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Palaeontology goes hi-tech

A cast skeleton of Gorgosaurus *on display at the Manchester Museum (University of Manchester). It is remarkably complete, with over 80% of the original bones preserved. This is a cast of the original bones, held at the Indianapolis Children's Museum (USA).*

Key words

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fossil

dinosaur

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Meet *Gorgosaurus*, a close cousin of *Tyrannosaurus rex*. She, alongside many of her prehistoric friends, is now the subject of the application of 21st century science.

Palaeontology strives to discover evidence so that we might learn more about the fossil remains of life and understand how they lived, functioned and even died. Scientists at The University of Manchester have been using state-of-the-art imaging, chemical analyses and computer modelling techniques to study the remarkable fossils that litter Earth's history.

The electromagnetic spectrum has become the key to unlocking the dilute traces of evidence that are changing the way we view dinosaurs and the fossil remains of all life. From visible light to infrared and from X-rays to gamma, the evolution of life on Earth is a mere wavelength away!

Visible light

This is the most familiar part of the electromagnetic spectrum that almost all life on Earth can detect and it is visible light that begins the interrogation of any fossil.

Using visible light alone, the surface geometry and features that define the morphology of *Gorgosaurus* can be described, photographed and resolved. We can see how complete and well preserved the remains of this animal are. In this case over 80% of the original bones were found when it came out of the Two Medicine Formation (a late Cretaceous geological slice of time) in Montana, USA.

Figure 1 *Two of the pathologies of the* Gorgosaurus *currently on display at the Manchester Museum. The left scapula has abnormal bone growth shown by difference in size, texture and morphology to the surrounding bone. Evidence of infection can also be seen on the lower jaw, caused by bacterial infection.*

Part of what makes this fossil so interesting is the many injuries that she sustained when she lived over 72 million years ago. Figure 1 shows that some of these healed, showing that she survived the massive trauma that caused them. The catalogue of injury and disease would floor many living species, including us. A key muscle attachment site at the top of her femur (thigh bone) tore away. Her fibula juts painfully at a right angle to her leg, a result of a compound fracture where the broken bone literally pierced the skin envelope. Along with many broken ribs, fused tail-vertebrae (back bones) and bacterial infections that ate away at her lower jaw, she also had an abnormal growth on her left scapula (shoulder blade). All these pathologies can be seen by simply looking at the bones and evaluating the differences in shape, texture and size using visible light.

X-rays

Synchrotron-based X-ray fluorescence mapping can be used to image the chemical make-up of fossils. This can highlight specific elements in very small quantities that are crucial in living animals for bone healing and growth. Figure 2 shows an image produced using Synchrotron Rapid Scanning X-ray Fluorescence (SRS-XRF). This can show the distribution of elements and their coordination chemistry within the bone, helping us to decide if they were organic or inorganic in origin.

Was it there to begin with?

Endogenous chemical components are useful as they reflect the animal. However exogenous chemical components may also be present. SRF-XRF and XANES spectroscopy can be used to determine whether the chemical composition of the fossil is a fair reflection of the chemical composition of the animal that produced it.

Pathologies

We know that the broken bones were not the result of the fossilisation process or someone dropping the skeleton; they happened when she was alive. We know this because, like humans, this dinosaur's body started to heal itself by growing more bone or compensating for an injury by limping. We can see this on the scapula (Figure 1) where there is a difference between left and right in shape, surface texture and amount of bone growth.

Bone does not form scar tissue, like a skin injury. Instead, the body has to completely reform new bone in the same way that the skeleton grew in the first place. By detecting astoundingly dilute traces of certain chemicals, we can discover how the damaged bone healed. This means we can discover how dinosaur bone developed.

Of course, the chemical composition of a fossil may change as it lies in the ground. It is a fine line when deciding what was the original chemistry of *Gorgosaurus*. Scientists at Manchester were able to make such judgments through the precise measurements that can be made at facilities such as the Diamond Synchrotron Light source in the UK and the Stanford Synchrotron Light source in the USA. Previously, bone-healing was studied using thin sections of bone, viewed under a microscope. Newer techniques provide more information and are less damaging to the fossils.

