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The elusive echo: The mystery of Africa's sparse bat fossil record

Significance:

The scarcity of bat fossils in Africa poses a significant challenge to both scientific understanding and current conservation efforts. While this article engages in informed speculation regarding the reasons behind this scarcity, it does not lessen the importance of the issue. Without a robust fossil record, tracing the evolutionary history, biological adaptations, and historical ecological roles of bats becomes difficult. Understanding their past is instrumental in mitigating current threats to bats like habitat loss and climate change. Thus, the intriguing lack of a comprehensive fossil record not only limits scientific inquiry but also hinders effective conservation measures.

Bats, the only mammals capable of sustained flight, are a fascinating group of creatures. With over 1400 species[1], they are the second most diverse group of mammals, surpassed only by rodents[2]. From the tiniest serotine bat, weighing only two grams, to the giant golden-crowned flying fox with a wingspan of over a metre, bats are found in nearly every habitat worldwide.[1] They play crucial roles in ecosystems, from pollinating flowers to controlling insect populations. In addition to keeping ecosystems healthy[3], their activities have direct economic benefits for agriculture and forestry. Without bats, crop yields would be lower, and the cost of pest control would rise dramatically.[4] Yet, despite their global presence and ecological importance, the story of bat evolution, particularly in Africa, remains elusive due to a surprisingly sparse fossil record. This scarcity renders bats a 'silent taxon' in the annals of palaeontology; they are vitally important yet leave few traces behind. Why are bat fossils in Africa so rare, and how does this impact our understanding of modern bats and their conservation?

To understand the gap in our library of bat fossil discoveries, it is important first to understand how fossils are formed.[5] Bones require the correct mixing pot of ingredients to become fossilised. If these criteria are unmet, the material simply decays, leaving no trace of existence. Following an organism's death, it must be quickly covered by sediments, such as sand, silt, or mud, to protect it from scavengers and decomposition. Over time, these layers of sediment accumulate, with the weight of the upper layers compacting the lower layers into rock. As groundwater saturates the remains, it carries minerals like silica or iron that replace the organic material in the bones or plant matter, a process known as permineralisation, leaving behind a permanent imprint of the material in the rock.

Rich in bat biodiversity, Africa presents a puzzling gap in our understanding of bat evolution. The fossil record of bats in Africa, especially during the Paleogene period (66 to 23 million years ago), is notably scarce compared to those of North America or Europe. Until recently, the evidence for early Tertiary African bats came from a handful of localities[6], primarily in North Africa, with only one site in sub-Saharan Africa, in Tanzania. The oldest known bat fossils from Africa date to the early Eocene, around 50 million years ago, and were discovered in Algeria.[6] None of these fossils represents complete specimens and consists only of a few fragments of bone and teeth. South Africa has an extremely sparse bat fossil record, with currently only 55 specimens recovered across the country, most of them relatively 'young' fossils from the Pleistocene (2.58 million to 11 700 years ago).[7] This scarcity becomes even more intriguing when we consider the fossilised evidence of bat guano found in African caves, like Arnhem in Namibia[8] and Gcwihaba in Botswana[9]. These remnants suggest that large bat colonies thrived in these locations many years ago, making the question even more pressing: where are the fossils of these bats? According to a 2019 article published in *Palaeontology*[10], there may be several reasons why the global bat fossil record is so sparse, which can be extrapolated to South Africa. Early bats likely resided in forested areas – environments not typically conducive to fossil formation. In these hot and humid settings, rapid decay of organic matter is common[11], largely due to high bacterial activity. If we extend this logic to caves, the same factors – heat, humidity, and heightened bacterial activity – can accelerate decomposition, thereby reducing the likelihood of fossilisation, even in places where large bat colonies may have existed.

