PALEONTOLOGY

Scientists Flock to Explore China's 'Site of the Century'

BEIPIAO, CHINA—Zhao Yibing doesn't have time for idle reading any more. Instead, he spends his evenings poring over high school geology textbooks. Zhao, an official in this small town 400 kilometers northeast of Beijing, was recently given the task of safeguarding one of the hottest sites in the world for paleontologists. As the new director of the Administration of Fossil Birds Preservation Zone, Zhao manages a 46-square-kilometer region south of town, called Sihetun, that forms part of the fossil-rich Yixian formation. In the past few years, this formation has produced a series of spectacular fossils that are helping rewrite a key chapter in evolution.

"It's probably the most important site discovered this century," says vertebrate paleontologist Philip Currie of the Royal Tyrell Museum in Drumheller, Canada, who has worked with Chinese colleagues since 1986. "The taxonomic diversity, the incredible quantity, and the exquisite preservation and beauty of the vertebrate fossils are unprecedented for the Mesozoic," adds Zhexi Luo, a vertebrate paleontologist at the Carnegie Museum of Natural History in Pittsburgh, who with Chinese researchers recently published a description of a primitive mammal from the site. "In a few short years, new fossils from the Yixian Formation have far surpassed the fossils from the famous Solnhofen Limestone of Germany that yielded the bird *Archaeopteryx*."

All this excitement is understandable. Thanks to exquisite preservation of soft parts, it's possible to see dragonfly wings, feathers, and fur on fossils estimated to be perhaps 120 million to 130 million years old. Since 1992, new sites of the Yixian formation have yielded such specimens as *Sinosauropteryx*, the controversial "feathered dinosaur" (*Science*, 14 November 1997, pp. 1229 and 1267); *Zhangheotherium*, an early missing-link mammal; *Protoarchaeopteryx*, a primitive bird that appears to have feathers; and hundreds of skeletons of *Confuciusornis*, one of the most primitive birds known (*Science*, 15 November 1996, pp. 1083 and 1164). Although the age of the formation is subject to debate, Chinese scientists think it could be as old as the latest Jurassic period.

The area has become a magnet for researchers. Teams of scientists from three rival Chinese institutions—the National Geological Museum of China (GMC) and the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), both in Beijing, and the Nanjing Institute of Geology and Paleontology (NIGP)—are mounting expeditions, and hordes of foreign scientists are clamoring for the opportunity to help study some of the bounty.

The discoveries have also set off a mini–economic boom after local farmers learned that the stone plates with bird skeletons they had dug up from nearby hills were worth up to $1200, or 2 years' income. Many fossils were sold to research institutions, and others ended up overseas in the commercial fossil trade. Now Zhao employs five full-time guards to provide 24-hour-a-day, 7-day-a-week security for one of the key localities, the Sihetun site, in an attempt to make sure that the newly discovered natural resource is not pilfered. "Beipiao produces nothing that deserves attention but those fossils," says Zhao. "They are our tickets to the outside world."

Those tickets were minted by the unusual circumstances that preserved Yixian plants and animals. The barren hills south of Beipiao, swept by an icy wind from Mongolia, stand in stark contrast to the ancient environment, which stratigrapher Hao Zhaolin of the Beipiao Bureau of Mineral Resources Administration describes as "a shallow, warm lake whose waters teemed with shoals of fish," with flocks of birds overhead. The lake lay in a fault basin flanked by volcanoes.

The volcanoes are the key to the site's value. Sporadic eruptions "killed the [animals] en masse, and they were buried before rotting away," so that delicate structures like feathers were preserved, says NIGP's Chen Peiji, who has worked in the region for decades. The victims sank to the lake bed and were covered by volcanic ashes before they decomposed, says GMC paleontologist Ren Dong, pointing to the tuffaceous sedimentary rocks, produced in part by volcanic ash, that encase the fossils.