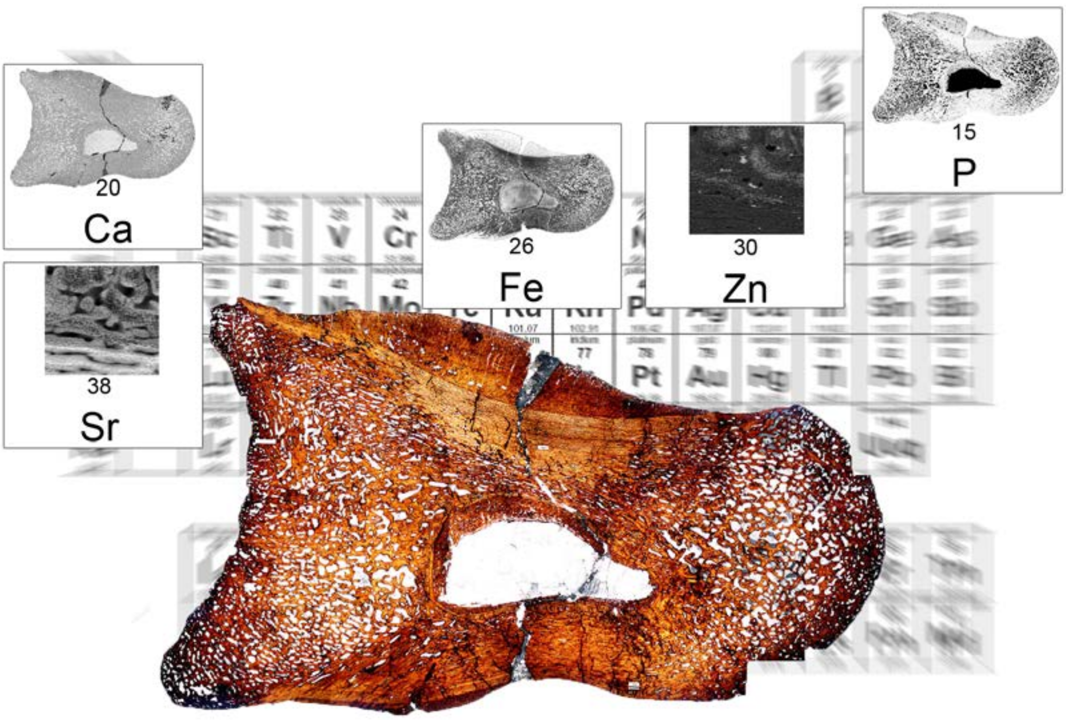

Figure 2 A thin section of a toe bone from Allosaurus fragilis*, approximately 6 cm long. This shows the variation in texture and elemental concentration of trace metals in normal bone and that which has formed a callus as a result of injury.*

Looking at pigments

SRS-XRF can also be used to determine the presence of specific biomarkers that represent pigments, such as melanin, in extinct animals. Melanin pigments can reflect differences in diet, sex and even the age of animals, both living today and in the past. Colour is also important in the behaviour of animals, for example in communication and protection in their environment by camouflage. Therefore to understand as much as possible about the fossilised remains of an animal, it is important to establish what they looked like.

Prof. Phil Manning, Uni. of Manch.