Dispersal mechanisms of ancient bat species pose another layer of intrigue in our quest to understand their fossil scarcity. Modern bats exhibit remarkable dispersal capabilities[1], ranging from local migrations to extensive journeys. These behaviours influence where their remains might be found postmortem. However, when it comes to their prehistoric ancestors, our knowledge is limited to speculation and educated conjecture.

Another proposed reason could be the delicate nature of bat bones. Generally, most southern African bats alive today are relatively small and lightweight, ranging from about 2 g to 100 g.[12] One of the earliest fossil bats, *Icaronycteris index*, discovered in Wyoming, USA, had tiny bones, some reportedly as thin as human hair.[13] These bats lived during the Eocene, approximately 52 million years ago. We only know about them because they lived around lakes that facilitated extraordinary preservation; the combination of fine sediment and oxygen-depleted water at the lakebed enabled rapid burial of fossils, protecting the remains from scavengers and other decomposers.[10] However, the tiny fossil of a prehistoric bird chick called *Enantiornithes*[14] from 127 million years ago shows that size is probably not an issue when it comes to fossilisation, and the type of sediment where an organism dies plays a more important role.

Alternatively, the nature of fossil discovery and collection could contribute to bat fossil scarcity. Fossil discovery requires significant resources and specialised equipment. Specialised mesh sieves are used to sift soil for fossils and fragments, known as traditional or dry sieving.[15,16] The sieving process typically begins with larger meshes, which filter out bigger fragments. Following this, progressively finer sieves are employed to capture smaller and more delicate specimens. However, it is during these initial stages of sieving with larger meshes that the brittle bones of bats are most at risk. The process can inadvertently damage these fragile specimens, thereby contributing to their scarcity in the fossil record.

Fossil hunting also requires a significant amount of time and expertise, and some regions may simply have been explored less than others. In 2008, after 25 years of fieldwork[17], scientists published the discovery of six new bat species from Egypt, dating to about 35 million years ago[18]. The study was based on 33 fossil specimens, translating to a little over one specimen discovery per year. This highlights the effort and patience required in palaeontology and the necessity of long-term commitment. Certainly, the niche nature of studying bats, particularly bat fossils, presents unique challenges. In academia and research, areas that garner more attention often receive more funding and resources. North America and Europe have historically seen more extensive palaeontological funding and efforts, naturally leading to a richer fossil record. In contrast, Africa, despite its potential for significant discoveries, has faced limitations in financial and human resources. As bats are not as popular to study as other animals or topics, finding experts specialising in bat palaeontology is rare. This scarcity of specialists compounds the existing issues caused by the lack of a comprehensive fossil record for bats. Addressing this imbalance would require not only increased investment in African palaeontological research but also a concerted effort to cultivate local expertise and infrastructure in this field.

Regardless of the reason, the absence of bat fossils significantly hinders our understanding of these fascinating mammals. Without a robust fossil record, tracing bats' evolutionary history and biological adaptations like flight and echolocation becomes a daunting challenge. Our gaps in knowledge extend to their historical roles in ecosystems as well. The scarcity of fossils limits our understanding of how bats have interacted with their environments over time, which in turn could offer valuable insights into their present-day ecological roles. Bats play crucial roles in the ecosystem[18] through insect control, pollination, and seed dispersal; however, without a comprehensive fossil record, we lack a baseline to understand how these roles might have evolved or how resilient they might be to current or future ecological changes.

This limited understanding carries immediate implications for bat conservation. Conservationists are navigating partially in the dark without knowing the historical ranges and ecological roles of different bat species. The absence of a comprehensive fossil record could result in an underestimation of the historical diversity and population density of bats, thus leading to insufficient or misguided conservation efforts. Furthermore, understanding a species' past genetic diversity could be instrumental in current conservation strategies, particularly in mitigating the threats posed by habitat loss and climate change. In essence, the scarcity of bat fossils not only hampers scientific understanding but also complicates the implementation of effective measures to protect these ecologically vital and interesting creatures.

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Competing interests

I have no competing interests to declare.

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