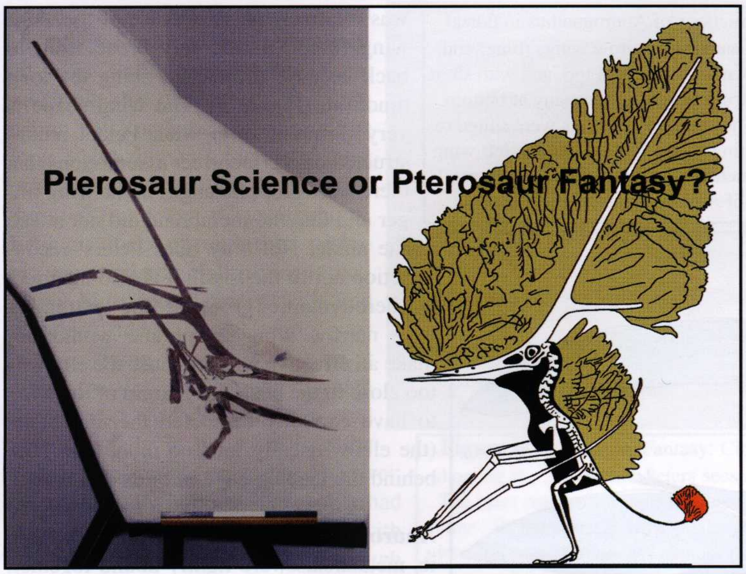
Pterosaur Science or Pterosaur Fantasy?



by S. Christopher Bennett PhD

Department of Biological Sciences
Fort Hays State University
Hays, KS 67601-4099
E-mail: cbennett@fhsu.edu
Http://www.fhsu.edu/biology/cbennett

In the past fifteen years, scientists have made tremendous strides in understanding pterosaurs, the first vertebrates to evolve powered flight, and we have forged a remarkable general consensus. Meanwhile, the amateur David Peters has produced literally hundreds of new interpretations of pterosaurs contradicting that general consensus, many of which he presented in recent articles in Prehistoric Times (Issues #64, 65, 67, 68 & 69). Peters styles himself as a maverick, discovering wonders that are overlooked and ignored by narrow-minded academically-trained paleontologists like me. I admit there is something romantic about the image of the amateur, toiling on his own time and beating the professional scientists to exciting discoveries, and I am especially aware of the potential contributions of amateurs because of Michael Ventris, an architect by profession, who as a teenager dedicated himself to the problem of deciphering the ancient Mycenean writing called Linear B. After years of work, Ventris made the leap to the solution based on earlier analytical work by Sir John Myres, Alice Kober, and my father, Emmett Bennett, and the decipherment led to a vastly improved understanding of the Mycenean world. However, there is a big difference between Peters and a successful amateur like Ventris, and that is that Ventris operated within the framework of archaeological research and strove to convince other scholars that his solution was correct, whereas Peters has ignored the framework of paleontological research, has made no attempt to convince academic paleontologists of his findings, and has taken his ideas directly to the general public and presented them as true and correct.

In his articles in Prehistoric Times, Peters described pterosaurs as outrageously bizarre like Dr. Seuss's imaginary animals, and claimed that all pterosaurs had tall frills of skin sticking up along their backs, that seemingly short-tailed pterosaurs actually had long whip-like tails tipped by a tuft of hairs, that most pterodactyloids (the advanced short-tailed pterosaurs of the Late Jurassic and Cretaceous) had small previously unseen nostrils, and that small pterosaurs previously thought to be juveniles were actually adults with babies both within their bodies and scattered around them. These claims and many more stem from his photointerpretation methodology, in which he finds photographs of specimens, scans them into his computer, manipulates the resulting digital images, and pores over them to outline features that he then interprets as bones and traces of soft tissues. Unfortunately, Peters' method is flawed and his reconstructions are fantasy.

