

# Did Dinosaurs Break the Sound Barrier?

By JOHN NOBLE WILFORD

**M**OVE over, Chuck Yeager, and give way to supersonic dinosaurs.

At least 150 million years before Mr. Yeager in 1947 became the first human to break the sound barrier in a rocket plane, the largest dinosaurs, a group known as sauropods, could have mustered the right stuff to send sonic booms resounding over the Mesozoic landscape. No, the 100-ton creatures never got off the ground. All they would have had to do was flick their long tails like a bullwhip.

The idea had occurred to some paleontologists examining fossils of the enormous sauropod tails, which

tapered to thin tips. Could they have been used like whips to defend themselves or to produce a loud "crack" to intimidate predators or communicate with fellow sauropods, including potential mates? As physicists have known since 1958, the crack of a whip is actually the shock wave, or sonic boom, caused by the thin tip of a whip exceeding the speed of sound for one moment.

No one had put the idea to a test until a master of computer simulations, Dr. Nathan P. Myhrvold of the Microsoft Corporation, struck up an extended electronic-mail conversation with a leading dinosaur expert, Dr. Philip J. Currie of the Royal Tyrrell Museum of Paleontology in Drumheller, Alberta. The result

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A tail might have been as fast as a whip, but louder.

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could be the beginning of a new research specialty that Dr. Myhrvold calls cyberpaleontology.

In analyzing fossils and developing computer models of sauropod tails, the two researchers said they had found evidence that dinosaurs like Apatosaurus (also known as Brontosaurus) and Diplodocus could indeed have flicked their tails to supersonic

velocities. But the sonic booms produced by the 3,500-pound tails of these behemoths would probably have sounded more like cannon fire than the crack of a bullwhip.

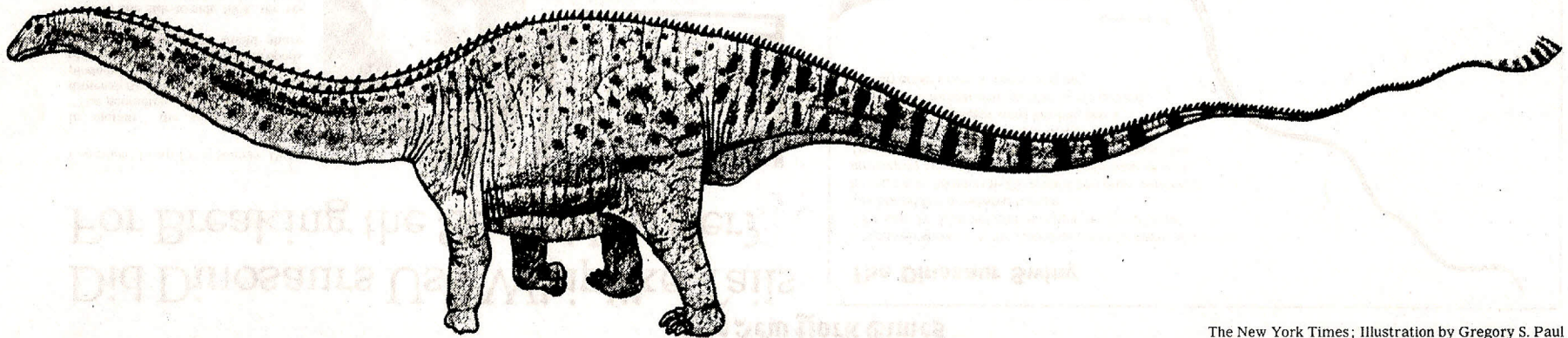
Dr. Myhrvold and Dr. Currie described the research in interviews and in a report in this month's issue of the journal *Paleobiology*. They conducted a variety of computer simulations, testing different assumptions about the biomechanical capabilities of these giant dinosaurs. They compared tails with whips in their computer analysis to see how similarly they behaved.

"In all cases, it was easy to find simulations that produced superson-

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## A Computer Spawns a Noisy Dinosaur

Scientists have long speculated that dinosaurs like this Apatosaurus used their tails to attack prey or defend themselves. Now researchers using computer models have proposed that Apatosaurus used its tapered tail like a bullwhip, making noise to attract a mate or establish dominance. Energy waves would have picked up speed as they rippled along the tail from the wide base to the narrow tip. The very end of the tail could have moved faster than sound, creating a loud sonic "crack."



The New York Times; Illustration by Gregory S. Paul



The New York Times

## Did Dinosaurs Use Whiplike Tails For Breaking the Sound Barrier?

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ic motion," the scientists wrote. "The geometric scaling of vertebral dimensions found in the various diplodocids strongly suggests that any of them, or non-diplodocid sauropods with 'whiplash' tails, would share this capability."

With one side-to-side flick, the researchers determined, a wave of energy could accelerate through the length of one of the tapering, segmented tails, gaining momentum to propel the tip of the tail to velocities of more than 750 miles an hour, faster than the speed of sound.

"We must confess that it is pleasing to think that the first residents of Earth to exceed the sound barrier were not humans, but rather the diplodocid sauropods," Dr. Myhrvold and Dr. Currie concluded.

Other dinosaur experts are sharply divided over the research. Gregory S. Paul, an independent specialist in dinosaur anatomy who is based in Baltimore, said he thought the concept of sauropods with supersonic tails was physically plausible. But at a recent paleontology conference, he said, he heard "other people who just

### The possible explanations for tail cracking range from love to war.

hate the idea."

One critic is Dr. Kenneth Carpenter, a paleontologist at the Denver Museum of Natural History. "To be blunt," he said in an interview, "the computer simulations are another case of garbage in, garbage out."

