest glaciations of the Quaternary, as well as Early Quaternary environments, representing the onset of glacial–interglacial cycles. These fossil assemblages provide rare glimpses into the history of the Arctic, and the origins of the modern insect fauna of this vast region. Because regional environments were substantially different in the Late Tertiary, there are no modern analogues for the fossil assemblages of this interval. Nevertheless, it is possible to discern ecological and taxonomic patterns in these faunas that began in the Late Tertiary and carried through the Pleistocene glaciations, ending in the modern fauna. In this paper, we trace these patterns through a series of fossil beetle faunas, from the Miocene to the Early Quaternary.

These fossil insect faunas bridge a paleontological gap between the actual exoskeletal remains preserved in the unconsolidated sediments of the Pleistocene, and the mineral replacements and trace fossils preserved in

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bedrock, from the Tertiary back to the Paleozoic. The Late Tertiary and Early Quaternary fossils discussed here range in age from perhaps 8 to 1.8 million years ago (my), yet they are the same kind of chitinous exoskeletal remains found in much younger (Pleistocene and Holocene) deposits. All of the fossil assemblages discussed here have been preserved in permafrost. Once removed from frozen sediments, these fossils are as well preserved as Holocene fossils from lower latitudes.

Fossil sites containing chitinous insect remains more than 1 million years old are extremely rare. Their long-term preservation was made possible by permafrost, but permanently frozen ground occurs almost exclusively in the high latitudes, and many high latitude regions were repeatedly glaciated in the Quaternary. Repeated glaciations obliterated nearly all organic terrestrial deposits in the Arctic during the Pleistocene. However, there were some regions in the Arctic that remained unglaciated through much if not all of the Pleistocene. Chief among these was the region known as Beringia, which included the unglaciated lowlands of northeastern Russia, Alaska, and the Yukon Territory, linked together by the Bering Land Bridge. The first signs of Arctic permafrost come from Early Quaternary, or slightly older deposits. The Miocene sediments discussed in this paper were unfrozen for at least a few million years, prior to the development of permafrost in northeastern Siberia.

A number of sites in the Canadian High Arctic islands and Greenland have also yielded Late Tertiary insect fossils. Most of the high Arctic was glaciated in the Pleistocene, but unconsolidated Late Tertiary and Early Quaternary deposits were nevertheless preserved at these sites. Notable among these are the Beaufort Formation deposits of the Queen Elizabeth Islands in high Arctic Canada. This formation consists of unconsolidated sands, gravels, and organic sediments. On Meighen Island, the Beaufort Formation is overlain by glacial till and glacially striated cobbles (Matthews, 1974a). But this could have resulted from expansion of the local ice cap during the Holocene and not glaciation of the entire region. Similarly, High Terrace Sediments on the Fosheim Peninsula of Ellesmere Island, Canada, are overlain by glacial deposits (Matthews and Fyles, 2000). The High Terrace Sediments consist of unconsolidated sands, gravels, and peats. Finally, the Kap København Formation in northernmost Greenland is an unconsolidated deposit of sand, silt and clay with beds of organic detritus. There is post-depositional disturbance of the sediments, ascribed to pressure from an overriding glacier (Funder et al., 1984).

1.1. Dating of fossil assemblages

One of the most difficult aspects of this research has been establishing the chronologies of the fossil assemblages. While radiometric dating has been used to establish the age of a few samples (notably the Lava Camp assemblages from Alaska), most of the assemblages discussed here have only been dated on the basis of site stratigraphy. These assemblages necessarily have only approximate age estimates. The ages discussed below represent the most recent geologic interpretations of the sites, but the chronologies will almost certainly be refined or changed as more geologic research is done in the study regions.

2. Research in Alaska and Canada

The work of John Matthews on the topic of Late Tertiary and Early Quaternary insect faunas from Alaska and northern Canada spans 25 years and 19 publications. Nine faunal assemblages dating from about 5.7 to 1.8 my have thus far been analyzed (Table 1). The sites range from just south of the Arctic Circle at the Lost Chicken site, to north of 80° latitude at the Meighen Island and Wolf Valley sites. The individual sites are discussed below, roughly in chronologic order, starting with the oldest site.

2.1. Lava Camp Mine, Alaska

The Lava Camp Mine site is located on the Seward Peninsula of Alaska (Fig. 1, No. 2). The fossil insect fauna was described by Hopkins et al. (1971). A fossil forest bed at this site was capped by a lava flow that has been dated by potassium–argon, yielding an age of 5.7 my ± 0.2 my. The forest bed was preserved in a section of alluvium. The alluvial sequence evidently consists of basal gravel deposited in an open river channel and an overlying mass of finer sediment deposited on a forested flood plain. The fossil flora includes at least 10 species of conifers, including species found today in the forests of the Pacific Northwest region, such as Sitka spruce and western hemlock. The floral assemblage is thus indicative of relatively warm, maritime climate. The Lava Camp Mine fossil insect fauna was quite rich, containing 84 insect and arachnid taxa (Matthews and Telka, 1997). MCR analysis of the beetle fauna yielded TMAX and TMIN estimates as much as 2 °C warmer than modern values (Elias and Matthews, 2002). White et al. (1997, 1999) considered the Lava Camp assemblage to represent a cool climate during the Messinian (latest