HOW TO RETRIEVE 55 TONS OF DINOSAUR BONES FROM THE SAHARA DESERT

Millions of years ago, what's now North Africa was a lush landscape teeming with an incredible variety of life. To reveal more about the mysteries of this lost age, paleontologist Paul Sereno mounted perhaps the boldest dinosaur hunt ever attempted.

WORDS BY **PAUL SERENO**
PHOTOGRAPHS BY **KEITH LADZINSKI**

The author (at left) and fellow paleontologist Daniel Vidal excavate a pair of huge femurs belonging to a sauropod skeleton on the Irhazer Plain, one of three focus areas during a blitz of an expedition across Niger's desert.

Acacia trees are well adapted to the Sahara, with long taproots that reach water deep in the ground and thorns that protect them from grazing animals—and snag paleontologists' tarps taken by fierce desert winds.

Ancient mud captured the footprint of an unknown species of the long-necked herbivores called sauropods. The expedition found fossils from what National Geographic Explorer Paul Sereno says are many newly identified species.

AS THE SAHARAN SUN ROSE ON MY WAYLAID TEAM,

one morning in September 2022, it seemed to burn with particular intensity. For nearly three weeks we'd been holed up in a mud-walled compound in the oasis town of Agadez, in central Niger, stalled because of officials' insistence on assembling for us a large armed escort. Now, as dawn broke, we were finally ready to embark: Nearly a hundred people packed into 15 vehicles, a motley caravan of SUVs, pickups, and one large dump truck, all strapped with sand ladders and spare tires, heading out on an extraordinary desert dinosaur hunt—without question, the most ambitious of my career.

Among our number were Tuareg guides and drivers, a film crew, 64 armed guards, and my paleo dream team of 20 students and freshly minted professors, recruited to spend three months venturing across one of the planet's least hospitable landscapes. Our mission was to explore and excavate three distinct sites, spread across hundreds of miles of blazing, roadless desert. The fossils we found we would ship to my University of Chicago Fossil Lab for careful cleaning and study, later returning them for display in Niger, to celebrate the country's stunning ancient heritage.

Gusty winds make operating drones tricky in the Sahara, but Sereno's team used aerial footage to prospect, map digs, and find campsites. Technology enabled an expedition timeline that would have been unthinkable 20 years ago.

I had crisscrossed Niger's Sahara during 11 previous expeditions going back 32 years. The last two, in 2018 and 2019, had been for reconnaissance, and I'd spotted bone-rich pockets in some of the desert's most remote and sandswept corners, with dinosaur skeletons jutting from the desert floor. But without the team or tools to collect them, I could only log the sites and imagine our return trip. Then a global pandemic shut down the world, and I spent two years drawing up an audacious plan—and fundraising, with little success. That is, until a benefactor, requesting anonymity, agreed to fully fund the quest. My appeal had aimed at our innate human curiosity, a chance to uncover creatures from paleontology's last great frontier.

Niger is a dino wonderland because of two chance geologic events. The first unfolded 180 million years ago, during the early Jurassic, when the great landmass Gondwana began to break apart, forming a massive depression in the center of what is now the West African nation, then a verdant region teeming with life. For millions of years, the depression took in sediment and the skeletons of dinosaurs and other creatures.

The second event happened 20 million years ago, when a volcanic hot spot raised what's known as the Aïr Massif on the edge of this depression, tilting the strata upward and returning to the surface the now fossilized skeletons. Driving across these rock layers today, heading from Agadez into the open desert, is a journey through deep time.

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Our timeline was ambitious even before the delay in Agadez, and the expedition's success would hinge on benefiting from lessons I'd learned in the past, along with some novel technology we would deploy in the field. Our perseverance would be tested—many of my young colleagues had never set foot in the Sahara, worked under armed guard in 130-degree heat, or gone a month without a shower. Those with me on previous expeditions, meanwhile, had seen it all: food poisoning, malaria, sandstorms, expedition-ending breakdowns, gun-toting bandits, government coups. And yet I am always eager to go back.