Dr. Carpenter questioned whether the bony segments of the dinosaur tails could have produced a supersonic boom. Even if that was possible, he said, using the tail like a whip might have been both painful and damaging to dinosaurs. The last few segments might even snap off.

In their report, Dr. Myhrvold and Dr. Currie emphasized that only the last two or three inches of the dinosaur tail would have exceeded the speed of sound. The possibility of pain or damage might be minimized



Frances Roberts for The New York Times

Dr. Nathan P. Myhrvold of the Microsoft Corporation, who creates computer models of dinosaurs, calls his work cyberpaleontology.

or eliminated, they pointed out, if the most extreme part of the tail extended past the last vertebra as a piece of skin, tendon or keratin, the protein that can take the form of scales, claws or feathers. "If whips made from the skins of cows and kangaroos are able to withstand supersonic motion," they said, "why not dinosaur skin and tendons?"

But the two researchers agreed with the paleontologists who now reject the idea that the sauropods regularly used their tails defensively. The animals would probably have sustained as much injury to their tails as they inflicted on attackers.

As chief technology officer at Microsoft, Dr. Myhrvold presumably has more pressing research matters than dinosaur tails. But dinosaurs have fascinated him since childhood, and he has probably never met a research problem he did not try to use a computer to solve. He got in the habit of stretching the imagination when he studied cosmology under Dr. Stephen W. Hawking at Cambridge University in England.

"I don't claim it's relevant to Microsoft," he said of the dinosaur simulations. "It's just an interesting problem to me."

In particular, Dr. Myhrvold was intrigued by the analogy of the bullwhip to explain the sauropod tails, as suggested a few years ago by Dr. R. McNeill Alexander of the University of Leeds in England. The progressive rate of tapering from the

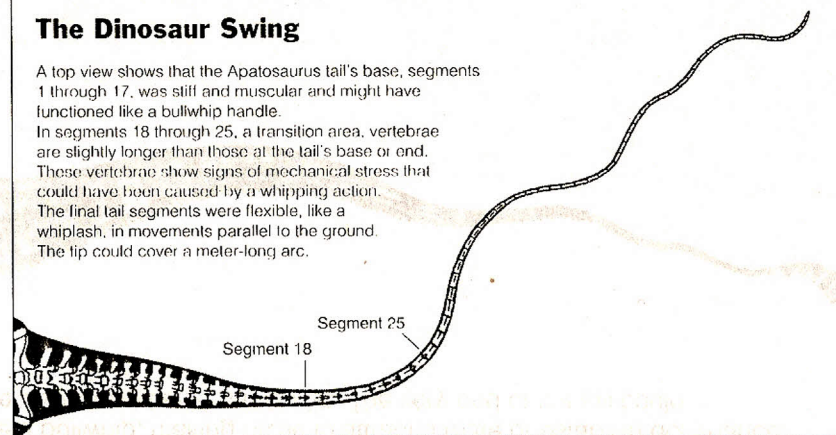
base of the tail to the tip is comparable to that of a bullwhip from the grip to the tip. Each successive vertebra in a sauropod tail is about 6 percent smaller than its predecessor.

An analysis of fossils, especially those of an apatosaur at the Carnegie Museum of Natural History in Pittsburgh, showed that in 41-foot tails of 80 vertebrae, the lengths of each connecting segment reached a maximum of some 4 inches in the section between the 18th and 25th vertebrae.

### The Dinosaur Swing

A top view shows that the Apatosaurus tail's base, segments 1 through 17, was stiff and muscular and might have functioned like a bullwhip handle.

In segments 18 through 25, a transition area, vertebrae are slightly longer than those at the tail's base or end. These vertebrae show signs of mechanical stress that could have been caused by a whipping action. The final tail segments were flexible, like a whiplash, in movements parallel to the ground. The tip could cover a meter-long arc.



The New York Times; Illustration by Gregory S. Paul

That happens to correspond to an area of ossification, fusing pairs of vertebra and otherwise indicating injuries from repeated stress.

As Dr. Myhrvold and Dr. Currie noted, the injury is consistent with overextension of the tail joints from whiplike motions in a plane parallel to the ground. Fossils suggest that the sauropods could probably move their tails about 30 degrees side to side; for purposes of the computer simulations, the researchers limited the motion to 9 degrees side to side. The animals were presumably extremely limited in vertical movements of their tails.

Next, Dr. Myhrvold recalled trying to learn everything possible about whips. As a computer expert, he naturally consulted the Internet, but

that directed him mainly to discussions of sado-masochistic practices. Finally, he learned that the man who made whips for Hollywood movies lived nearby in Seattle. Purchasing one, after pledging to use it only for dinosaur studies, he began to understand the Newtonian physics of whip dynamics, and he applied this in adapting commercial software for conducting the computer simulations of dinosaurian whiplike tails.

The two researchers offer several explanations for why sauropods would have engaged in tail cracking. It might have been a way to enforce discipline within a group, as herders of cattle and horses sometimes do with whips. It might have been a way to resolve disputes without resorting to combat. Or, they wrote, tail crack-

ing "could have been used as a nonlethal form of male-versus-male dominance contests."

What if the loud crack of a tail was a male's way of calling or attracting females? A test of this idea, Dr. Myhrvold said, would be to study many more fossils of dinosaur tails to see if the stress scarring was confined to males. That would mean tail cracking had been a "male thing." But paleontologists are not sure that they can distinguish a male sauropod fossil from a female fossil.

Even if the issue of dinosaur tail cracking is never resolved, Dr. Currie said, the computer simulations — cyberpaleontology — promise to be "the simple first steps for more complex models of dinosaur movements."