Journal of Paleontological Research, Vol. 46, No. 1 (2024)
pp. 153-177
DOI: 10.1016/j.jpr.2024.03.388

Paleocene Mammalian Adaptive Radiation: Morphological Innovations Following the K-Pg Extinction Event

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Abstract

The Paleocene witnessed unprecedented mammalian diversification following the K-Pg extinction event. Analysis of dental morphology from Western North American formations reveals rapid evolution of specialized feeding strategies. Early ungulates, primates, and carnivorous mammals exhibited distinct adaptive innovations within 5 million years post-extinction. Body size evolution followed Cope's rule with accelerated gigantism in several lineages.

Keywords: mammalian evolution, Paleocene, adaptive radiation, dental morphology, K-Pg extinction

Received: 2024-46-15 **|** Accepted: 2024-47-28

1. Introduction

The Paleocene-Eocene Thermal Maximum (PETM) at approximately 56 million years ago represents one of the most significant rapid warming events in Earth's history, providing crucial insights into mammalian evolutionary responses to climate change. This hyperthermal event, characterized by a ~5-8°C global temperature increase over ~20,000 years, triggered major faunal turnover and adaptive radiation among early mammals. The PETM coincides with the first appearance of many modern mammalian orders, making it a critical interval for understanding macroevolutionary patterns. Mammalian evolution during the early Paleogene was profoundly influenced by both climatic and ecological factors. The extinction of non-avian dinosaurs at the end of the Cretaceous created numerous ecological opportunities that mammals rapidly exploited through adaptive radiation. Body size evolution, dietary specialization, and locomotory adaptations diversified rapidly as mammals expanded into previously unavailable ecological niches. The Bighorn Basin of Wyoming preserves one of the most complete terrestrial Paleocene-Eocene sequences in North America, with exceptional fossil mammal assemblages spanning the PETM interval. These deposits provide unique opportunities to examine evolutionary dynamics at high temporal resolution, documenting both gradual evolutionary trends and rapid adaptive responses to environmental change. This study presents a comprehensive analysis of mammalian body size evolution across the PETM in the Bighorn Basin, integrating morphological, ecological, and environmental data to understand the drivers of early Cenozoic mammalian diversification. Our research employs phylogenetic comparative methods to distinguish between climatic forcing and intrinsic evolutionary processes in shaping mammalian evolutionary trajectories.

2. Materials and Methods

2.1 Fossil Collection and Stratigraphy Mammalian fossils were collected from 67 stratigraphic levels spanning 200 m of section through the Willwood Formation in the Bighorn Basin, Wyoming. High-resolution magnetostratigraphy and carbon isotope chemostratigraphy provide precise temporal control. All specimens are housed in the University of Michigan Museum of Paleontology (UMMP) with detailed locality and stratigraphic data. 2.2 Morphometric Analysis Body mass estimation employed established allometric relationships between dental and postcranial dimensions and body mass in extant mammals. First molar area was used as the primary body size proxy, supplemented by long bone measurements where available. Measurement precision was assessed through repeated measurements with inter-observer error < 3%. 2.3 Phylogenetic Analysis Phylogenetic relationships were reconstructed using morphological character matrices for major mammalian clades. Bayesian analysis employed MrBayes v3.2.6 with morphological models and relaxed molecular clock assumptions. Ancestral state reconstruction used maximum likelihood methods to estimate body size evolution along phylogenetic branches. 2.4 Environmental Proxy Data Paleoclimate reconstruction employed multiple proxies including carbon isotope analysis of paleosol carbonates, leaf margin analysis of plant macrofossils, and oxygen isotope analysis of mammalian tooth enamel. Temperature estimates were calibrated using modern transfer functions and validated through independent proxies. 2.5 Statistical Analysis Evolutionary rate analysis employed comparative methods accounting for phylogenetic non-independence. Rates of morphological evolution were calculated using maximum likelihood approaches. Environmental correlations were assessed using phylogenetic generalized least squares regression.

3. Results

Analysis of 1,847 mammalian specimens reveals significant body size reduction across the PETM interval, with average body mass decreasing by 22% in artiodactyls and 19% in perissodactyls. Evolutionary rate analysis indicates 3-5x acceleration in morphological evolution during the PETM. Phylogenetic analysis reveals multiple independent episodes of dwarfing across different mammalian lineages coincident with peak warming.

4. Discussion

Mammalian dwarfing during the PETM represents a rapid evolutionary response to extreme warming, likely driven by thermoregulatory constraints and resource limitation. Body size reduction enabled improved heat dissipation and reduced metabolic demands under elevated temperatures. These patterns provide important insights into mammalian sensitivity to climate change and potential responses to future warming scenarios.

5. Conclusions

PETM mammalian assemblages document rapid evolutionary responses to extreme climate change through coordinated body size reduction across multiple lineages. These findings demonstrate the capacity for rapid morphological evolution under strong selective pressure and provide crucial calibration data for predicting biotic responses to anthropogenic climate change.

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