So what is wrong with Peters' photointerpretation methodology? One problem is that he usually relies on small photographs in books and magazines that simply do not have enough resolution to show the fine features he claims to see. However, the main problem is that his method lacks one of the essential elements of the scientific method, repeatability. A scientist repeats an experiment a number of times to ensure they get the same results each time, and other scientists also repeat the experiment independently to test it. If the results cannot be repeated, they are bogus and we need to find out why. There is nothing inherently wrong with studying photographs of specimens, paleontologists do it all the time, but Peters has failed to demonstrate that his results are repeatable. He has not analyzed multiple photographs of the same specimen produced under different conditions, he has not compared his findings to what can actually be seen on the original specimen under a microscope, and none of the new features he claims to have found can be seen by pterosaur researchers. I have not examined all the specimens that Peters has reinterpreted, but I have studied some of them thoroughly, and here I will focus on a couple of examples to compare Peters' fantastic reconstructions with what can be seen on, and reconstructed from, actual specimens.

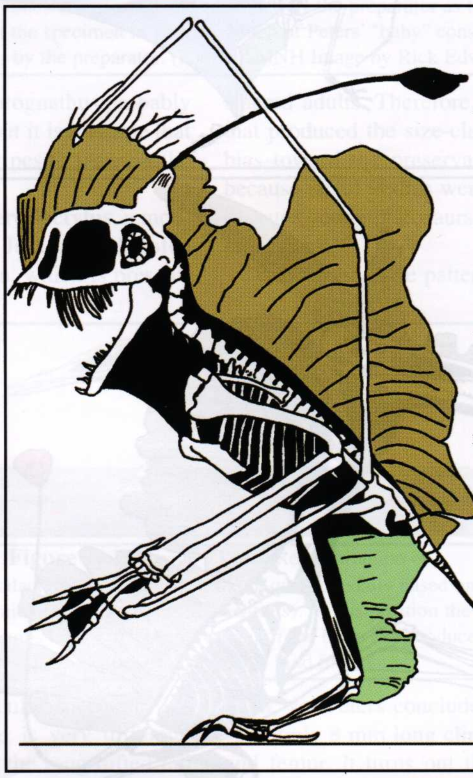


Figure 1. Pterosaur fantasy: Reconstruction of Anurognathus in a bipedal pose redrawn after Peters. Note the long teeth, bony skull crest, forehead and dorsal frills (tan), fishing pole and lure, and the tufted tail. The uropatagium (green) is shown, but the wing membrane is omitted for clarity.

Anurognathus is a small pterosaur from the Late Jurassic Solnhofen Limestone of southern Germany that is closely related to **Jeholopterus**, which Peters discussed and illustrated in one of his articles. Peters' ideas about

