Fossils on the move

3D reconstructions highlight new characteristics of crocodiles and dinosaurs that lived millions of years ago in Brazil

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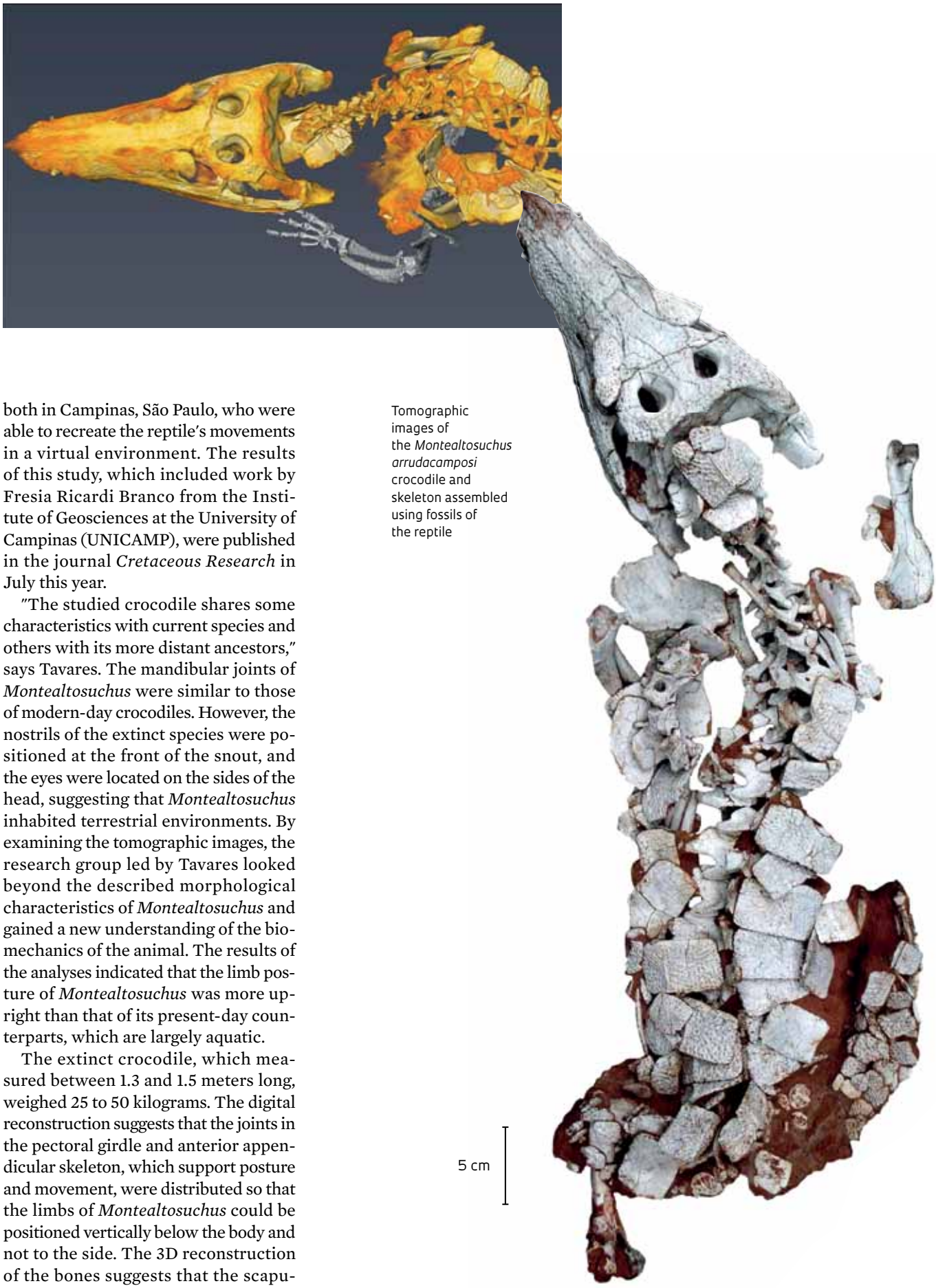
Finding fossils is an important—and perhaps the most celebrated—part of a paleontologist's work; however, in many cases, this activity is only the first step in an intense effort to interpret the echoes of a past so distant that they are almost inaudible. Two recent studies by Brazilian teams have shown how three-dimensional images produced by tomography can be used to reinterpret the habits and characteristics of known fossils, enabling researchers to digitally reimagine the probable movements of animals that lived hundreds of millions of years ago.

