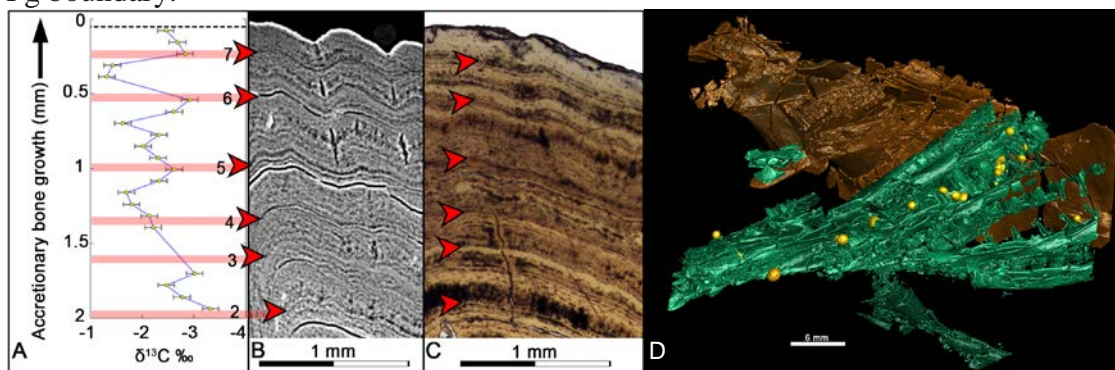


# Synchrotron X-ray imaging of sturgeons and paddlefishes from Tanis, North Dakota (USA), reveals End-Cretaceous seasonality

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The Chicxulub impact on the Yucatán Peninsula (~66 Ma) obliterated ~75% of all species. As such, the Cretaceous-Paleogene (K-Pg) mass extinction was among the most selective extinction events in the history of life on Earth. The timing of impact relative to their seasonal cycles likely influenced survival of latest-Cretaceous biota. However, until now, impact timing was constrained on a millennial timescale, and the season of impact remained unclear. Here, we demonstrate that the bolide responsible for the K-Pg mass extinction struck during boreal spring. This impact was geologically recorded by impact spherules, shocked quartz, and a global iridium anomaly. Seiche deposits preserving mass-death assemblages of fishes with impact spherules lodged in their gill rakers was recently discovered (Tanis, North Dakota, USA). Using non-destructive propagation phase-contrast synchrotron X-ray micro-computed tomography at beamline BM05 of the ESRF, tektites were only encountered in the gill region but are notably absent elsewhere in the fossils. Synchrotron microtomographic osteohistology delivered high-resolution growth records from dermal bone of sturgeons and paddlefishes. These data resolved continuous annual cyclicity during the final years of the Mesozoic. The periosteal surfaces preserve an unfinished growth zone with a  $\delta^{13}\text{C}$  value of -2.5 ‰, intermediate between winter minima of -3.3 ‰ and summer maxima of -1.3 ‰. Our high-resolution records thereby demonstrate that the fish perished in spring. Annual cyclicity, including timing and duration of reproduction, ingestion, and metabolic activity, strongly varies across biota. Seasonal sensitivity to the effects of both ejecta re-entry and wildfires, and reduced insolation and acidic precipitation induced by sulfuric aerosols, will have substantially influenced relative biotic survival rates across the K-Pg boundary.



**Figure 1:** A, Paddlefish  $\delta^{13}\text{C}$  ‰ vs. VPDB. B,  $\mu\text{CT}$  0.1mm thick slab (4.35  $\mu\text{m}$  voxel size). C, Cut thin section. **Arrows** indicating LAGs. D, The tektites in the gill rakers behind the suboperculum at 13.67  $\mu\text{m}$ .