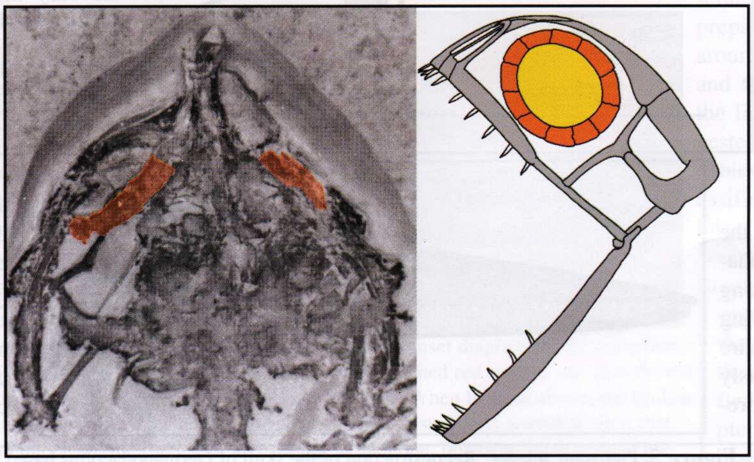


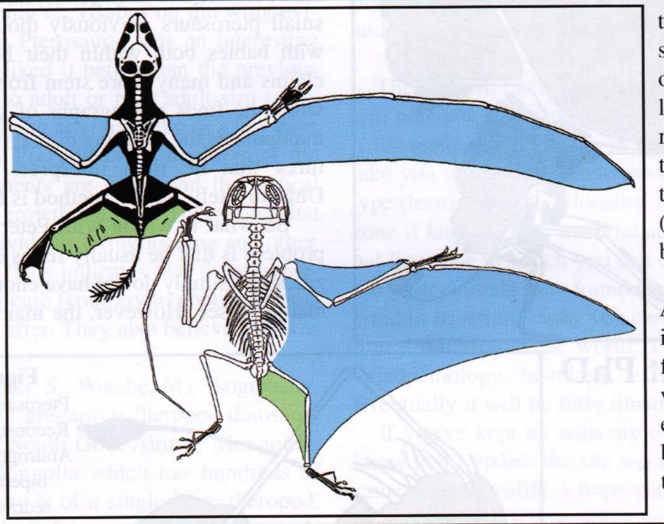
Figure 2. Pterosaur science: Photograph of the skull of the new specimen of Anurognathus from Eichstätt, Germany in dorsal view (left), and reconstruction of the skull in left side view (right). Note the large bony sclerotic ring (highlighted in orange) in the orbit, which shows that the eye was huge and dominated the skull. The area inside the sclerotic ring (yellow) represents the approximate size of the cornea and shows that the iris behind it could have been opened very wide for hunting insects in twilight. The jaws could be opened at an angle of 90 degrees to engulf flying insects.

Anurognathus are presented on his web site and are based on his interpretation of a small (126 mm square) photo with strong shadows in Wellnhofer's Illustrated Encyclopedia of Pterosaurs. Peters' reconstruction shows a bizarre animal with a short skull bearing many long curving teeth, a moderate-sized eye at the very back of the skull, and a tall frill of skin on its forehead (Figure 1). A sharply pointed bony crest supports an anglerfish-like pole and lure extending backward from the head, another frill runs down the back, and the tail is long and bears a tuft of hairs at the tip. In separate reconstructions, **Anurognathus** is shown with extremely long narrow wings spread as in flight and standing bipedally. I spent a lot of time studying the original specimen of **Anurognathus** and a new complete specimen under a microscope, and what I found is very different. The limestone around the first specimen, upon which Peters based his reconstruction, shows random irregularities resulting from splitting it into layers, but neither specimen has any evidence of a bony crest, frills and lures, or a long tail, and neither specimen supports Peters' reconstruction of the wing or bipedal posture.

The skull of the first specimen is incomplete and badly damaged, but that of the second is beautifully preserved and reveals that the skull was broad and tall with small numbers of short peg-like teeth evenly spaced along the jaws. Instead of the long beak of most pterosaurs, the front part of the skull is very short and the nostril and antorbital fenestra are small. The broad mouth can be opened very wide (Figure 2). A well-preserved bony sclerotic ring lies in the opening that Peters thought was the antorbital fenestra and shows that the eye was enormous and placed forward in the skull where it would have provided some binocular vision. Clearly **Anurognathus** hunted its food by eyesight, and probably at dusk or at night.

The new specimen shows that the wing finger consisted of only three phalanges, which is unusual among pterosaurs. As a consequence, the wing finger was quite short and the entire wing much shorter than previously thought even though the arm and forearm were quite long. There are traces of wing membrane attaching along the hindlimb down to the ankle, and a reconstruction of the wing shows that although it was relatively short because of the short wing finger, it was very broad front to back because it attached along the long hindlimb (Figure 3). The wing shape is very different from what Peters reconstructed on the incorrect assumptions that there were four phalanges in the wing finger and that the membrane did not attach to the ankle. Not only does Peters' reconstruction not fit the fossil, it is also incorrect on aerodynamic grounds: the extremely long narrow wing membrane would not make an effective wing because the elbow is too close to the posterior margin of the wing to have correctly cambered the membrane (the elbow usually falls no more than 30% behind the leading edge in birds and bats).

Figure 3. Science vs. Fantasy: Reconstructions of Anurognathus in dorsal view scaled to the same humerus length, with long narrow wings (blue) and unconventional uropatagium (green) redrawn after Peters at top, and with short broad wings based on the new specimen from Eichstätt, Germany at bottom. Note the great difference in skull shape. The short broad wings were suited to a slow highly maneuverable flight for hunting flying insects, and the left wing and hindlimb of the short-winged reconstruction show the folded wing sprawling resting posture that is characteristic of Anurognathus and its relatives.