A paper by paleontologists from São Paulo and Rio de Janeiro suggests that terrestrial locomotion was common among an extinct crocodile species discovered in Monte Alto, São Paulo, in 2004. This hypothesis is based on anatomical analysis of the limbs of the reptile, which lived 80 million years ago. Another study by paleontologists from the Brazilian states of São Paulo and Minas Gerais and from Germany reconstructed the brain of a 230-million-year-old dinosaur found in Rio Grande do Sul State, Brazil, in the 1990s. In the corresponding article, the authors argue that the dinosaur's neck was so flexible, the species may have been carnivorous, rather than strictly herbivorous, as is typical of its genus.

More than a decade after participating in the discovery of *Montealtosuchus arrudacamposi* crocodile fossils, paleontologist Sandra Simionato Tavares, director of the Monte Alto Museum of Paleontology, recreated the animal's muscle system and joints. In partnership with researchers from the Institute of Radiology at the University of São Paulo's School of Medicine (FM-USP), she obtained tomographic images of different parts of the fossil comprising skull fragments, vertebrae, and a front limb. These images were sent to research partners at the Renato Archer Information Technology Center (CTI) and the National Synchrotron Light Laboratory (LNLS),



Tomographic images of the *Montealtosuchus arrudacamposi* crocodile and skeleton assembled using fossils of the reptile

both in Campinas, São Paulo, who were able to recreate the reptile's movements in a virtual environment. The results of this study, which included work by Fresia Ricardi Branco from the Institute of Geosciences at the University of Campinas (UNICAMP), were published in the journal *Cretaceous Research* in July this year.

"The studied crocodile shares some characteristics with current species and others with its more distant ancestors," says Tavares. The mandibular joints of *Montealtosuchus* were similar to those of modern-day crocodiles. However, the nostrils of the extinct species were positioned at the front of the snout, and the eyes were located on the sides of the head, suggesting that *Montealtosuchus* inhabited terrestrial environments. By examining the tomographic images, the research group led by Tavares looked beyond the described morphological characteristics of *Montealtosuchus* and gained a new understanding of the biomechanics of the animal. The results of the analyses indicated that the limb posture of *Montealtosuchus* was more upright than that of its present-day counterparts, which are largely aquatic.

The extinct crocodile, which measured between 1.3 and 1.5 meters long, weighed 25 to 50 kilograms. The digital reconstruction suggests that the joints in the pectoral girdle and anterior appendicular skeleton, which support posture and movement, were distributed so that the limbs of *Montealtosuchus* could be positioned vertically below the body and not to the side. The 3D reconstruction of the bones suggests that the scapu-

PHOTOS TAVARES, S. *ET AL.* / CRETACEOUS RESEARCH

Skull bones of the *Saturnalia tupiniquim* dinosaur, which lived 230 million years ago

la, coracoid, and humerus were joined, and the metacarpals were more compressed and closer together than those of present-day crocodiles, meaning the extinct crocodile was able to travel long distances on land in search of prey without depending on large bodies of water or wet environments.

"Our understanding of past life on Earth must transcend the simple knowledge of the diversity of existing forms of life," says paleontologist Ismar Carvalho, who is from the Institute of Geosciences at the Federal University of Rio de Janeiro (UFRJ) and one of the coauthors of the paper. He believes that evaluating the mechanics of movement and the physiology of extinct animals allows us to improve ecological interpretations. "The anatomical and physiological solutions identified in animals reflect the ecological spaces in which they lived, but our knowledge is limited by difficulties in extracting information from fossils without damaging them. Tomographic images allow us to model muscle arrangements and insertions, aspects that are difficult to evaluate by simply observing fossil records," he reports.

