Case 11

New technologies used to study fossils

Many of the fossils in Elgin Museum's Recognised Collection were found at least 100 years ago; since their discovery, the technology used to study these fossils has changed considerably.

In the 19th and 20th centuries, fossils were recorded by sketching or photographing them and details determined by creating rubber or latex moulds of the specimen. These processes could exclude important information or even partially destroy the object, making it difficult for researchers to share their findings or to recreate them if necessary.

Today new technologies provide digital, highly accurate, and non-destructive ways of studying fossils. These techniques include micro-computed tomography (µCT) scanning and photogrammetry.

Researchers are using these methods to make new discoveries about the animals that lived in this area millions of years ago, including aspects of their behaviour and method of locomotion. These developments are also shedding light on the relationships between species over geological time.

Dr Davide Foffa: University of Birmingham

Micro-CT scans of *Erpetosuchus* and *Leptopleuron*

1. Photograph of sandstone slabs

These quarried slabs are Late Triassic Lossiemouth Sandstone Formation and come from Spynie Quarry. The fossils were studied by Dr Alick Walker in 1964: he thought that the armoured plates (known as scutes or osteoderms) were from a predatory animal, *Ornithosuchus*. The blocks were then stored at the British Geological Survey headquarters in Keyworth, where they remained unlooked at for over 50 years. In 2018, Dr Davide Foffa embarked on a new research project for National Museums Scotland using micro-CT scanning to investigate the Triassic fossils found in the Elgin area.

BGS GSM 91072-81; BGS GSM 91085-6

2. Results of micro-CT scanning

Remarkably, scanning revealed that the sandstone blocks contained the fossils of three animals: *Leptopleuron lacertinum,* possibly a new species or a variant of *Erpetosuchus granti*, and fragments of a third unidentifiable reptile.

Foffa, D et al. 2020. Revision of Erpetosuchus (Archosauria: Pseudosuchia) and new erpetosuchid material from the Late Triassic 'Elgin Reptile' fauna based on µCT scanning techniques. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, *111 (4), 222 Fig 1 (D), 223, Fig 2.*

3. Reconstructions of two of the fossilised animals

Reconstructions of two of the smaller 'Elgin Reptiles' *Leptopleuron lacertinum* and *Erpetosuchus granti* created by James Robins under guidance from Dr Davide Foffa. The drawings are reproduced at half actual size of the animal.

Emily Keeble: Virginia Tech, USA

Micro-CT scans of *Stagonolepis robertsoni*

4. Fossil of scutes of *Stagonolepis robertsoni*

This fossil, together with exhibit [9], was found in Spynie Quarry in May 2018. Tennants (Elgin) Ltd excavate rock from the Late Triassic Lossiemouth Sandstone Formation at Spynie for use in the building industry; members of the Geology Group have permission from Tennants to examine debris when the quarry is not being worked.

These two specimens were sent to the University of Bristol for micro-CT scanning by Emily Keeble, under the supervision of Prof. Mike Benton, a long-time friend of Elgin Museum. Their findings show that the fossils are from a reptile, *Stagonolepis robertsoni*, a member of an extinct family of aetosaurs. These crocodilian-looking omnivores were covered in armoured plates called scutes or osteoderms and were up to 3 m long. 'Our' fossils are from a juvenile reptile, rather than a fully grown adult.

ELGNM: 2018.6.1

5. Results of micro-CT scanning

Micro-CT scanning of this fossil shows the shape and ‘tear drop’ texture of the armoured plates around the animal’s lower body. The fossil, as it appears to the naked eye, shows the underside of these seven scutes, with the detail and texture hidden within the rock. The scans clearly show the tear drop shaped ornamentation of the outside of the scutes and, indeed, the meaning of *Stagonolepis* is ‘drop-shaped form’. This is the first time that the detail of how aeotosaur scutes interlock has been seen. These results will help scientists studying other aetosaurs in the future and will allow them to make predictions about their physiology, e.g. where muscles were attached to bones.

ELGNM: 2018.6.1

6 and 7. Two fossils of *Stagonolepis robertsoni*

Two fossils from *Stagonolepis robertsoni* showing armoured plates (scutes or osteoderms) from the lateral or dorsal (side or back) of the animal.

When specimens of these scutes were first found and examined in the 1840s, they were thought to be fish scales: there is more information about Louis Agassiz and his classification of Devonian fish in the Rear Gallery. In the following years, more fossils were found, including bones and teeth. These were studied by Prof. Thomas Huxley in the 1850s who proclaimed that the scutes weren’t from a fish but from a crocodilian-like animal called an aetosaur. The numbers painted in red indicate that Huxley himself studied these specimens.

[6] ELGNM: 1978.562.8 and [7] ELGNM: 1978.562.19

8. Results of scans from second fossil (see [9] below)

This image shows that the fossil is part of the animal’s tail: it gives a transverse section of the tail with the scutes arranged in the shape of a high arched window (false-coloured by Emily Keeble for ease of study).

This arrangement had been predicted by Prof. Thomas Huxley in 1877 and these scans were the first evidence confirming that his theory was correct!

The yellow crutch-shaped bone shown in the scan is a chevron bone; the small cavity is the space where blood vessels ran along the ventral part of the tail. This bone is almost completely hidden within the rock: the top of the fossil shows the end of the bone as a small, faint circular feature (visible in the mirror).

9. *Stagonolepis robertsoni* fossil found in Spynie Quarry

This small fossil, found at the same location as exhibit [4], is a fragment from the tail of *Stagonolepis robertsoni.* The fossil shows Late Triassic bone around 230 million years old. Note the small, dark circular feature on the top surface of the fossil and compare with the scan results. This is the eroded top of the chevron bone (see [8] above).

