



SAVING FOSSIL HILL

An Australian farmer safeguards a time capsule of the world's first complex life

By **Elizabeth Finkel**, at Nilpena cattle station in South Australia;
Photography by **Jason Irving**

Fly over the cattle station here in a Cessna 172 and you'll see a dry riverbed snaking through brown, mottled earth punctuated by the occasional patch of saltbush. There's no sign of the 200 cattle currently being run on this property, which is about the size of New York City and sits 450 kilometers north of Adelaide, Australia. But cattle are not the main asset of this remote station.

Instead, Nilpena's prize specimens lie exposed and motionless on the gentle slopes of Mt. Michael like some open-air diorama: the weird forms of Earth's first multicellular creatures, frozen in rock for 560 million years. About 60 species from the Ediacaran period pattern the hillside, the richest collection of such forms on Earth. Some creatures exhibit bilateral sym-

metry, others the trifold symmetry of the Mercedes-Benz logo; still others resemble heraldic shields, or are leafy with a repeating, fractal structure.

The plethora of species here isn't the only thing that sets it apart. Almost alone among Ediacaran sites, Nilpena preserves entire communities of organisms, intact because of ancient accidents of preservation and the foresight of its modern landowner, a rancher named Ross Fargher.

At Nilpena, "We can see who was living with whom and what they were doing," says paleontologist Doug Erwin of the Smithsonian Institution's National Museum of Natural History in Washington, D.C. Whereas most paleontologists study early life forms through museum specimens, here they can see the animals—for that is what many of the Ediacaran creatures appear to be—in the

context of their ecosystems. "We invented a new way of doing paleoecology here," says University of California, Riverside, paleontologist Mary Droser, who, together with Jim Gehling of the South Australian Museum in Adelaide, has worked on the fossils for the past 17 years.

Droser and Gehling have published more than 40 papers describing a peaceful, predator-free community where segmented creatures such as the pancake-shaped *Dickinsonia*—up to a meter long—and mollusklike *Kimberella* grazed on slimy bacterial mats; tiny helminthoidichnites tunneled just below the surface; and tethered, leafy, fractal creatures absorbed nutrients from the seawater directly through their outer skin.

Researchers owe that opportunity to Fargher. For more than 30 years, he has helped guard the fossils from looters who





have pilfered nearby Ediacaran sites; he also runs tours and helps scientists with logistics. But in recent years, ranchers in the region have struggled with persistent drought and low beef prices, and researchers have worried about what would happen if the 59-year-old Fargher were to sell his property. “We all thought Fargher’s efforts were remarkable, but we also thought: what now?” Erwin says.

As of this week, those worries are over: On 28 March, the state government of South Australia, using AU\$2.2 million raised in a public-private partnership, will purchase about half of this station from the Farghers to add to the existing Ediacara Conservation Park, increasing its size more than 10-fold. The new status may also boost a government bid for World Heritage status for Nilpena and nearby sites. “I am thrilled with this news,” says paleontologist

Guy Narbonne of Queen’s University in Kingston, Canada, who works at Mistaken Point Ecological Reserve, an Ediacaran site in Canada’s Newfoundland and Labrador province. “Now, this outstanding assemblage of fossils from the dawn of animal life is available to view and study for time immemorial.”

CLAD IN BLUE JEANS with a prominent brass belt buckle, boots, and Akubra hat, Fargher comes across as an iconic outback stockman, with an easygoing, forthright manner of speaking. But he quickly veers off script. As he leads a group of tourists across the fossil beds, Fargher holds forth on the life and times of Ediacaran creatures. On one rippled golden rock, he points out a large imprint the size of a dinner plate made up of concentric circles. It’s not a complete

Ross Fargher (above, in his wool shed) has helped save Nilpena’s half-billion-year-old platforms (left), which show the rippled rocks of an ancient sea floor on one side and the imprints of life on the other.

animal, he tells us, but the holdfast for a frondlike creature called *Arborea* that was torn off by a storm that swept across the ancient sea floor and buried this community in sand.