NO ONE KNOWS the land and its secrets better than those who live on it, and our site nearest to Agadez was a return to a tantalizing find that a local Tuareg nomad had shown us. Years before, he'd led my team by motorbike into the desert, to a spot that the Tuareg call Tchinekankaran (CHIN-kan-KAR-an), or "place of insects," for the locusts that swarm after seasonal rains. It's a gravel rise about 10 feet high that stretches for nearly a mile and a half across the acacia-studded Irhazer Plain. Atop the little ridge, a series of large, spool-shaped vertebrae breached the surface. Some digging exposed more of the backbone, which belonged to a 50-foot-long sauropod, the classification given to long-necked, plant-eating dinosaurs.

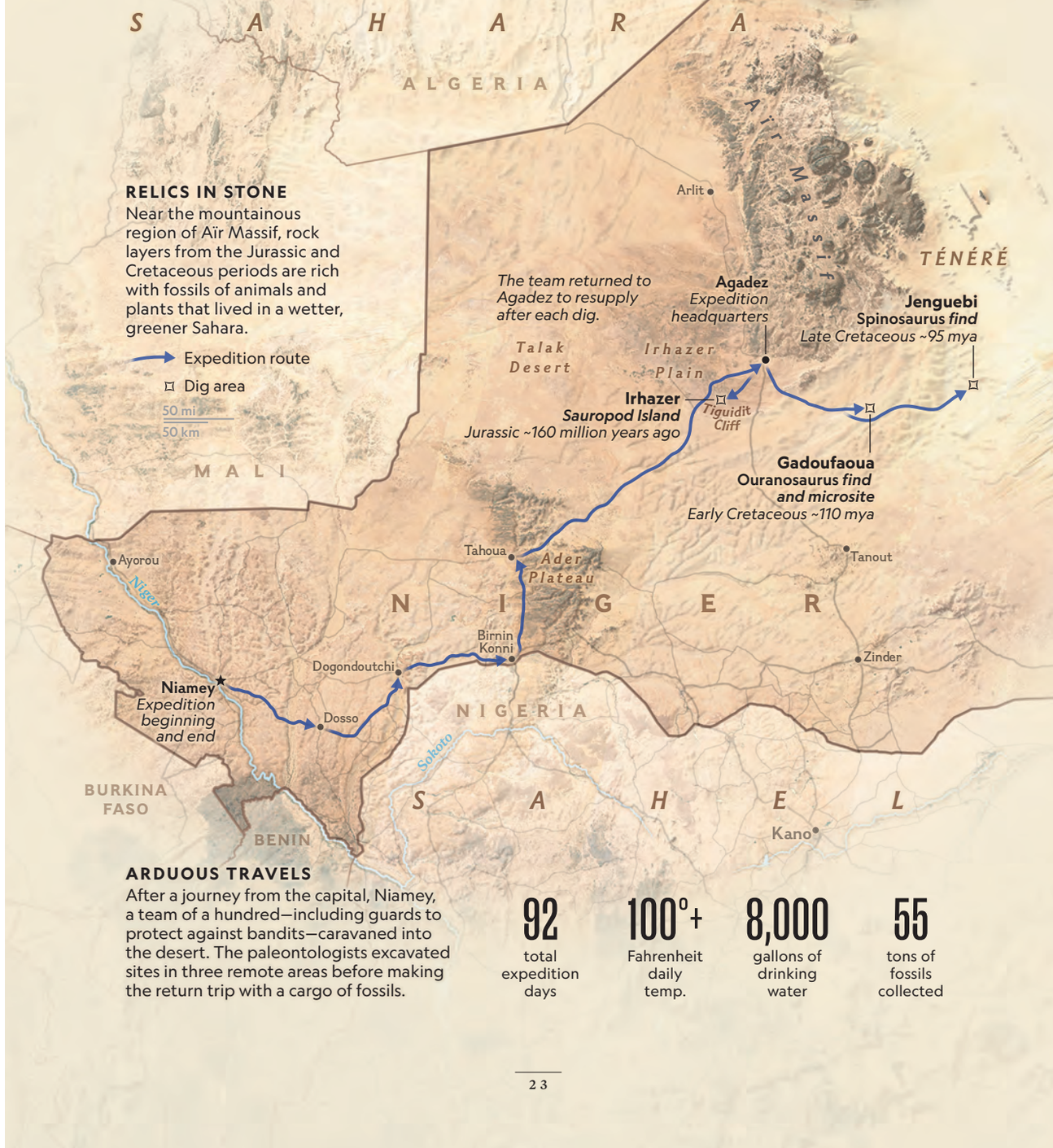
For this expedition, my team fanned out over the rise and quickly made a series of stunning discoveries, encountering four more of these massive creatures, including one whose neck ended with the most cherished of paleo prizes: a skull. All four seemingly belonged to the same yet-unnamed species. We nicknamed it Ipod, shorthand for an Irhazer Plain sauropod. The elevated fossil field, meanwhile, became Sauropod Island.

