

Large European Cretaceous enantiornithines: morphometrics, phylogenetics and implications for the biogeography of early birds

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We review historical approaches to the systematics of Enantiornithes, the dominant birds of the second half of the Mesozoic, and discuss the known fossils of several large taxa from the European Late Cretaceous. These fossils, although comprising incomplete specimens, are hugely important to our understanding of avian evolution because of their age and biogeographic implications.

Large enantiornithine taxa are currently known in Europe from Late Cretaceous deposits of southern France and western Hungary. Fossils from the Santonian Csehbánya Formation, Bakony Mountains of Hungary plug a temporal gap in the Cretaceous avian record and are referable to Avisauridae, with a largely unfused foot morphology similar to the Argentine *Soroavisaurus* and to the North American *Avisaurus*. Specimens from the Masecaps locality close to the village of Cruzy in Hérault, southern France are euenantiornithine, anatomically indistinguishable to elements from New Mexico (USA) and the Argentine locality of El Brete (Salta Province, Patagonia). European records testify to the global distribution (Gondwana and Laurasia) of large flighted euenantiornithine birds by the Late Cretaceous.

We add the known European records to morphometric and stratigraphic analyses that encompass the fossil record of enantiornithines. Analyses of fossil record dynamics show that enantiornithine 'collectorship' since the work of Cyril Walker in 1980s approaches an exponential distribution, indicating that an asymptote in proportion of specimens has yet to be achieved. Data demonstrate that the fossil record of enantiornithines is complete enough for the extraction of biological patterns. Comparison of the available fossil specimens with a large data set of modern bird (Neornithes) limb proportions also illustrates that the known forelimb proportions of enantiornithines fall within the range of extant taxa; thus these birds likely encompassed the range of flight styles of extant birds. In contrast, most enantiornithines had hindlimb proportions that differ from any extant taxa.