BCAS Vol.24 No.2 2010

Dinosaurs of a Feather

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From the earliest days of paleontological research, the origin of birds was an area of special interest. Largely thanks to the work of Thomas Huxley and the discovery of *Archaeopteryx*, theropod dinosaurs (the large group of bipeds that contain all the carnivorous species) rapidly became the most likely candidate for the ancestor of birds. However, controversy over this idea raged for many decades, and while the evidence supporting the dinosaur theory grew, there remained one outstanding problem. Apart from *Archaeopteryx*, there were simply no fossils of dinosaurs with feathers.

All this changed in the 1990s with the description of the Chinese dinosaur *Sinosauropteryx* (Ji & Ji, 1996). This was originally described as a bird, but its real identity was rapidly revealed. It was an international sensation—at last, feathered dinosaurs. It proved, however, to be merely the start. This small and unassuming fossil with just a few patches of filamentous fuzz along its spine was to be the first of a great many feathered dinosaurs recovered from China and described by Chinese palaeontologists, many of whom based at the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) of the CAS.

Part of the holotype specimen of *Sinosauropteryx* with a small crest of protofeathers running along the neck and spine. (Photo by Dr. D. Hone)

Dozens of specimens representing at least fifteen species of dinosaurs with feathers have now been described from Chinese fossil localities of Jurassic and Cretaceous beds. They come from a wide variety of theropod groups including tyrannosaurs (*Dilong*), therizinosaurs (*Beipiaosaurus*), dromaeosaurs (*Sinornithosaurus*) and oviraptorosaurs (*Caupidteryx*) spanning most of the clade of theropods called coelurosaurs that include famous examples like *Tyrannosaurus* and *Velociraptor*. This wealth of evidence does of course provide huge support for the dinosaur origin of birds.

While these new specimens eventually brought clarity to the question of bird origins, emphasis turned to the evolution of the feathers themselves and, by extension, the origins of flight. The wide variety of dinosaurs now found with feathers was themselves sporting a wide variety of feather types but how and when did these evolve? If asked to think of a feather, most people will perhaps

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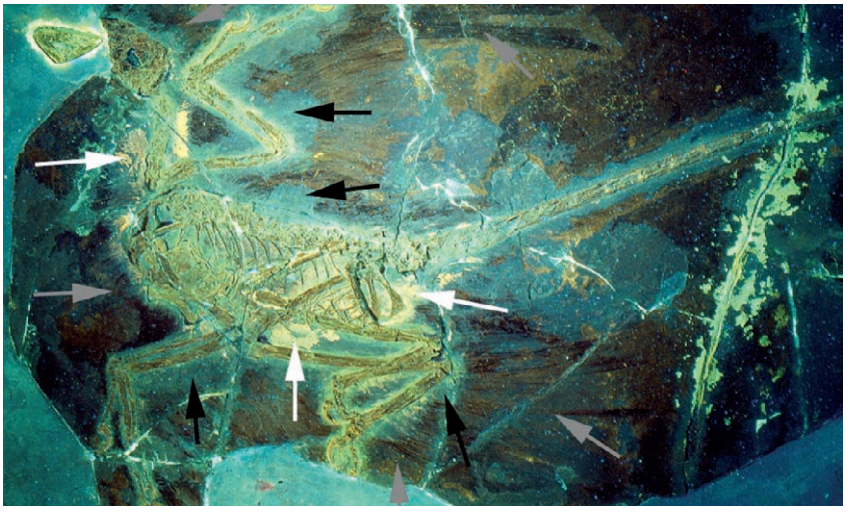
image the feathers of the wing or body of a bird, but even in living species there are quite a number of types such as the hair-like feathers seen on kiwis, or the downy fluff that cover baby birds. All of these are seen in feathered dinosaurs, but critically they appear in a fairly consistent pattern of increasing size and complexity.

The earliest feathers as seen in theropods like *Sinosauropteryx* are very short, simple structures that are just single filaments. Later branched feathers appear that look like the down covering of young birds, then as feathers get longer they evolve a central shaft and start to look like the feathers seen in modern birds, and finally the asymmetric feathers needed for flight appear in the dinosaurs closest to birds. A different, but important pattern was also shown very recently in feathered dinosaurs from China. As birds grow, the type and pattern of the feathers on their bodies change with the juvenile plumage being shed and the adult one appearing. We now see this in dinosaurs (Xu *et al.*, 2010) with a juvenile specimen of *Similicaudipteryx* having different feathers in a different pattern to that of an older specimen of the same species. Dinosaurs were clearly moulting and feathers were changing on individual species as well as evolving over time. However, these various kinds of feathers are not the only ones present in Chinese fossil dinosaurs.