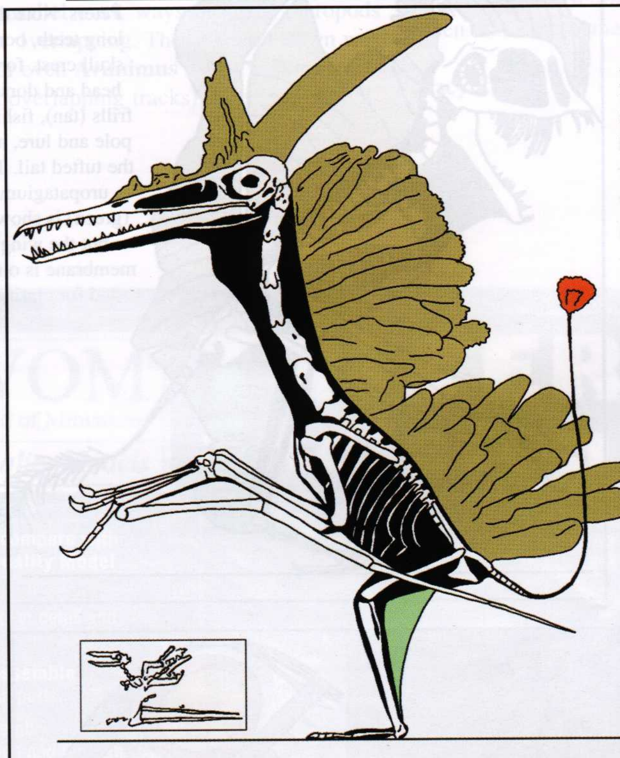


Figure 4. Pterosaur fantasy: Reconstruction of Pterodactylus in a bipedal pose redrawn after Peters. Note the frills (tan) on the skull, neck, and back, and the long whip-like tail with the cracker (red) at the tip. The uropatagium (green) is shown, but the wing membrane is omitted for clarity. The inset shows Peters' interpretation of the "baby" he sees on the slab near the specimen's chest at the same scale as the reconstruction.

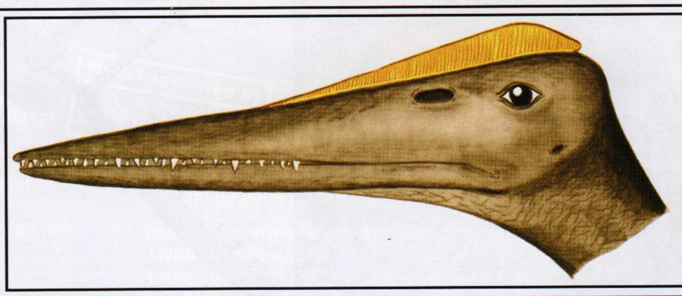


Figure 5. Pterosaur science: Reconstruction of the skull of Germanodactylus based on a specimen from Solnhofen that preserves traces of a horny soft tissue crest (orange) growing upward from a bony crest. The crest may have been larger in older individuals, and it might have been brightly colored or patterned. Pterodactylus had a similar crest though with a slightly different shape, and the colors and patterns may have varied between species.

Peters probably reconstructed **Anurognathus** in a bipedal posture because its metatarsals were tightly bound together, forming a compact metatarsus. In the past, it was thought that the compact metatarsus of early pterosaurs, which superficially resembles that of theropod dinosaurs, indicated a theropod-like digitigrade bipedal stance; however, I have argued that the compact metatarsus was correlated with leaping around in trees like living galagos and tarsiers, and evidence from trackways, series of fossilized footprints, shows that pterosaurs were quadrupedal. In addition, **Anurognathus** had large strongly curved claws on it fingers and toes, and a specimen of **Jeholopterus** that preserves the horny sheathes on its claws reveals that they were perfectly suited for clinging and climbing. Those claws, plus the fact that the forelimbs (not including the wing finger) and hindlimbs were about the same length and size, suggest that **Anurognathus** was an adept quadrupedal climber that could also have scurried around quadrupedally on the ground if it chose to.

The new specimen is preserved with its wings folded at its side and its knees pulled forward in a relaxed sprawl as if it was resting. Interestingly, most specimens of **Anurognathus** and its relatives are preserved in similar positions, which suggests that at rest they sprawled on all fours in an almost bat-like pose, though there is no evidence that they could or would have hung by their hind feet.

