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Synchrotron Micro Computed Tomography for Non-destructive 3D Studies of Fossil Fish

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Introduction: Fossil remains of fish provide data on the rich record of the group and help us understand the origin and evolution of modern members of the group. Some fish fossils are exquisitely preserved as full skeletons. However, studying these fossils can be challenging because individual elements are often partially or wholly covered by matrix or other bones. Removing individual elements from articulated specimens by mechanical means is generally not feasible because that would result in the destruction of the specimen. Thus details of anatomy often remain elusive. This has proved to be a significant limit to our understanding of the fossil fish, especially fish that lived in the rivers and shallow lakes in North America during the Cretaceous Period, many of which are of very small size. In these environments, fish are typically represented by isolated elements, such as centra and jaws. However, because they are not visible in any of the rarely preserved articulated specimens known from the same time period, only rarely can they be identified.

Because of these challenges, a study of small fossil fish preserved in a matrix using synchrotron radiation CT was undertaken. Traditional CT imaging instrumentation involves the use of a polychromatic X-ray source to create 3D models of samples. Synchrotron Radiation CT (SR-CT) imaging differs because it provides a monochromatic source to rapidly image specimens with resolutions that cannot be achieved through traditional instrumentation.

Experimental: A specimen of a fossilized fish consisting of a complete skeleton of approximately 6 cm in length was selected from the Royal Tyrell Museum collection (Fig. 1A). This skeleton was partially embedded in the matrix with only one side of the skeleton visible. The specimen is of particular interest because it appeared to be an early member of the pike family (*Esocidae*), and was likely from a new genus. As well, it was of interest because isolated fish elements from the same locality are available, and some of these should belong to the same kind of fish. However, as is typical for complete skeletons, many elements of the skeleton that were of interest, such as vertebrae and jaws, were fully obscured by either matrix or other bones so direct comparison with the isolated elements was not possible. Because of the size of the specimen, it was concluded that synchrotron radiation CT offered the best chance of obtaining high-quality scans of the specimen, allowing for details of individual elements of interest to be observed.

Micro-CT scanning of the specimen was conducted at the Advanced Photon Source (APS) XSD-IMG 2-BM beamline. The 2BM beamline is fully dedicated to microtomography with the capability to perform large field of view imaging with applications in the life sciences, geosciences, and paleontology among others. The incident energy was 25 keV. The field of view was 4.2 mm (hor) x 1.2 mm (vert). Over the 180° rotation, 1500 projections were acquired with 140 msec. exposure time per projection. Data was collected and reconstructed using custom software at the beamline [1].

Results: Examples of the 3-D reconstructions of isolated elements developed from the scans are shown in Figure 1B-C. One particular area of interest is the base of the tail (Fig. 1 B). One side of the tail was visible in the original specimen so the general shape of the tail could be seen. However, the individual elements forming the tail were impossible to differentiate. The scans showed a strong contrast between the matrix and bone, allowing a digital reconstruction with clear definition of the individual bones forming this part of the skeleton. Also, both sides are visible, never possible in an articulated specimen of such a small size.

The second example is a lower jaw (Fig. 1C). This was preserved in a small counterpart block with only a small part of this element visible, so no information on the full shape of the jaw was available. Scans allowed for both sides of the lower jaw to be seen.

Summary: This new approach to the study of articulated skeletons of fossil fish preserved in their original matrix is allowing breakthrough research into the history of fossil fish. For the first time, it is possible to obtain 3-D images of individual elements from articulated specimens of very small fossil fish preserved as articulated skeletons. As well as allowing for a better understanding of those fossils, it is allowing isolated elements of fossil fish to be compared directly with corresponding elements from an articulated skeleton from the same time period. This is especially significant for the study of freshwater aquatic communities of the Late Cretaceous of North America, where articulated skeletons are extremely rarely preserved but isolated elements are abundant. Thus, with a team of diverse and highly capable specialists, the 3-D visualizations made possible by Synchrotron Radiation μCT will propel palaeontological research into a new age of analysis to help further our understanding of diversity, distribution, and evolution of creatures that came before us.