From the details of its skeleton, I suspected the Ipod dated to the middle Jurassic, some 160 million years ago. But without an ash bed to date it by, this was only a guess. Finding a seam of volcanic ash near a dig site is every paleontologist's dream, since crystals within it can contain

MAP: CHRISTINE FELLENZ AND PATRICIA HEALY, NGM STAFF
SOURCES: PAUL SERENO, UNIVERSITY OF CHICAGO; DANIEL VIDAL, UNED & UNIVERSITY OF CHICAGO

A FORMIDABLE FOSSIL QUEST

Paleontologist Paul Sereno's latest foray into the desert of central Niger covered hundreds of miles on sand-track "roads." The expedition found his team facing extreme heat, logistical puzzles, and security risks while working to retrieve a remarkable number of fossils.



Alexandre Demers-Potvin, then a Ph.D. student at Canada's McGill University, consults a site map that Sereno made by hand upon first discovering this skeleton in 2018. The fossil remained covered for years, awaiting the team's return.

datable radioactive isotopes. I'd had my eyes out for ash beds on previous expeditions, but like every Saharan explorer before me, I'd come up dry. This time, however, I brought along one of the world's great time tellers, MIT research scientist and isotope whiz Jahan Ramezani.

Jahan's big discovery came by accident, after a rock punctured a tire on one of our battered Land Rovers not far from Sauropod Island. As a few of us set about the repair, he scrambled up the side of a nearby cliff. Soon, Jahan was calling my name, and I found him poking at a greenish clay—an indicator of ancient volcanism, to his expert eye. Would that clay contain the crystals we'd need to date our fossils? Jahan smiled at me confidently. "I'll bet my career on this one," he said.

Finding bones at Sauropod Island was the easy part. The challenge was whether we could collect all we saw in the three weeks we could devote to the site. Most of my team doubted it was possible.

Thirty years ago it likely wouldn't have been, but our tools have come a long way. Some of what we bring to the Sahara today still resembles the equipment and supplies from my first foray in 1993. We still use plaster, burlap, and wood to cocoon fossils in portable field jackets. Our Land Rovers are trusty survivors of past treks. We still get by on packets of dehydrated food—although these days, adding boiling water to a package labeled "lasagna" yields something closer to the real deal.

But new gear and technologies have dramatically transformed both the speed of excavation and the imaging of fossils as they emerge. Drill breakers powered by lithium batteries have largely replaced chisels and rock hammers.

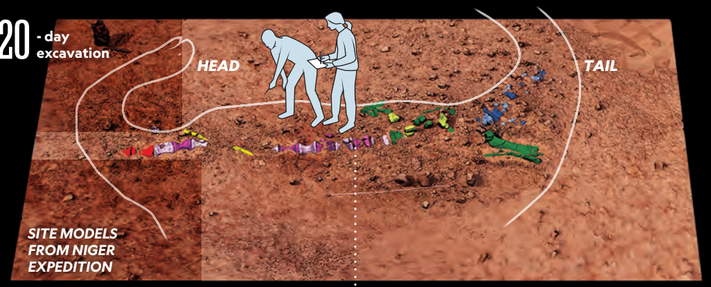
Working under floodlights after dark relieved the crew from oppressive daytime heat. It also lengthened workdays, permitting excavation, in less than three months, of three different areas separated by forbidding stretches of desert.

