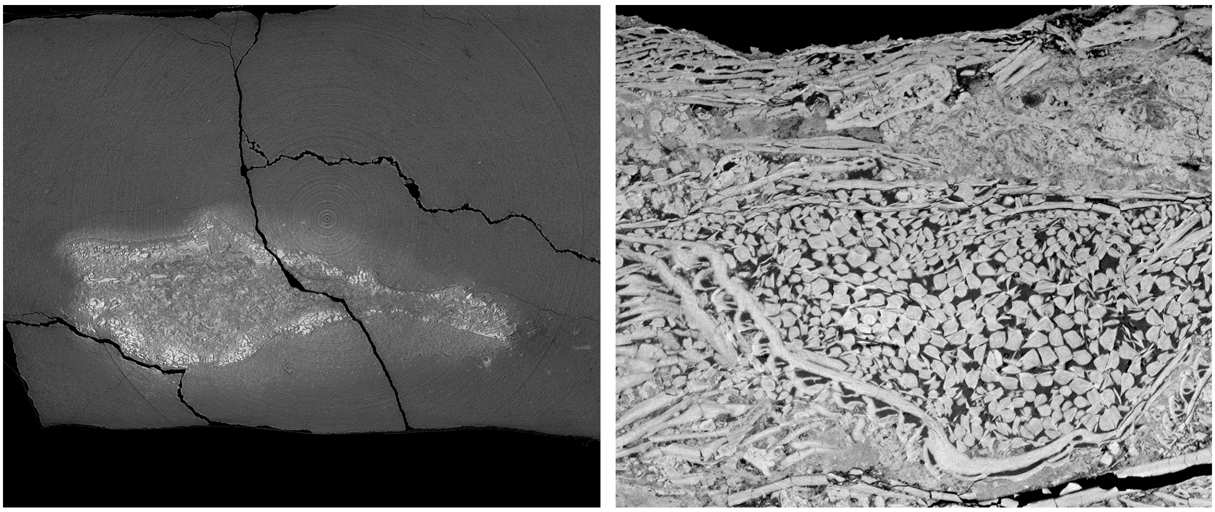
Report on ES-1297

The aim of the proposal was to image, by propagation phase contrast synchrotron microtomography (PPC-SRµCT), a large collection of fossil tetrapod material retrieved from latest Devonian strata on Celsius Bjerg, Ymer Ø, Greenland, during July-August 2023. The material is unusually important, even in the context of research on the fish-tetrapod transition, because it represents an entirely new biota that looks likely to double the known diversity of Devonian tetrapod from Greenland, discovered during the past 90 years of research. Furthermore, the decision to study the material entirely by synchrotron microtomography rather than by the traditional technique of mechanical removal of the surrounding rock (which is extremely time-consuming and inevitably damages the fossils as well as destroying their context) is a world first, made possible by the unique capabilities of Beamline BM18.