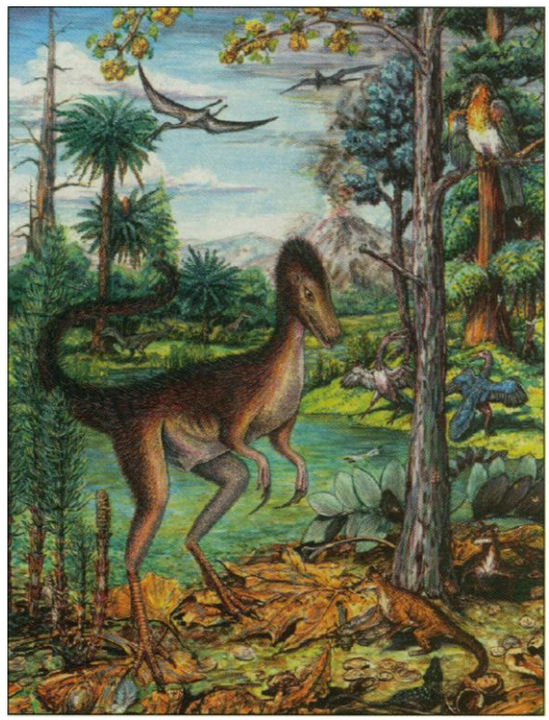


ILLUSTRATION: MARK A. KLINGLER/CARNEGIE MUSEUM

A rich past. A portrait of this warm, shallow lake 120 million years ago might have included a "feathered" dinosaur *Sinosauropteryx*, center; the early mammals *Zhangheotherium*, foreground; the primitive bird *Confuciusornis*, perched in tree; and two feathered *Protoarchaeopteryx*, background.

The rocks are present through much of the region and cover 80,000 square kilometers. The formation in western Liaoning Province was explored and studied for decades by Chinese and American researchers, who discovered a rich fauna of insects, mollusks, and crustaceans, and tens of thousands of specimens of a freshwater fish called *Lycoptera*. Fossil birds were reported and studied from several sites in Liaoning. "The diversity and quantity of fossils discovered in the area of western Liaoning is indeed rare around the world," says IVPP's Jin Fan. Then in the early 1990s, exquisite vertebrates from the two newest sites just south of Beipiao city, Jianshangou and Sihetun, recaptured the attention of paleontologists worldwide.

The stunning preservation, matched by only a few other sites worldwide, allows paleontologists to explore how feathers and flight evolved, as well as the relationship of dinosaurs to primitive birds. Both topics feature major scientific questions about the history of life. "It's a spectacular place, a very promising site for future discoveries," says Peter Wellnhofer, director of the Bavarian State Collection of Paleontology and Historical Geology in Munich and an expert on early birds as well as the famed Solnhofen limestone. "The soft structures are much better preserved in [the Yixian] than in the Solnhofen."

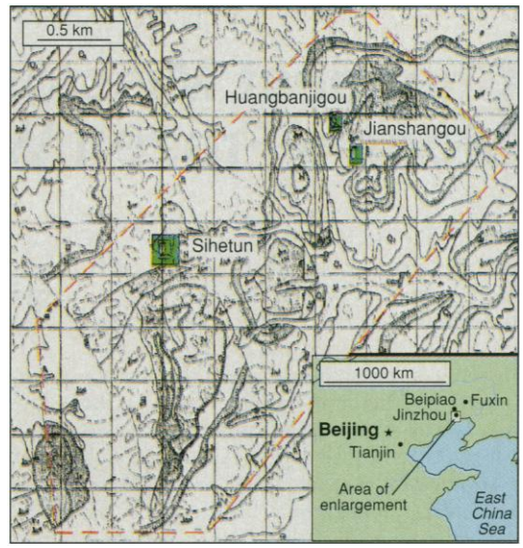
Now that the lid has been lifted on this scientific treasure, Chinese scientists are eager to learn more about what it contains. Among rival institutes working in the Yixian, NIGP and IVPP have mounted several field expeditions to various sites. But GMC and local branches of the Ministry of Geology and Mineral Resources (MGMR) have compiled the longest record of exploration at the

Sihetun site and taken advantage of earlier and easy access to its fossils. MGMR also is in charge of approval of field explorations and fossil management. MGMR has earmarked about $250,000 for exploration projects and construction of a fossil museum near Beipiao, and they obtained a $70,000 research grant from the China National Science Foundation. IVPP and NIGP, both within the Chinese Academy of Sciences, also have conducted projects related to the site and received funding for further exploration.

Blocked by existing local regulations on access to the site, institute scientists could not carry out their first fieldwork there until last May. They were rewarded for their patience, however: Of 11 pits dug at random, involving the sifting of 2000 cubic meters of rocks, one yielded 11 bird fossils, while the other 10 yielded an average of two specimens each. Scientists at NIGP, which was China's chief geological agency until 1949, also have had difficulty in gaining access to the site, despite the fact that its staff members have worked on Yixian formation fossils for decades. But NIGP paleontologists hope to carry out fieldwork at Sihetun before the end of the year.

Such competition has made foreign access to the Sihetun site even more difficult. "At least for now, field exploration cannot be carried out alone by foreign scientists without collaboration with Chinese institutions," says Carnegie Museum's Luo. Even joint field excavations, he notes, "would not be easy given the current situation in Beipiao."