Arborea’s fractal body design disappears from the fossil record at the end of the Ediacaran period. But some of its bilaterally segmented neighbors may provide the answer to “Darwin’s dilemma”: Where did today’s animal life come from? Sites from the Cambrian period, 541 million to 490 million years ago, reveal an explosion of novel animal forms (*Science*, 23 November 2018, p. 880). But when Charles Darwin published



Concentric circles, once thought to be jellyfish (left), are now known to represent a holdfast that tethered a frondlike, fractal creature such as *Arborea* to the ancient sea floor. Ediacaran communities also included the pancakelike, segmented *Dickinsonia* (right), which reached up to a meter in length and appears to have been an animal.

On the Origin of Species in 1859, all known older rocks were barren of life. He called the lack of earlier forms “inexplicable” and wrote that it “may be truly urged as a valid argument” against evolution.

Then in the 1940s, Australian geologist Reginald Sprigg, exploring in the Precambrian rocks of the Ediacara Hills 15 kilometers north of here, discovered imprints of a pancakelike shape divided by segments emerging from a central ridge. He named it *Dickinsonia* after his boss, Ben Dickinson, director of mines in South Australia.

Later, amateur naturalists unearthed a plethora of smaller fossils at the same site, among them *Spriggina*, which resembled a segmented worm up to 3 centimeters long with a horseshoe head. Finally, in 2004, the International Union of Geological Sciences proclaimed a new geological period—the Ediacaran—from 635 million to 541 million years ago.

Researchers are still puzzling over exactly how the Ediacara relate to the rest of life on Earth. Many look nothing like modern organisms. But, Narbonne says, “A consensus is emerging that Ediacaran communities include the ancestors of the animals we see around us.” That interpretation got a big boost in September 2018, when other researchers examined *Dickinsonia* fossils from Russia that retained a dark film of organic matter. They detected a cholesterol-like molecule that is the biochemical signature of animals (*Science*, 21 September 2018, p. 1246).

Other Ediacaran sites have been discovered in the United Kingdom, Namibia,

Canada, Russia, and China. But Nilpena offers something rare: slabs of ancient sandstone, some bigger than a tennis court, that record entire ancient communities. Periodic storms repeatedly buried the ancient sea floor in sediment, preserving fine imprints of organisms “like a bologna sandwich,” Droser says, with the decaying organism as the bologna.

Exactly how these prints were preserved on the underside of the sandy slabs here is



a matter of debate. Gehling and Droser think the overlying sands turned to cement, perhaps because of high levels of the mineral pyrite, forming a death mask of the decaying creatures below. Another model, published this week in *Nature Ecology & Evolution*, posits that finer, more fluid sediments beneath the fossil flowed into the space vacated by the decaying creature, creating a mold that prevented the upper sand layer from collapsing.

The size of the sediment grains determines how detailed the fossil impressions

are. Some slabs with salt-size grains have revealed the 3-millimeter, shield-shaped *Praecambridium sigillum*. In other slabs, the grains themselves are up to 3 millimeters in size, making it hard to detect anything smaller than a centimeter.

Such coarse resolution makes studying the imprints under a microscope in a museum less important. And because the fossils have been preserved where they lay on the ocean floor, researchers can study them “as if you were going down in a submarine to view them,” Narbonne says.

Mistaken Point is the world’s only other site to preserve Ediacaran communities in situ. But those rocks are older by 5 million to 20 million years and the communities are dominated by the leafy fractal fossils. Nilpena offers a glimpse into a more developed Ediacaran world.

Researchers got their first panoramic view of that world in the mid-1980s, when a visitor asked Fargher about the rippled rocks paving the floor of his 100-year-old wool shed. More fossils turned up on the hillside nearby. Soon paleontologists from the University of Adelaide were making a beeline here and carting away slabs. That didn’t sit well with Fargher.

“Alarm bells started to go off,” he said, recalling that the Sprigg site in the Ediacara Hills was “pretty well stripped bare” by looters and even paleontologists carting specimens back to museums.

When Gehling came calling in 2001, Fargher was resolute. Research was fine but the fossils had to stay put. He agreed



Paleontologist Mary Droser (bottom right) speaks to tourists about how her team excavates Nilpena's fossils, which are likely to draw more visitors now that the site is part of a conservation park.

to make an exception for new species, so a "type specimen" that clearly exhibits diagnostic features of a species can be stored in a museum and analyzed by other scientists. But in most cases, paleontologists had to come here, where the lost world of the Ediacaran was on full display.