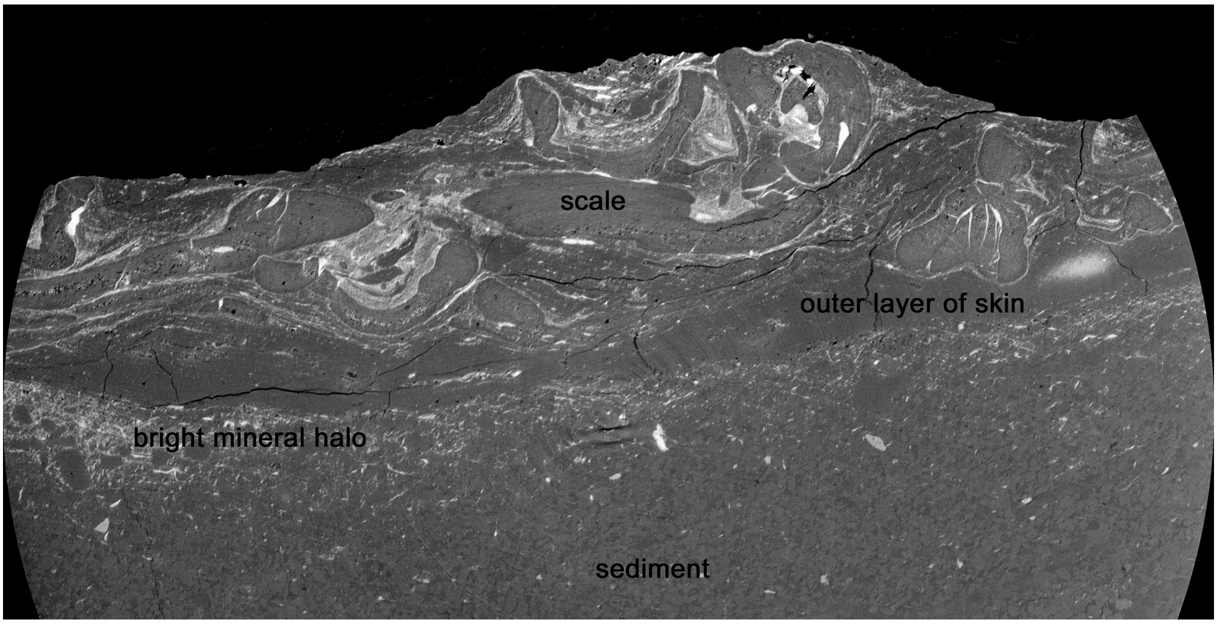
The tetrapod specimens consist of mudstone blocks of varying sizes, collected from an in-situ bone bed, containing tetrapod bones that for the most part have only been seen in cross-section at the time of collection. Preliminary conventional CT scanning of part of the collection at a facility in Uppsala revealed that the blocks mostly contain well-preserved but isolated elements such as limb bones, limb girdles and lower jaws. However, a few blocks contain partly articulated individuals. In addition to the tetrapod material, we also scanned a unique shark specimen in thinly-bedded shale from an overlying lake deposit within the same sequence, a series of coprolites (fossil excrement) from this lake bed and from the Late Devonian locality of Miguasha in Canada, and a potential tetrapod vertebra from an Early Carboniferous locality in Scotland.

The experiment was very successful. No scan time was lost because of beam failure or other technical problems. The majority of specimens were packed into tubes for long continuous runs at either 42.54 µm or 15.075 µm voxel size. The shark was scanned in a box because of its shape, also at 42.54 µm. In total we were able to scan 122 specimens, 85 at 42.54 µm and 37 at 15.075 µm. In addition, we performed 10 high-resolution spots with a voxel size of 1.72 µm. The scans have not yet undergone final reconstruction, but the reconstructed test slices produced during the experiment (see below) all show excellent clarity and contrast, with little in the way of ring artifacts even though no artifact correction had been performed.



Left: 42.54 µm slice through tetrapod pelvis. The pale halo is an x-ray-bright mineral stain, not a scanning artifact. Right: 1.72 µm slice through a coprolite showing an accumulation of acanthodian scales.

A quite remarkable discovery emerged from scans of areas of tetrapod belly squamation associated with a semi-articulated body. The main blocks, which should contain what remains of the skeleton, are large and have not yet been scanned (see below). By contrast, the counterpart slabs with belly squamation are small and could be scanned at 15.075 µm with spots at 1.72 µm. These scans revealed what appears to be structurally preserved skin:



Preservation of belly skin with embedded scales imaged at 1.72 µm. Natural orientation.

This is an absolutely unique find. There is no skin preservation of any kind in any previously known Devonian tetrapod, and previously known examples from Carboniferous-Permian forms are just carbonized outlines. Given that the transformation of the skin must have been a key component of the fish-tetrapod transition, about which we have until now had no direct evidence, the importance of this discovery cannot be overstated.

The only problem we encountered during the experiment related to our largest specimens. A test scan of a plaster-jacketed block with a maximum diameter of just under 30 cm produced a grainy image with poor resolution, and as the projected scan time for the whole block was very long (approximately 12 hours) we decided against proceeding with this and the other large blocks. This did not result in unused scan time as we had plenty of smaller blocks to scan, but the inability to image the larger blocks is problematic because the semi-articulated bodies they contain are key to identifying which among the isolated bones go together. It is already clear that we have, for example, several different kinds of jaws and shoulder girdles, so working out which ones represent the same taxa will be challenging.

Paul Tafforeau advised me that the problem was due to the detector, which is not optimal for such large specimens. A new detector has been ordered which combines a larger field of view (25 x 40 cm, 5000 pixels laterally) with a high-efficiency optic and a thicker scintillator. This will allow faster scans at higher energies and should produce much better results with large specimens. I have accordingly, on his recommendation, decided to submit a follow-on beamtime application to scan the large blocks with the new detector.