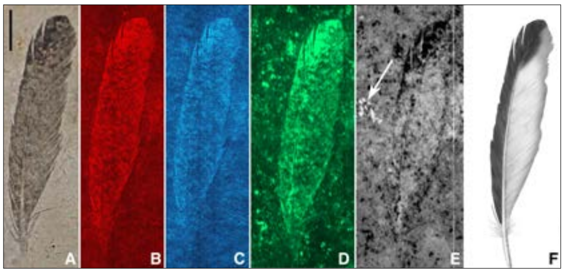

Figure 3 *A feather from* Archaeopteryx lithographica, *photographed in (A) visible light, together with SRS-XRF false colour images of concentration variations of trace metals and compounds, where the brightness indicates higher concentration: (B) copper, (C) nickel, (D) organic sulphur, (E) sulphate only and (F) an artist's restoration. The scale bar is 1cm (from Manning et al, 2013).*

Figure 3 shows the feather of *Archaeopteryx*. Visible light cannot show the presence or absence of pigment. However, SRS-XRF and Sulphur X-ray Absorption Near Edge Structure (XANES) spectroscopy have now been combined to show up both pigments and patterns in such feathers. It is remarkable that some of the original chemical composition of the feather tissues remains after 150 million years and can provide information on the type and position of pigments preserved in these Jurassic Age feathers. These techniques showed that the tip of at least some of the feathers from this early bird and also the outer edge were darker compared to the lighter, inner part.

It has been shown in earlier studies that pigments strengthen feathers, suggesting an early adaptation arose in *Archaeopteryx* that made its more exposed feathers less susceptible to wear through being pigmented. This is because the pigments act as a natural biocide, so that feathers survive better during their lifetime and long into deep time.

Infrared radiation

Broadly speaking there are two types of fossil: body fossils and trace fossils. Body fossils include the bones and shells of once living organisms. Trace fossils (such as footprints) record the behaviour of such creatures and are far less common than body fossils due to the unique settings they are created and preserved in. So how is it that we can understand the behaviour of animals that we cannot observe today?

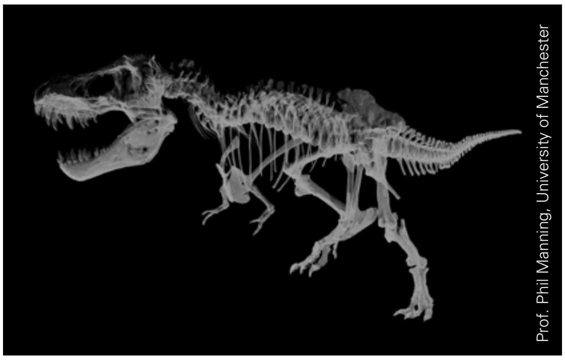

Figure 4 *A high resolution digital map of the skeleton of* T. rex, *made by scanning a mounted skeleton using a near-infrared laser scanner.*

A skeletal model, Figure 4, was produced from a laser scan of a mounted skeleton of *Tyrannosaurus rex*. Using data from living animals' muscle characteristics, a simulation was created that shows how this and other dinosaurs, including 40 m long giant sauropods, may have walked. This is a feat not possible without the use of computer simulations. Infrared provides the necessary imaging potential.

SRF-XRF

SRS-XRF is a technique that can produce a 2-D image of a scanned object. The image is a 'map' that shows the elemental composition of the object, in this case a fossil bird. Variations in elemental composition are highlighted and false-colour images can be produced showing these.

The potential for SRS-XRF is only beginning to be realised and is not limited to extinct animals but can be applied in archaeology, biology, forensics, etc. It is possible to chemically resolve lost words in ancient manuscripts that are invisible in visible light.

So which is best?

It is a multi-disciplinary approach that leads to the most conclusive and useful answers. By this I mean using several different technologies and directing them at one common aim. We can determine many things from the skeleton of a dinosaur, from its colouring to how it may have walked. The electromagnetic spectrum has more uses than ever and is greatly contributing to hi-tech palaeontology. See if you are able to spot the pathologies this *Gorgosaurus* has at the Manchester Museum, where she is now on display!

Ella Goodall is studying Geography and Geology at the University of Manchester and hopes to continue in her studies specialising in Palaeontology and museum preparation work of fossils.

Look here!

Find out more about the work of the Interdisciplinary Centre for Ancient Life at the University of Manchester: *www.ical.manchester.ac.uk*

Two previous Catalyst articles about the Diamond Light source:
www.catalyststudent.org.uk/cs/article/199
www.catalyststudent.org.uk/cs/article/267