The evidence from the two specimens of **Anurognathus** can be combined to paint a remarkable picture: the huge eyes could locate and track flying insects in dim light; the broad mouth could be opened very wide to form a huge insect trap, and the short peg-like teeth would be perfect for snagging and holding struggling insects when the trap snapped shut; the short broad wings were suited to a slow maneuverable flight much like that of many small insect-eating bats; and the absence of the long stabilizing tail found in most primitive pterosaurs would have further increased the maneuverability. Ecologically, **Anurognathus** probably was similar to night-flying insect-eating birds like whippoorwills and nightjars, and to insect-eating bats: hunting flying insects at dusk or at night, twisting and turning through the air as it chased them down, and resting quietly in hiding during the day, perhaps on the ground under cover, but more likely in trees. It probably had rather muted coloration to blend in with its surroundings when resting. Although there is no evidence of a furry body covering in either specimen of **Anurognathus**, a specimen of **Jeholopterus** shows coarse fur around the body, so Anurognathus probably had fur as well. The fur was probably brown to black, but it is possible that the fur and wings were mottled with lighter spots or stripes to increase the camouflage effect when at rest.

Figure 6. Science vs. Fantasy: Close-up of the Pterodactylus specimen showing the area where Peters sees a baby clinging to its mother's breast. The inset diagram of the same area at right shows bones in light gray (F, femur; H, humerus; P, wing phalanges; PP, prepubis; R, radius; T, tibia; U, ulna; ribs and gastralia are slender unlabeled bones), the "baby" in red, and areas of the limestone scraped and scratched by the preparator as they cleaned around the specimen in yellow. Much of Peters' "baby" consists of scratches made by the preparator. (Photo: AMNH Image by Rick Edwards)

A second animal that Peters has reinterpreted is **Pterodactylus**, a moderate-sized fish-eating pterosaur again from the Late Jurassic Solnhofen Limestone of southern Germany. Here his interpretation, which is presented on his web site, is based on a small image (518 x 500 pixels) on the American Museum of Natural History's web site. His reconstruction shows a long skull with a small nostril separate from the antorbital fenestra, a complex frill of skin on the skull that included a long backward-directed part that looks very much like the bony crest of **Pteranodon**, another tall frill on its neck and a third one on its back, a long whip-like tail with a cracker at its end, and bipedal posture (Figure 4). Peters also sees one tiny baby clinging to the specimen's breast. There are about 30 specimens of **Pterodactylus** and I have studied most of them, including the particular specimen that Peters based his reconstruction on, and what I found is very different. Nowhere have I seen any trace of the bizarre frills or the long tufted tail reconstructed by Peters. The specimen reconstructed by Peters is surrounded by a halo of lighter colored limestone, which seems to be what Peters interpreted as the extensive frill, but it is simply the result of the presence of the skeleton influencing the deposition of manganese and iron oxides on the bedding plane of the limestone, plus some scraping of the limestone surface around the specimen by the preparator to clean it up for display.

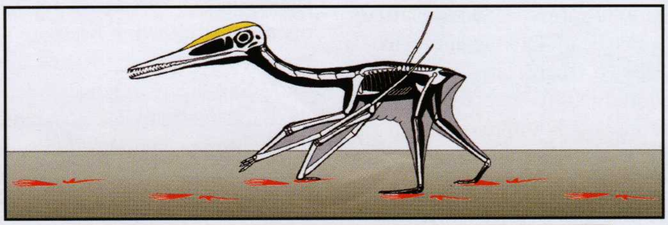


Figure 7. Pterosaur science: Reconstruction of Pterodactylus in side view walking quadrupedally based on Pteraichnus trackways (red footprints). In this position the forelimbs bear much of the weight of the body and produce deeper prints than the hind feet.

Examination of the entire sample of pterosaurs found in the Solnhofen Limestone shows that there was a strong bias toward the preservation of small individuals. The pattern is clearest in the case of **Rhamphorhynchus**, where specimens fall into three size-classes. The skeletons of specimens in the three size-classes differ in maturity—the bones of the smallest ones are incompletely ossified and often have simple shapes, those of the middle size-class are better ossified and some bones of the skull and limb girdles are fused, and the bones of the largest individuals are fully ossified and the bones of the skull and limb girdles are all fused together. The fact that the three size-classes are made up of individuals of different ages indicates that they are also year-classes, which occur when most specimens died and were preserved during a particular season of the year. In **Rhamphorhynchus**, there are 33 specimens that were hatchlings just learning to fly and beginning to grow, 46 specimens that were yearlings and half-grown juveniles, and only four specimens that are more than two years old and can be considered adults. Therefore, in addition to the seasonal bias in preservation that produced the size-classes, the Solnhofen Limestone also has a strong bias toward the preservation of hatchlings and juveniles. This might be because small bodies were more likely to be preserved than large ones or because young pterosaurs were more numerous and more likely to die than older ones.

