THE NEW MOTHER LODE

Palaeontologists in Argentina are exploring a trove of fossils that is rewriting evolutionary history. **Rex Dalton** reports.

In the shadow of Cerro Cndor, a 600-metre-high limestone bluff in Patagonia, two young palaeontologists gaze over waves of mountain ridges running west towards the Andes. Diego Pol and Ignacio Escapa, from the Egidio Feruglio Palaeontological Museum in Trelew, Argentina, have spent years trekking the winding gravel trails here in the Chubut River valley, meeting only wandering guanacos, rheas and sheep. Already, their team has hand-dug half a dozen quarries in nearby canyons that have yielded globally important fossils.

But many prizes remain among the uncharted sediments of the Middle Jurassic, a geological epoch spanning 160 million to 180 million years ago, when dinosaurs, plants and early mammals were all undergoing key evolutionary changes. This time period holds crucial clues to the explosion of evolutionary diversity in both dinosaurs and mammals. The oldest known dinosaur remains, for instance, are around 230 million years old; the oldest known fossil mammals have been dated at 193 million years ago¹. Both groups diversified to an enormous extent during the Middle Jurassic², yet relatively few sediments of that age have been studied. That makes Chubut province in southern Argentina a rare opportunity. "This has the potential to be a global landmark for the Middle Jurassic," says Pol. "For the Southern Hemisphere, it already is."

The Argentine finds may open a little-understood palaeontological window, just as China's rich fossil beds have illuminated the early history of mammals, dinosaurs, reptiles and birds. Chubut is "an amazing region because you get fairly complete skeletal material, which allows you to answer many evolutionary questions", says Peter Makovicky, a palaeontologist at the Field Museum in Chicago who has explored much of Argentina.

"The discoveries from the Middle Jurassic of Argentina are no ordinary field finds," adds Zhe-Xi Luo, a curator at the Carnegie Museum

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Diego Pol with the backbone of a fossil sauropod from central Chubut.

of Natural History in Pittsburgh, Pennsylvania, who has published on the earliest mammals from China. "They are of such a significant nature that the whole early mammalian evolutionary paradigm must be changed."

Within the past decade, for instance, Argentine fossils have helped rewrite conventional wisdom on the evolution of tribosphenic mammals, so named for having molars of a mortar-and-pestle design that can both grind up plant material and shear meat. Palaeontologists had thought that tribosphenic mammals evolved only on the ancient northern land mass of Laurasia, which included what is now Asia, Europe and North America. But in 2001, within sight of Cerro Cndor, Pablo Puerta of the Trelew museum unearthed a tiny jaw of a shrew-like tribosphenic mammal, *Asfaltomylos patagonicus*³. This confirmed that tribosphenic mammals had evolved on the southern supercontinent, Gondwana, before it began splitting from Laurasia about 180 million years ago. Another team had found one southern Middle Jurassic tribosphenic mammal, in 1999 on Madagascar⁴ — but "the Argentine discovery was overwhelming evidence there were multiple evolutions of the same innovation", says Luo.

More tribosphenic discoveries may await in the preparatory laboratory at Trelew, where Puerta and his colleagues are close to removing the matrix from about 20 small mammalian specimens. These include parts of skulls and skeletons — rare finds for creatures usually represented by jawbone fossils. "We need to more fully prepare them to know how many new species we have," says Argentine palaeontologist Guillermo Rougier, a mammal specialist at the University of Louisville in Kentucky. "But we will greatly increase what we know of mammals from that time."

Another type of Middle Jurassic mammal has emerged from the Cerro Cndor quarries — South America's first example of the proto-mammals known as triconodonts, and dubbed *Argentoconodon fariatorum*⁵. In this animal, Rougier and his colleagues see characteristics similar to triconodonts found in North America and Morocco, including teeth like those in modern seals and some other fish-eating mammals.

And last year, Rougier and his colleagues also reported the discovery of a mammal they named *Henosferus molus*, on the basis of three jawbones. Each bone had a lateral groove, marking where cartilage had attached three or four little bones to the back of the jaw⁶. Such bones, which are typically lost during the fossilization process, are the predecessors of the

ear bones of later mammals. Rougier believes *A. patagonicus*, *Ar. fariatorum* and *H. molus* are part of the ancestral lineage leading to monotremes — animals that, like the platypus, lay eggs like a reptile but nourish their young with milk.

Dinosaur heaven

Along with its mammals, the Chubut Valley offers new windows on dinosaur evolution. In 2005, Argentine researchers and colleagues in Germany reported the discovery in Late Jurassic rocks of a short-necked sauropod dinosaur⁷. *Brachytrachelopan mesai* had vertebrae that were shorter in length than those of long-necked sauropods. It had clearly evolved to browse on lower-growing plants — and its

ancestors, deep in the Middle Jurassic sediments of Chubut, may help to explain how and why.

Much of the time the palaeontologists aren't sure what treasures they have until they get a block of fossils into the lab at the Trelew museum — a decade-old building now a centerpiece of the city's historic downtown, in a frontier village that played host a century ago

to outlaws Butch Cassidy and the Sundance Kid. Technicians at the museum are currently removing rock from a large pod of fossils dug up last year. The size of a small convertible, the cache weighs several tonnes. Fossils stick out at various points from its plaster jacket.

"We believe it holds a new type of theropod," a two-legged, mainly meat-eating dinosaur, says Pol. "There could be more than one. But we won't know until it is prepared, hopefully by later this year."

