

## Ontogenetic stages of ceratopsian dinosaur *Psittacosaurus* in bone histology

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The early ceratopsians *Psittacosaurus* and *Protoceratops* have provided important information on dinosaurian development because of abundant specimens of adults, subadults, juveniles, and even hatchlings. Here we present new data and methods for identifying key growth stages from bone histology. Previous studies on *Psittacosaurus lujiatunensis* from the Early Cretaceous Jehol Biota of China did not present in-depth analysis of growth patterns. Based on a histological study of 43 thin sections from 17 individuals of this species, we recognize four histological ontogenetic stages, i.e., hatchling, juvenile, sub-adult, and adult, but no fully-grown stage. We estimate life history and longevity from diaphyseal growth line counts and other features of histology. We show that *P. lujiatunensis* grew fast in early stages (hatchling, juvenile, and subadult), according to the density of vascular canals and the different type of bone tissue; the deposition of parallel fibred bone tissue in the outer cortex of the subadult stage indicates that growth rate was slowing down. We introduce a new graphical method to estimate the occurrence and volumes of vascular canals from thin sections more accurately than current two-dimensional approaches.

**Key words:** Dinosauria, Ceratopsia, bone histology, ontogeny, growth patterns, longevity, Cretaceous, China.

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