We see the same pattern in **Pterodactylus**. There are three size-classes, most specimens are hatchlings and juveniles, and there is only one specimen that is large enough and old enough to have a bony cranial crest and be considered an adult. The adult probably had its bony crest extended by a horny sheath like that seen in the other pterosaurs **Germanodactylus** and **Ctenochasma** (Figure 5), also from the Solnhofen Limestone. The specimen that Peters based his reconstruction on is immature because it has unfused wrist, pelvic, and ankle bones, and it lacks a bony cranial crest. Its skull is only 83 mm long or about 42% of the size of the large adult, yet Peters concluded it was adult and identified a tiny baby with a skull only 8 mm long clinging to its breast, head down between the elbow and femur. It turns out that about half of the "baby" is just a pattern of scratches on the limestone made by the preparator when they were cleaning around the specimen to ready it for display and the rest is indistinct irregularities in the limestone (Figure 6). Peters has suggested that the reason no one has seen his babies before is that their bones are not ossified, but this has been shown to be false by a pterosaur embryo recently described from the Early Cretaceous of Liaoning, China. That embryo has eggshell preserved around it, showing that it had not hatched out of the egg, yet the shafts of all its long bones were ossified. This suggests that the Chinese pterosaur was precocial, that is, it was ready to fly soon after hatching and did not require parental care. That is just

Figure 8. Science vs. Fantasy: Close-up of the region of the antorbital fenestra and naris of the Pterodactylus specimen (indicated in the inset diagram by the red rectangle). Peters reconstructed a small separate nostril (dashed red outline; see also the red shape in the inset) in front of the antorbital fenestra. When lit from above, the broken ridge of bone above the area of the reconstructed nostril casts a shadow on it that Peters may have interpreted as an opening in the bone; however, there is bone preserved in the "nostril" and the smooth limestone below it shows that there had been bone there as well, but it flaked off and was lost when the limestone slab was split in two to expose the fossil. Note also the large manganese dendrite (red arrow) that Peters interpreted as a tooth (arrow on inset). (Photo: AMNH Image by Rick Edwards).

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what we see in the sample of pterosaurs from the Solnhofen Limestone—babies hatching out of their eggs and soon flying off to fend for themselves without parental care, and as a result many dying young.

Regarding the Chinese embryo, Peters argued that it is an adult of a new anurognathid pterosaur that crawled into a dinosaur egg to devour the tasty filling. The Chinese authors who described the embryo noted that the ends of the long bones were not well ossified, which indicates that the specimen was immature, not an adult as Peters suggested. Moreover, the ends of the long bones are very simple shapes, which suggests that the specimen is more immature than any previously known pterosaur. The simplest explanation (and science always prefers the simplest explanation) is that this tiny, most immature known pterosaur, which was found inside an eggshell, is an embryo.

Peters' reconstruction of **Pterodactylus** shows it in a bipedal posture, but **Pteraichnus** trackways made by Late Jurassic pterodactyloids as they walked across tidal mudflats show that they were quadrupedal. We know these trackways were made by pterosaurs because of the distinctive three-fingered hand prints that are more deeply impressed than the footprints, and by pterodactyloids because the footprints do not have the long fifth toe of the primitive rhamphorhynchoids. Reconstructing a **Pterodactylus** walking on a Pteraichnus trackway from Arizona results in an erect quadrupedal posture with the vertebral column horizontal. In this posture, the forelimbs carry more weight than the hindlimbs and produce deeper hand prints (Figure 7). The step cycle, the pattern in which the feet are picked up and put down, is a diagonal walk, a common step cycle used by many animals, in which there is always at least a forefoot on one side of the body and a hind foot on the other side in contact with the ground. In addition, each part of the cycle in which the body is supported only by diagonally placed feet is followed by a part in which three feet support the body and stabilize its position. Peters has reconstructed some pterodactyloids in a quadrupedal pose with the body almost as upright as in his **Pterodactylus** reconstruction, but the upright body position would not produce the deeply impressed hand prints or an efficient step cycle.