Plant fossils from Chubut are also promising. "I wouldn't be surprised if the first flowering plants come from Middle Jurassic sediments like those in Chubut," says Mark Norell, curator of vertebrate palaeontology at the American

Museum of Natural History in New York. Escapa, the palaeobotanist at Trelew, sighs at the thought, saying "that would be great, but I make no predictions". For now, Escapa is happy describing types of cypress never identified in the Southern Hemisphere. Fossils of the new species, called *Austrohamia minuta*, show incredible plant detail, complete with fossilized cones⁸.

Despite such potential, Argentine palaeontology has blossomed only in the past decade, due to a national political climate for science that previously varied from deadly to uninterested. When authoritarian generals ruled in the late 1970s, students and scientists were among the tens of thousands of Argentines killed for purportedly having left-leaning political beliefs. During the decade-long term of right-wing President Carlos Menem that ended in 1999, there was little support for any type of research.

But by the early 2000s, papers by Argentine palaeontologists began appearing in major journals, typically from the programme at the Argentine Museum of Natural Sciences in Buenos Aires, run by the now-retired Jose Bonaparte.

A technician without a doctorate, Bonaparte prowled the countryside for four decades making seminal discoveries. His protges — including Luis Chiappe, now curator of vertebrate palaeontology at the Los Angeles County Natural History Museum, and Rodolfo Coria, former director of the Carmen Funes Museum in Plaza Huincul in Argentina — subsequently discovered dinosaur eggs and revealed dinosaur nesting behaviour at Auca Mahuevo (see map), 100 kilometres or so north of Plaza Huincul. These studies produced detailed analyses of dinosaur eggs, nests and the discovery of a giant predatory dinosaur, from around 80 million years ago⁹.

Emerging from the shadows

Around 1980, Bonaparte briefly studied the Cerro Cndor sediments, which had been discovered in 1949 by Italian-born palaeobotanist Joaqun Frenguelli. But with many other sites available to work, he moved on. Now the Middle Jurassic sediments are coming under scrutiny from researchers such as Puerta, Rougier and a German collaborator, Oliver Rauhut of the Bavarian State Collection for Palaeontology and Geology in Munich. They have been joined by Argentine researchers who returned with doctorates from abroad, like Pol, who completed his Columbia University studies in 2004 at the American Museum of Natural History in New York before coming to Trelew in 2006 as curator of vertebrate palaeontology.

"This has the potential to be a global landmark for the Middle Jurassic."
— Diego Pol

There, he and colleagues have benefited from a 15-year-old Argentine policy to establish museums in provinces to exhibit and study specimens. A coastal town founded by Welsh immigrants nearly 125 years ago, Trelew — Welsh for ‘town of Lewis’, named for its founder — is a prominent stop for tourists heading to Patagonia and beyond. With about 110,000 visitors a year bringing in revenue, the museum has developed a healthy research programme. Its palaeontological exhibit area will soon be doubled, at cost of US\$5 million. “They have the best laboratory equipment in Argentina,” says Makovicky.

Local residents know it. Unlike in China, where farmers often scavenge fossil sites for specimens for sale¹⁰, digging in Argentina is controlled by national policy and private landowners. Near Cerro Cndor, in a village of a half-dozen homes, the community has embraced its palaeontological history, setting up a mini-museum to educate children and naming its traditional annual fiesta as the dinosaur holiday.

When Pol and Escapa visit, locals show them fossils they have found when riding after their livestock. But more often than not, the most promising new localities come from the palaeontologists’ own kilometres of hiking. As they survey the barren ground, Escapa looks for dark or black rocks — indicating carbonaceous material that was sealed ages ago, limiting oxygen so that a plant fossil can form. The first finds are often conifers, such as the cypress. Once a promising fossil is noted, the hikers stop, break rocks and dig. Frog and amphibian fossils usually are the first indication of vertebrates. With luck, those fossils lead to larger vertebrates.

On a brisk autumn day in June this year, Pol and Escapa checked such a site, where they had earlier found a metre-long dinosaur specimen, including the brain case, a valued find for any new species. They had hoped to be able to extract the fossil that day, but logistical

Rocks at the site also contain conifer and other plant fossils.

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problems caused by ash drifting from a Chilean volcano delayed its removal.

Extracting fossils can be onerous. For the large pod back at the lab, it took five years from the day in 2002 when technician Leandro Canessa discovered the fossils jutting from the hillside. First, the fossil clump had to be covered with casting material; then arrangements were made with a construction crew to bring a bulldozer to cut a road up a steep canyon. Finally, a crane was driven in to winch the fossil cluster into a truck. “This was really a project,” says Pol, giving credit to Puerta. But the hard work pays off in providing the exact geological context for a fossil. This stands in stark contrast to China, where palaeontologists often have to reconstruct the geology of a purloined fossil long after it has been removed from the ground.

With each new find, the Cerro Cndor scientists divide up the research based on their specialities. Beginning in 2000, Rauhut worked

on dinosaurs, with Pol joining him later. Escapa takes the plants.

There’s no shortage of work to go around. The Middle Jurassic, says Rauhut, is “the least-known part of dinosaur history. And the area around Cerro Cndor is incredibly rich.” Since first coming as a postdoc to Trelew in 2000, Rauhut has been on 13 field campaigns. New finds that have yet to be described include a sauropod and an ornithischian dinosaur, a bird-hipped creature. “The ornithischia is the one I am excited about,” says Pol. “We have a skull, a lower jaw and about 50% of the skeleton. There is nothing known about Middle Jurassic ornithischia from this region.”

And perhaps the biggest challenge is just the processing time to analyse and study all the new fossils. With a new three-year grant of €90,000 (US\$130,000), Rauhut and his colleagues will be heading out to Cerro Cndor again later this year, hoping to bring as many specimens back as possible from the field. “There is a lot more to come,” he says.

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The Cerro Cndor bluff overlooks a treasure trove of fossils.

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