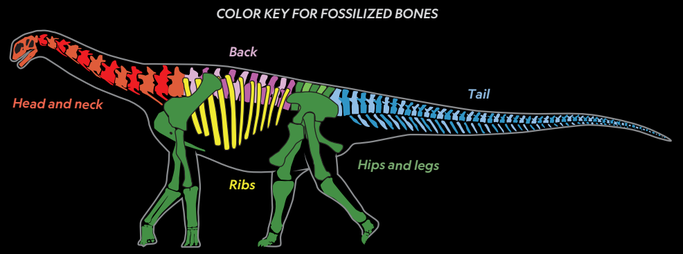
MAPPING DINOS IN THE DESERT

For decades, the standard means of documenting a dig site required patient field drawing and laborious measurement. Now photogrammetry can accomplish in minutes what otherwise takes days (and in 3D).

DIGITAL SITE MODELING

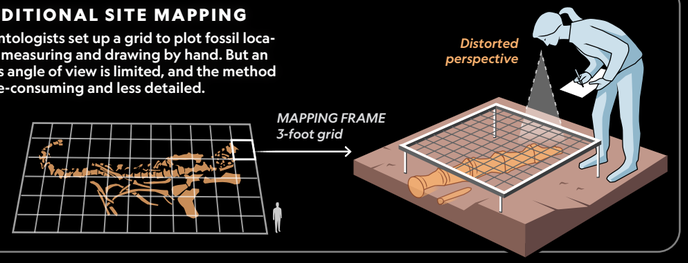
In Niger, Sereno and his team relied on tools that stitch together photos to make spatially accurate 3D site models. Less manual mapping meant more time for digging.





TRADITIONAL SITE MAPPING

Paleontologists set up a grid to plot fossil locations, measuring and drawing by hand. But an artist's angle of view is limited, and the method is time-consuming and less detailed.

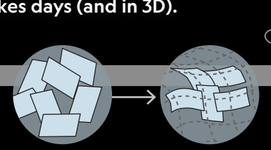


1. DISCOVERY Day 1

The team found fossils on a prior trip to the Irhazer Plain, preserving them from erosion with a plaster cap. In 2022, they returned to excavate the mysterious animals.