The 'four-winged dinosaur' *Microraptor*, here seen under UV light. There are feathers on all four limbs and the tail too. White arrows point to fossilized soft tissues, grey arrows point to the feathers and black arrows to the 'halo' of apparently absent feathers. (Photo: Hone *et al.*, 2010)

While every feather seen in living birds has some counterpart in the fossil record, it appears that some dinosaurs also experimented with other unique feather types. *Beipiaosaurus* was a large-bodied herbivorous animal which had very long and spike-like feathers along its neck and back which might have acted as a simple form of defense from predators. The tiny arboreal climbing dinosaur *Epidexipteryx* had a set of four elongate (but shaftless) 'ribbon' feathers sprouting from its short bony tail that may have been used as a form of display. Clearly these early feathers were not used for flight and could have had a variety of functions such as helping to keep the animals (or their eggs) warm. Display has long been a central idea behind the origin of feathers, but testing this has understandably proved difficult. If only it were possible to see what colors the feathers may have been. Actually, the small packets of chemicals that help give modern feathers their colors have distinct shapes according to the colors they contain and these can be matched to those of the fossils (Zhang *et al.*, 2010). We really can now tell the colors and patterns of dinosaur feathers. Work in ultraviolet light has also revealed new details of the structure and size of the fossil feathers as some of their details reflect differently under UV revealing previously hidden information (Hone *et al.*, 2010).

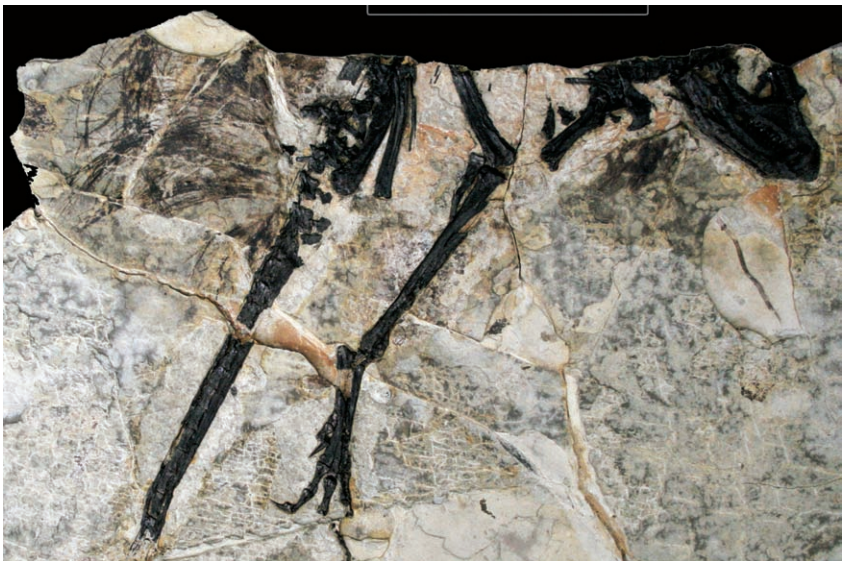
The superbly preserved feathers of *Anchiornis* which even 160 million years later still look like the feather seen on modern birds. (Photo: Dr. D. Hone)

It is flight though which we most associate with birds and a feature which the evolution of feathers ultimately permitted. However, while early birds such as *Confuscisornis* were clearly flying, it appears that dinosaurs may have taken to the air

as well. The wonderfully preserved *Microraptor gui* shows how early birds might have first started to defy gravity, with four wings! *Microraptor* has asymmetrical flight feathers on both arms, but also on both legs too. This might have given this species an early boost when gliding (but not flying) by providing extra lift or more control or both. As a close relative of the ancestors of birds, *Microraptor* can help inform us about the first steps into the air taken by dinosaurs and then birds.

For all the evidence from the bones and feathers that support a dinosaurian ancestry of birds, for a long time one problem with this theory remained. The earliest recognized bird, *Archaeopteryx*, is from fossil beds in Germany that are around 145 million years old. If dinosaurs truly were the ancestors of birds, why are the feathered dinosaurs more recent? Of course, the answer to this lies partly in the fact that few fossil beds preserve feathers, and feathered dinosaurs were incredibly rare, so this was no great surprise. However, as a final answer to the critics, a number of feathered dinosaurs, such as the troodontid *Anchiornis* (Xu *et al.*, 2009), have now been recovered from rocks that predate *Archaeopteryx*—feathers really do come before flight.

Feathers were limited to the theropod dinosaurs but another recent discovery has shown that other dinosaurs may have had similar filaments in their skin. The tiny ornithischian *Tianyulong* from Liaoning Province was described late in 2009 and clearly has long hair-like plumes arrayed along its back. It seems that there might have been a great many more dinosaurs with plumes and frills than just those preserved as bony horns and ornaments. Our whole picture of dinosaur and bird evolution is clarifying and getting stronger and bigger all the time thanks to discoveries like these.



The ornithischian dinosaur *Tianyulong* with its odd filaments along the spine. (Photo: Courtesy of Prof. Xu, X.)

There is of course more to come. New feathered species and new specimens are constantly being found and described. In the last year alone we have seen new species published, feathers studied in UV light, their true colors discovered and more. It is genuinely hard to know or even guess what the next revelation might be. China has contributed enormously to the study of the origins of birds and flight thanks to the remarkable feathered fossils, and the research of the scientists. It may not be clear what the next great discovery will be, but China will be at the forefront of it.

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