

# Fossil remains of the walnut family (Juglandaceae) from the Eocene fossil forests of Axel Heiberg Island, Canadian High Arctic.



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**ABSTRACT:** The Eocene fossil forests of Axel Heiberg Island (45 million years old) provide insight into the vegetation and climate of ancient polar environments. Remains of Cupressaceae (dawn redwood, swamp cyprus, cedar), Fagaceae (oak), Betulaceae (birch, alder), Pinaceae (pine, spruce, larch, golden larch), Ginkgoaceae (ginkgo), and others are exquisitely preserved and reveal the existence of lush forest ecosystems throughout the far north during a time of warm global climate. Fossil nuts of the Juglandaceae (walnut family) have been found within these deposits. Comparison with living and fossil Juglandaceae indicates that the remains represent nuts of three new extinct species of two genera, *Juglans* L. (walnut) and *Carya* Nutt. (hickory). Since the Eocene, global climatic deterioration, leading ultimately to Pleistocene glaciation, has transformed high latitude vegetation, and has resulted in the American/Eurasian disjunct distribution found in many north-temperate families, of which the Juglandaceae is typical. The Axel Heiberg Island fossil nuts are the earliest records of both *Juglans* and *Carya* in the polar regions and are among the oldest specimens from either genus. As important components of the ancient polar landscape, members of the Juglandaceae have played a significant role in the evolution of temperate forest ecosystems.

**INTRODUCTION:** The Eocene (approx. 55-35 Ma) represents the last episode of mild global climate, with temperatures in the polar regions sufficiently high to prevent the development of polar ice caps. It was thus a time of particular relevance to our understanding of global climate change, and the potential impact of an enhanced greenhouse effect. The Eocene is also of significance as a time of the emergence of many angiosperm families which still remain prominent in modern day ecosystems. Examples include the birch, elm, legumes, oak, rose, and walnut families.

The discovery of exquisitely preserved fossil forests of Eocene age on Axel Heiberg Island, Canadian High Arctic, provides an excellent window into Eocene climate, as well as an opportunity to examine some of the early stages of angiosperm evolution.

**RESULTS:** The Axel Heiberg Island fossil nuts possess a hard, septate, bivalved shell typical of animal-dispersed fruits of the walnut family (Leroy 1955). Internal and external anatomy indicates that three distinct species are present, and that two appear to be closely related to the modern hickories, of the genus *Carya*, and that one is an early walnut of the genus *Juglans*.

Fig. 4a-d: Alpha species, exterior and interior of valves. Note nut in fig. 4c has been gnawed open. 4e-h: Ascending cross section series through mid region of Alpha nut.

Fig. 5a,b: Beta species, exterior and interior fruit morphology. 5c-f: Ascending cross section series through mid region of Beta nut.



6a: Mass of Gamma nuts, collected from single locality (level N, Fig. 3). 6b,c: Gamma species, showing exterior and interior of nut.

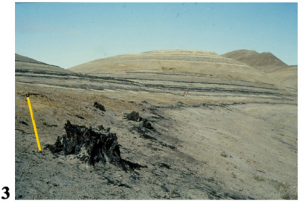
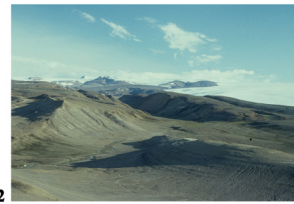
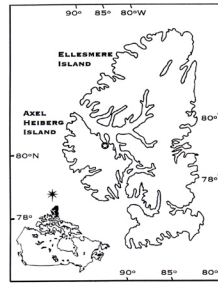
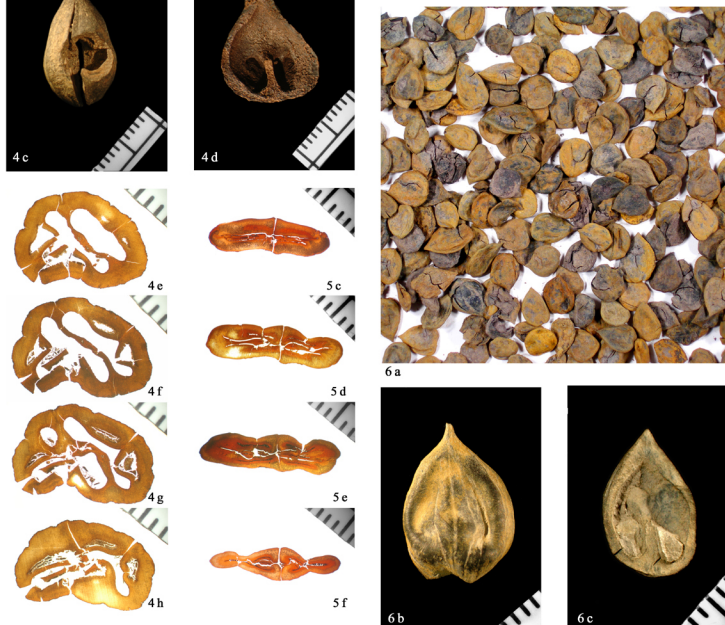