TO EXPLORE ANCIENT NILPENA, researchers examine a slab of rippled rock—usually flipping it over to see the fossils underneath—study it on-site, and then replace it on the hillside. New species have come to light, such as *Funisia dorothea*, described a decade ago by Droser and Gehling (*Science*, 21 March 2008, p. 1660). Although bits and pieces of this creature had previously been found, the slabs revealed enough intact specimens for the researchers to realize it represented a colony of tubular, corallike creatures tethered to the sea floor. Each individual was the same size, suggesting they had been spawned at the same moment through reproduction, rather than budding one by one.

Some of the creatures that populate the slabs have body plans never seen again in the evolutionary record, such as *Tribrachidium*—a creature with triradial symmetry that resembles a ninja throwing star—or the fractal rangeomorphs. But in some cases, the slabs record behavior resembling that of later animal life. *Dickinsonia*, for example, apparently moved around, because it left tracks: a series of faint, identical imprints, ranging from the size of a thumbprint to the

length of a forearm. Each set of tracks leads up to the main fossil.

Gehling and Droser hypothesize that *Dickinsonia* grazed like modern-day placozoans—millimeter-size pancakes that represent the simplest multicellular animals. The researchers think *Dickinsonia* lay atop the bacterial mat, digested it for a while—leaving an imprint—and then moved on to the next grazing spot, where it left another print. Gehling says he got the idea by seeing how his son's Frisbee imprinted his lawn after a few days.

Kimberella, a limpet-shaped creature with a front and back, also left trails, possibly scratch marks made by its radula—a sawlike structure similar to that used by molluscs to chop their food.

Droser doesn't think any of the Nilpena creatures were predators, though. "None have teeth that we can see," she says.

Researchers can also see how these communities changed over time. Repeated burials over perhaps 40 million years created fossil layers—35 so far—that can be carefully prized apart to reveal successive snapshots. Like ungumming the pages of a book, "we literally go in and pull off layers," Droser says.

This ability to follow the interrelationships of Ediacarans and the tracks they left behind on successive snapshots of the sea floor has allowed researchers to resolve 10 genera and a total of 60 species, far more than any other Ediacaran site.

One recently exposed slab earned the title "Alice's Restaurant" for its exquisite display of many rare species, some first discovered

here. Its exceptionally fine grain gives the fossils the appearance of having been expertly stamped with a cookie cutter. "Just when I think we've captured it, I'm on to a whole new learning curve," Droser says. In June 2018, the team reported two new genera, which they named after Barack Obama and David Attenborough.

FARGHER HELPS THE SCIENTISTS by using his earth-moving equipment to flip slabs. He also guards the site with fencing and video surveillance during the months the researchers are away. Looting is a constant worry: In 1994, one slab illegally heaved out of Bunyeroo Gorge in a reserve some 60 kilometers southeast of here ended up on sale in Tokyo for \$330,000, Gehling recalls.

"Ross is heroic," Droser says. Last year, the U.S. Paleontological Society gave Fargher its Strimple Award for amateur paleontology, the first time it has been awarded to an Australian.

Jane Fargher, Ross's wife, advocates for the fossils from the outback pub she runs in a nearby town. It was she who, in 2016, persuaded state government ministers visiting nearby to meet Droser. Surprised to find that California schoolchildren were learning more about Nilpena than Australian children were, the state government created the Ediacara action plan and provided AU\$1.7 million to purchase the land and establish the park, and to support research and education.

"Nilpena's story is unique and you don't need to be a paleontologist to understand why," says the author of the plan, Jason Irving, manager of protected areas for the South Australian Department for Environment and Water in Adelaide. "It's all laid out here, the rise of animal life."

The enthusiasm has spread. "That's what is so inspiring about this story," Droser says. "It's all the nonscientists who've made this their mission." To help fund the conservation park, Adelaide teacher Mary Lou Simpson established the Flinders Ranges Ediacara Foundation as the vehicle for a public-private partnership to help buy the land and support its ongoing maintenance. It raised more than AU\$500,000 from local fossil enthusiasts, philanthropists, and foundations. According to the deal, the Farghers will stay on as caretakers, running cattle on their remaining portion of the station.

"People have been trying to protect Nilpena for a long time," Irving says. "There is so much goodwill to make it happen and the stars are definitely aligned to create a new way of protecting the fossils." ■

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Science

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