Chinese researchers hope to parlay increased domestic funding and global interest in the site into a more important role in future international collaborations. "Important achievements on Chinese fossils should be made by Chinese researchers," says IVPP's Ren. NIGP's Chen adds that government guidelines make clear that "fieldwork must be led by Chinese researchers, and important articles must place Chinese researchers as the first authors. China should have the proprietary rights of academic achievement." At the same time, Chinese scientists emphasize the benefit of working with foreigners. "We have long cooperated with Canadian scientists," such as Currie, says Chen. "International collaboration can help us to publish our articles, as our English is not as good [as a native speaker]."



SOURCE: GMC

Beipiao bonanza. Sites in northeast China being excavated include Sihetun, Jianshangou, and Huangbanjigou.

Chinese authorities are also hoping to reap benefits. An $800,000 museum is expected to open later this year, and there are also plans to slice through a section of the site to expose the strata as a tourist attraction. "Local development of the fossil site will not affect [our fieldwork], and its impact [on fossil research] is positive," says Chen. He is confident that other sites like Beipiao will be discovered in western Liaoning and developed in a similar fashion.

In the meantime, Zhao's top priority is to make sure that the site remains in prime shape for scientists. "We have educated local farmers to protect fossils," he says, "and those who trade fossils already excavated will be convicted according to law." For that task he relies on his squad of guards, who operate from a cabin perched right over the bird fossil site. The better they do their job, the more time he can spend with his textbooks, exploring the record of a long-ago world buried under his feet.

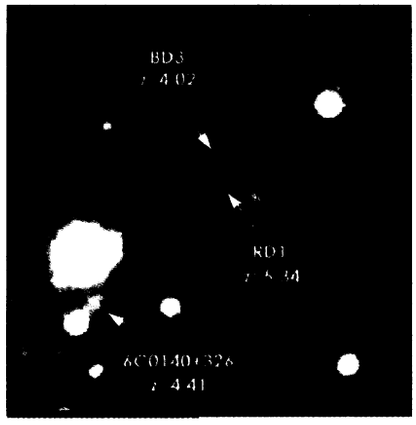
–Justin Wang

Justin Wang writes for China Features *in Beijing.*

ASTRONOMY

A Most Precocious Galaxy

Astronomers have found the most distant galaxy yet. Discovered at the world's largest telescope, the 10-meter Keck on Mauna Kea, the galaxy lies so far out in the expanding universe that the wavelengths of its light have been stretched more than sixfold. In cosmologists' units, the galaxy, called RD1, has a redshift of 5.34, compared to 4.92 for the old record holder. The light astronomers are now seeing left the galaxy less than a billion years after the universe formed, so it may offer a faint, smudgy portrait of a galaxy in its infancy. "It's possible that it's just forming," says Johns Hopkins University astronomer Arjun Dey.



DEY *ET AL.*

First blush. The new galaxy, RD1, is so far away that its ultraviolet radiation has been stretched into near infrared light.

Dey and his colleagues Hyron Spinrad, Daniel Stern, and James Graham from the University of California, Berkeley, and Frederic Chaffee at the Keck telescope found the new record holder last December following a systematic search for distant galaxies. While observing one galaxy at a redshift of 4, they noticed the spectral line of hydrogen from another object at a much higher redshift. After 10 hours of exposure, they had collected enough light to confirm the redshift of the galaxy, which is more than 100 million times fainter than the faintest star visible to the naked eye.

RD1 is too faint for the astronomers to collect a full spectrum, which would give them clues about the nature of its stars and gases. But the galaxy is bright in the ultraviolet wavelengths that are the signature of newly formed stars. Other galaxies that have been found by the hundreds at redshifts between 2 and 4—2 billion years or so after the birth of the universe—were also rapidly forming stars. But the faint image of RD1 hints at a difference: While later galaxies are compact, this one appears spread out. "Maybe it's multiple clumps, or maybe it's very diffuse and forming stars over a large volume," Dey says. Otherwise, "it's a very average sort of galaxy."

Theorists trying to explain how galaxies took shape from primordial gas say they don't expect average galaxies to be common in the universe's first billion years. But, says theorist Joseph Silk of Berkeley, "the current theory of galaxy formation is full of holes, so sure, current theory can certainly cope with the odd galaxy at redshift 5." Astronomers hope to put more pressure on theory, however, by finding even more precocious galaxies. "It wouldn't be surprising if this record was broken in a month," says Dey.

–Ann Finkbeiner

Ann Finkbeiner is a science writer in Baltimore.