And what about that separate nostril? Peters reconstructs a separate nostril in front of the large antorbital fenestra. Scientists have been studying pterosaur skulls for over 200 years and some of those skulls are a meter or more long, and yet no one has ever seen a separate nostril in any pterodactyloid. It is inconceivable that there could be a real hole through the bone of pterodactyloid skulls that every pterosaur worker in the past 200 years has missed. Examination of the **Pterodactylus** specimen shows that what Peters identified as a nostril is an area that was in shadow on the photograph that Peters studied (Figure 8). With different lighting the area reveals bone and no opening. Below the supposed nostril is an area where some of the bone flaked off, exposing the underlying limestone. However, we can tell that there had been bone there because the limestone is smooth and bears an impression of the bone. The adjacent limestone between the jaws has a rough irregular texture that resulted from splitting the limestone slab to expose the skeleton. The limestone above the snout is smooth because the preparator smoothed it while cleaning around the specimen, scraping away some of the manganese oxide dendrites in the process. If there had been an opening, the limestone would have had a rough irregular surface or would have had tool marks if the preparatory had smoothed it; it does not, so there was no opening in the bone there. Even if there had been one, it could not be a nostril because in archosaurs the nasal bone forms part of the margin of the nostril, and yet in pterodactyloids the nasal bone does not extend as far forward as Peters' purported opening. The identification of the nasal is quite clear due to its position relative to the premaxilla and the series of bones surrounding the eye, and in all pterodactyloids it is found above and behind the large opening in front of the eye, showing that that opening is a combined nostril and antorbital fenestra.

Peters used the supposed presence of the separate nostril in pterodactyloids to argue that the Pterodactyloidea is not a real group, suggesting instead that separate groups of pterodactyloids evolved from earlier rhamphorhynchoids: ctenochasmatids from **Parapsicephalus**, ornithocheirids from **Scaphognathus**, azhdarchids from **Dorygnathus**, and so forth. Unfortunately, Peters' cladistic analysis uses many characters that he has found using his photointerpretation methodology, characters that pterosaur workers cannot see, and so his cladistic analysis is as unreliable as his reconstructions of **Anurognathus** and **Pterodactylus**.

One last example shows just how absurd Peters' claims are. Peters reconstructed the beautiful crested specimen of **Nyctosaurus** shown on the first page of this article based on a photo I provided him. His reconstruction, shown facing the specimen, has an extremely large frill encircling the skull and crest and extending almost to the edges to the chalk slab. The chalk slab had been scraped smooth by the preparator and was then painted white, a fact that I noted in the caption of my original description of the specimen. Despite that, Peters reconstructed the huge frill using his photointerpretation technique. There is no way that the photograph of the scraped and painted chalk surrounding the **Nyctosaurus** specimen could have revealed any evidence of soft tissues, so the fact that Peters still created a reconstruction of soft tissues from irregularities on the painted surface (e.g., brush marks, dust, smudges) and digital artifacts produced by manipulating the image shows that Peters methodology and results are completely unreliable.

The evidence that I have used to reconstruct **Anurognathus** and **Pterodactylus** is evidence that every reader of this article could see on the actual specimens or on large, sharp photographs of the specimens. Other pterosaur researchers can see the evidence as well, although we may sometimes disagree about how to interpret the evidence. However, when pterosaur researchers look for the features that Peters claims to see, when we look for his evidence, we cannot see any, all we see are random irregularities in the texture and color of the rock surrounding the specimen. Peters is the only one who sees his evidence, and he has not even bothered to look at the actual specimens to find out if it is really there. He has been telling pterosaur researchers like me about his ideas for years and asking for our advice, but when we tell him we cannot see his evidence, when we suggest he try to repeat his results or actually look at the original specimens, he ignores or dismisses us. Now he has turned to you, the interested public, in the hopes that he will have better luck convincing you of his ideas. So what do you want to believe, pterosaur science or pterosaur fantasy?


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