Brain structure suggests that the *Saturnalia* was a predator and not strictly a herbivore

It was thanks to advances in computed tomography that researchers from the University of São Paulo in Ribeirão Preto and the Ludwig Maximilian University of Munich were able to analyze in more detail the fossils of the bones that surround the brain, known as the neurocranium, of *Saturnalia tupiniquim*. Found in rocks from the Triassic period in the Brazilian state of Rio Grande do Sul, *S. tupiniquim* is one of the oldest dinosaurs in the world. The species is part of the sauropodomorph genus, the a group that includes the largest terrestrial animals that ever inhabited the planet, namely, long-necked herbivores that were up to 40 meters long and weighed as much as 90 tons. Unlike its more famous relations, however, the Brazilian dinosaur was small, averaging approximately 1.5 meters in length. In addition to plants, *S. tupiniquim* may have eaten small animals. For S. tupiniquim, reconstructing the internal structure of the skull allowed scientists to estimate the size, shape, and formation of the brain, shedding light on the animal's eating habits. The analyses provided additional evidence that earlier sauropodomorphs may also have been predators.

Paleontological site in Rio Grande do Sul, Brazil, where the dinosaur was found

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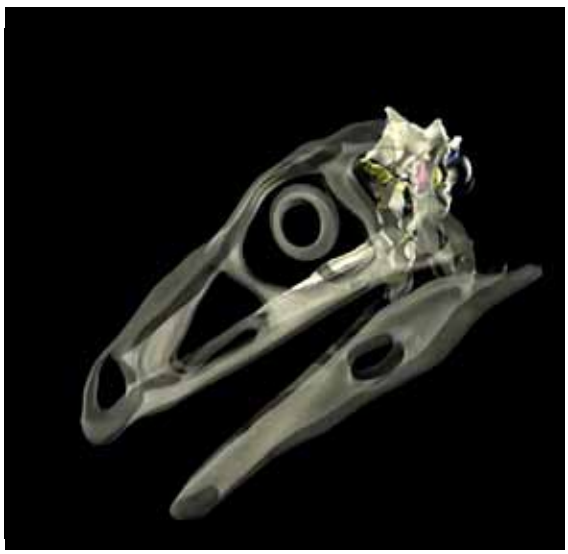

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Artistic reconstruction of the dinosaur and modeling of its skull

Using digital reconstruction, researchers filled in the fossilized neurocranium of *S. tupiniquim* and noticed that certain areas, such as the flocculus and paraflocculus, which are part of the cerebellum and are related to the control of vision and head and neck movements, certain areas were larger than expected. "Such developed structures suggest that the animal may have exhibited behavior typical of predators, who use rapid neck and head movements to catch small and agile prey," says paleontologist Mario Bronzati Filho, the lead author of the article, which includes the results of the analysis and was published in *Scientific Reports* in September. Bronzati is currently studying a doctorate at the Ludwig Maximilian University of Munich.

According to Max Cardoso Langer, from the Department of Biology at USP's Ribeirão Preto School of Philosophy, Sciences, and Languages and Literature (FFCLRP-USP), this is the first time that parts of the brain of such an ancient dinosaur have been digitally reconstructed. "This study allowed us to better understand habits that are closely related to the evolution of life on Earth and that are usually inferred based only on the morphology of teeth and other parts of the skeleton," says the researcher, who was involved in the discovery of the dinosaur in the 1990s. Paleontologist Jonathas de Souza Bittencourt Rodrigues, from the Federal University of Minas Gerais (UFMG), also participated in the *Saturnalia* study.

Paleontologist Sérgio Alex Azevedo, from the UFRJ National Museum, who did not participate in the studies on the Monte Alto crocodile or the Brazilian dinosaur, believes that while the use of tomography in paleontological research is not new, the technique has become more effective with the development of higher-resolution technologies. The more sophisticated equipment is capable of providing greater detail than medical CT scanners. With fossils, there is no need to worry about strictly controlling radiation levels, since no living organisms are being examined. "Tomography is a noninvasive technique that does not alter the form of the object under analysis. This is fundamental when dealing with materials at risk of natural deterioration, which must not be subjected to mechanical damage. The technique gives us access to a whole range of previously unavailable information, such as the structures of internal cavities," he explains. ■

Project

The origin and dispersal of dinosaurs in Gondwana (Neotriassic – Eojurassic) (No. 14/03825-3); **Grant Mechanism** Thematic Project; **Principal Investigator** Max Langer (USP); **Investment** R$1,959,890.17.

Scientific articles

TAVARES, S. *et al.* The morphofunctional design of Montealtosuchus arrudacamposi (Crocodyliformes, Upper Cretaceous) of the Bauru Basin, Brazil. **Cretaceous Research**. July 11. 2017.

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PHOTOS 1 JAY NAIR **2** USP-RP **3 AND 4** RODOLFO NOGUEIRA