Fig. 1. Map showing Axel Heiberg Island and location of fossil forest site.  
Fig. 2. Axel Heiberg Island, showing ice cap (background), camp (lower left), and fossil forest hill (right foreground).  
Fig. 3. Row of stumps representing one of many preserved fossil forests. Level "N", source of fossil nuts species gamma, is immediately above the stumps.

**MATERIALS:** The fossil forests of Axel Heiberg Island occur within the Buchanan Lake Formation, a Middle Eocene (approx. 45 Ma) unit of interbedded silt, sand and coal. The fossil localities are now found at 80° N latitude, which has changed little since the Eocene epoch. These remains therefore provide insight into the vegetation and environments of the ancient polar regions. Numerous nuts of the Juglandaceae (walnut family) have been discovered in these deposits amongst the remains of a rich forest ecosystem that included dawn redwood, swamp cyprus, oaks, alders, sycamores, katsuras, ginkgoes, yellow larch, pine and spruce (McIver & Basinger 1999).



Fig. 7 *Juglans regia*, modern Persian Walnut.  
Fig. 8 *Carya illeinoensis*, modern Pecan  
Fig. 7, 8 adapted from www.wikipedia.org



Fig. 9 Map (adapted from Manchester 1987; Aradhya et al. 2004) showing fossil and modern distribution of *Juglans*. Modern distribution indicated by shading. Fossil fruit deposits indicated by dots. Axel Heiberg Island deposit indicated by arrow.



Fig. 10 Map (adapted from Manchester 1987) showing modern and fossil distribution of *Carya*. Modern distribution indicated by shading; fossil fruits, by dots. Axel Heiberg Island deposit indicated by arrow.

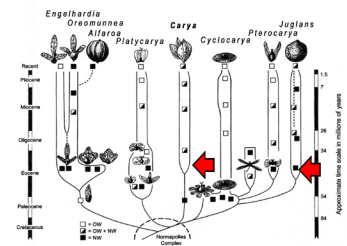


Fig. 11 Evolutionary history of Juglandaceae adapted from Manchester (1987) and Manos & Stone (2001). Axel Heiberg Island fossil *Carya* and *Juglans* indicated by arrows.



Fig. 12 Modern global distribution of the Juglandaceae. The arrow indicates the Axel Heiberg Island fossil forest locality.

**DISCUSSION:** The Juglandaceae is found throughout the temperate and subtropical regions of the Northern Hemisphere, and includes three tribes, of which one, the Tribe Juglandaceae, hosts the Subtribes Juglandinae (including the walnuts, *Juglans*) and Caryinae (the hickories, *Carya*) (Manning 1978; Manos & Stone 2001). The family has a rich fossil record, indicating an origin and early diversification about 50 Ma (Mai 1981; Manchester 1987). The Axel Heiberg Island walnuts and hickories are some of the oldest known records of these important genera, and indicate that they played important roles in the forests of the north polar regions during the Eocene. Climatic deterioration since the Eocene led to extinction of the Juglandaceae from the far north until ultimately forests were entirely excluded from the polar regions and replaced by arctic tundra. The family largely became extinct in Europe and is now primarily confined to southeastern North America and southeastern Asia, where it coexists with other remnants of the once-extensive polar ecosystem.

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