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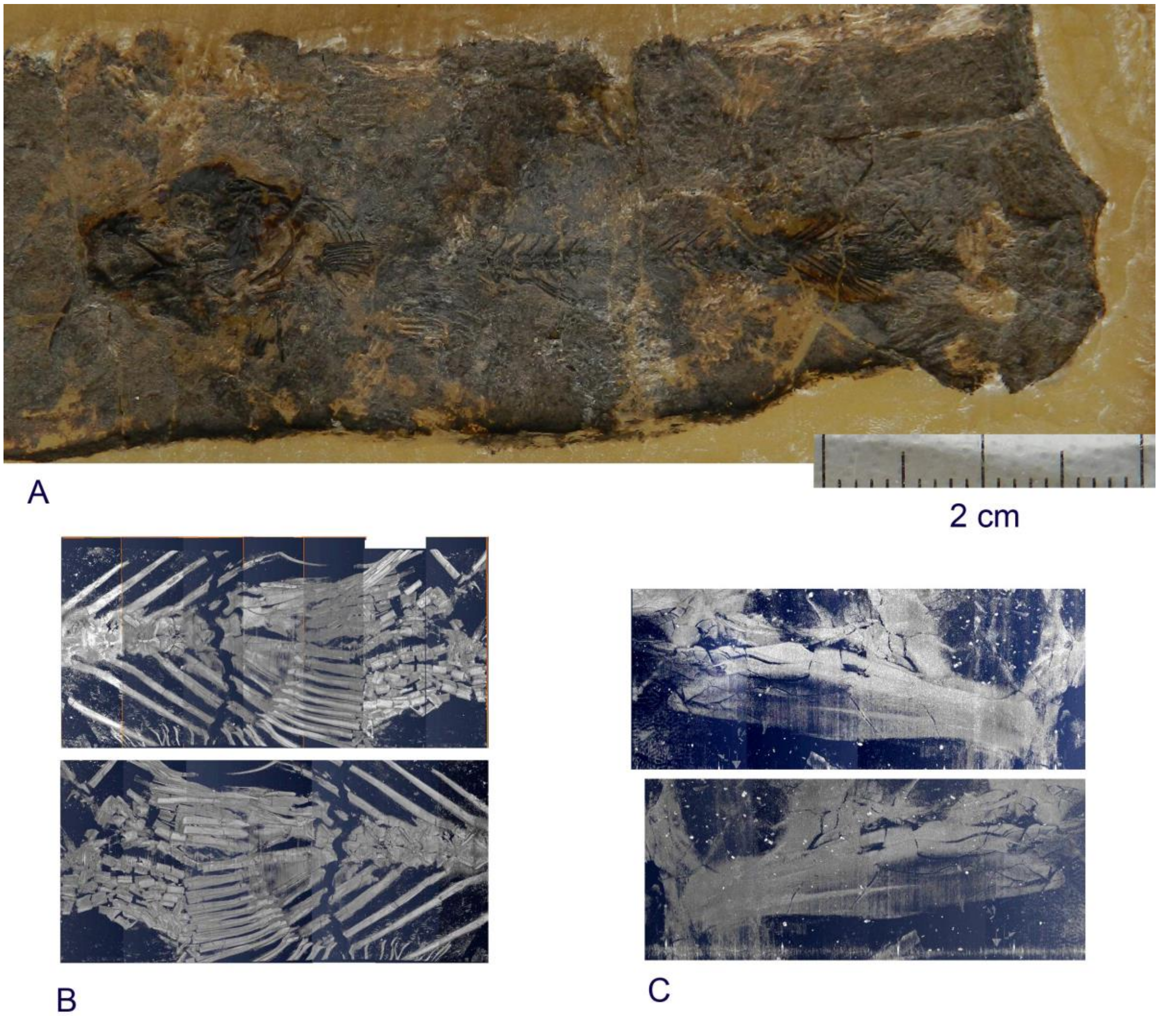

Figure 1. Fossil fish studied through the use of synchrotron radiation μCT. A) Skeleton of articulated fish as preserved, specimen TMP 2013.45.1433, a small unnamed esocids (pike) from the late Maastrichtian Scollard Formation of Alberta, Canada. B) Digital reconstructions of both sides of the tail based on CT scans of the articulated specimen. C) Digital reconstructions of the lower jaw, which is preserved in a counter-part block.

References

[1] https://www.aps.anl.gov/Imaging/Scientific-Software

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