ELGNM: 2018.6.2

Keeble, E. & Benton, M.J. 2020. Three-dimensional tomographic study of dermal armour from the tail of the Triassic aetosaur *Stagonolepis robertsoni. Scottish Journal of Geology*, **56**, 55-62

Huxley, T.H. 1859. On the *Stagonolepis Robertsoni* (Agassiz) of the Elgin Sandstones; and on the recently discovered Footmarks in the Sandstones of Cummingstone. *Quarterly Journal of the Geological Society*, **15**, 440-460.

Hady George: University of Bristol

Micro-CT scans of dicynodont *Gordonia traquairi*

10. Model of sandstone block found in Clashach Quarry

This model is based on the Permian sandstone block found in Clashach Quarry on display in the Rear Gallery (Case 6). The block from the Hopeman Sandstone Formation was discovered by quarrymen in 1997**.** The voids in the block were highly unusual and local geologist Carol Hopkins informed Dr Neil Clark at the Hunterian Museum of the find.

The block was examined using micro-CT scanning at the Western Infirmary, Glasgow, and then by magnetic resonance imaging (MRI) at the Glasgow Royal Infirmary to give more detailed information. The resulting digital data were studied by Dr Neil Clark and fellow palaeontologist Dr Arthur Cruickshank. The voids were cavities created when fossilised bone within the rock was dissolved by percolating (acidic) groundwater. The information allowed the contents of the block to be recreated, revealing a complete skull of a dicynodont: *Gordonia traquairi.*

Clark, D.L. et al. 2004. The Elgin marvel: using magnetic resonance imaging to look at a moldic fossil from the Permian of Elgin, Scotland, UK. *Magnetic Resource Imaging, 22, 269-273.*

Model of ELGNM: 1995.5.1

11. Results of micro-CT scanning by Dr Neil Clark

This compilation of six scanned images shows the results of the micro-CT scanning in 2003. The top left image shows the dorsal (viewed from the top) skeletal structure of the dicynodont; the adjacent image to the right shows the ventral (looking upwards) view. The next two images to the right show the jaws of the animal. The lower images show, on the left, the back of the skull and the image bottom right shows the lateral (side-on) view of the skull with the two tusks and ‘beak’ of the animal clearly visible. There is enough detail in the scans to identify the dicynodont species, but some features lack fine resolution.

12. Results of micro-CT scanning by Hady George

These images are the result of a 2022 study of the Clashach sandstone block by Hady George at the University of Edinburgh, although the actual scanning was done by Dr Liz Martin-Silverstone at the University of Bristol. The scanner used was more powerful than those available in 2003 and thus enabled minute anatomical traits to be captured. These scans allowed the internal structure of the brain cavity to be studied for the first time and Hady George was able to identify an unusually shaped pineal body. More commonly known as the ‘third eye’, this gland is light sensitive and regulates the animal’s circadian rhythms. This first study of a dicynodont brain shows that *Gordonia* is a very close cousin of a Chinese species of dicynodont (*Jimusaria*), greatly helping to construct a family tree of these creatures.

Scale bars = 4 cm

New micro-computed tomography based data on the cranial anatomy of the Late Permian Scottish dicynodont *Gordonia* reveal novel insights into dicynodont taxonomy phylogenetics, and non-mammalian synapsid neuroanatomy. George, H. 2023. University of Edinburgh unpublished dissertation.

13. 3D plastic model of Gordonia skull.

A 3D model of a dicynodont skull from *Gordonia traquairi* printed at actual size from 2003 digital scans of the Clashach Quarry sandstone block(see [10] above). The model was funded by the Scottish Government Recognition Fund and manufactured by Campbell Evans, Laser prototypes, Belfast, in 2012.

ELGNM: 2012.30

Digital photogrammetry of a Permian fossil footprint

Dr Elsa Panciroli: National Museum of Scotland and Alan Thompson: Highland Geological Society

This shelf shows different photogrammetry methods used to highlight features on rock surfaces, including, in this case, fossilised footprints (trace fossils)**.**

14. Photogrammetry using a digital camera

This board shows four images created by Alan Thompson using Agisoft Metashape software to generate a 3D model of the fossil footprint from 50 digital photographs. The results can be manipulated to show changes in direction of view and can incorporate ‘artificial light’ from any angle, to bring out the greatest level of detail from the photographs. The image top left is a heat map showing the depth of the footprint in the sediment. This gives an indication of the gait of the animal and can also help determine the slope of the ancient land surface that the animal was walking over. The image top right shows a ‘pencil’ black and white contour map, used to capture the structure of the print and which can also be used to give a technical description if required.

15. A 250-million-year-old (Permian) fossil footprint

This sandstone slab with fossil footprint was rescued from quarry debris at Clashach Quarry, Hopeman, in 2019. The animal was probably the size of a small dog and would have had five claws. Note the very short stride length and width between prints.

In addition to the well-defined footprint, there are three partial footprints on the slab. It is impossible to identify the animal that made the trackway but it is most likely to have been a reptile or a dicynodont. A small, curved worm track can also be seen.

ELGNM: 2022.6

16. A standard photograph of the fossil footprint

Although features are clearly visible in this photograph, there is no additional digital information that can be manipulated to better study the footprint. (© Dave Longstaff).

17. A laser scan of the fossil footprint

This shows the result of laser scanning of the slab, undertaken by Dr Elsa Panciroli whilst at the Oxford University Museum of Natural History. This method requires expensive scanning equipment and powerful computers to process the information, but the resulting digital information is extremely accurate and can be used for a variety of purposes. Like board [14], this also shows a heat depth map but is of far greater accuracy than that generated by standard photogrammetry. Laser scanning can potentially capture detail not visible to the naked eye.