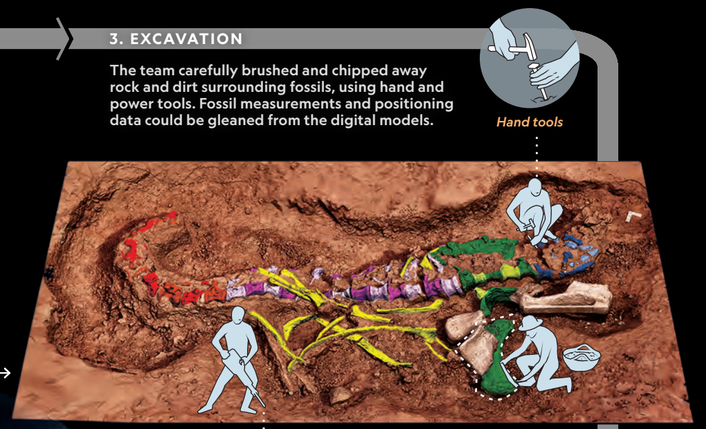
2. MAPPING WITH PHOTOS

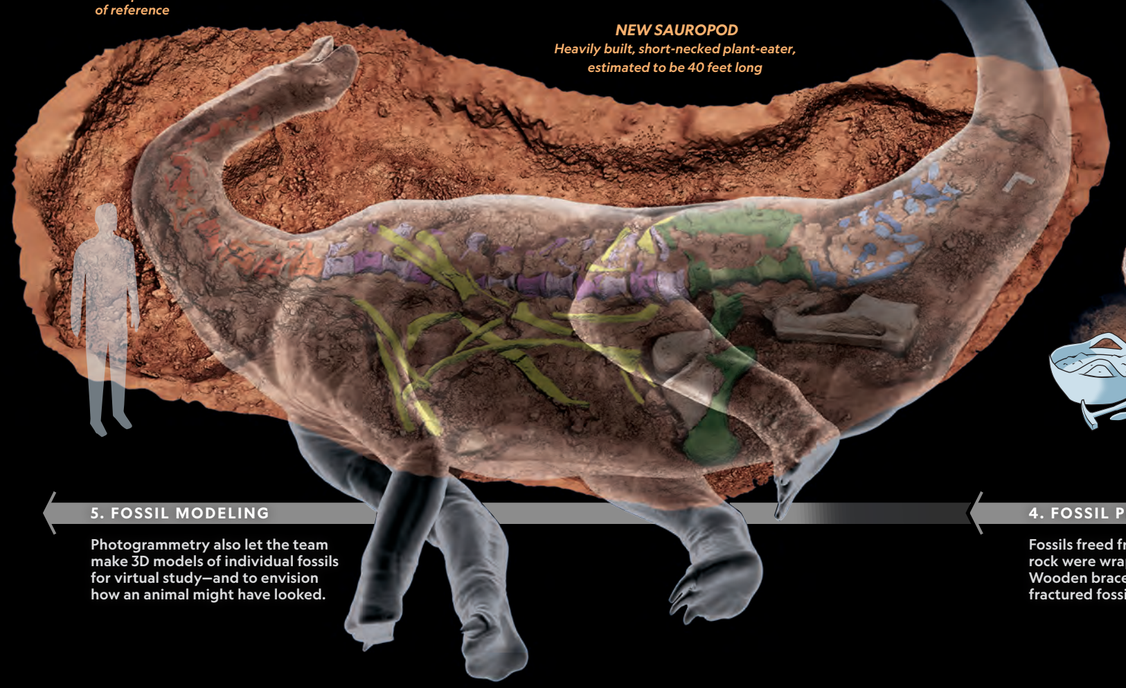
Hundreds of photos from drones and handheld cameras recorded the excavation's progress. Anchor points common to the images allowed photogrammetry software to connect them.



3. EXCAVATION

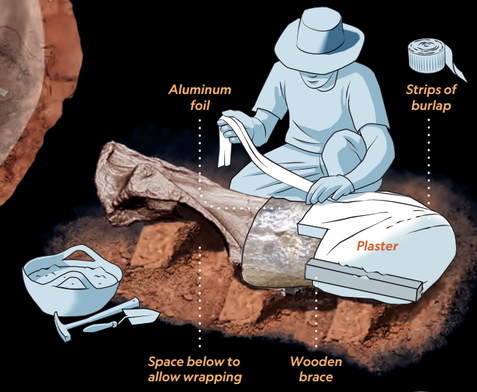
The team carefully brushed and chipped away rock and dirt surrounding fossils, using hand and power tools. Fossil measurements and positioning data could be gleaned from the digital models.





PREPARING THE BONES FOR TRANSPORT

Day 12



4. FOSSIL PREPARATION Day 20

Fossils freed from most of their surrounding rock were wrapped in casts, called jackets. Wooden braces helped protect brittle or fractured fossils during transport.

5. FOSSIL MODELING

Photogrammetry also let the team make 3D models of individual fossils for virtual study—and to envision how an animal might have looked.

GRAPHIC: FERNANDO G. BAPTISTA, PATRICIA HEALY, AND LUCAS PETRIN, NGM STAFF. 3D RENDERS BY DANIEL VIDAL
SOURCES: PAUL SERENO, UNIVERSITY OF CHICAGO; DANIEL VIDAL, UNED & UNIVERSITY OF CHICAGO

Lightweight electric jackhammers have replaced picks. GPS and digital imaging technology have replaced hand-drawn maps, while drones and photogrammetry can generate 3D images in minutes, on scales that range from sprawling dig sites to individual bones. At Sauropod Island, a drone flying overhead captured the entire scene, our tracks weaving between skeletons like ant trails.

I wouldn't say modern equipment makes the work easy, but it does make the job safer and more efficient. Together with good old-fashioned sweat and 15-hour days, it helped our efforts pay off. When we pulled away from Sauropod Island, triumphant and exhilarated, our trucks strained under a load of some 25 tons of fossils.

EVEN MORE REMOTE country awaited us at a site called Gadoufaoua, said to mean "place where camels fear to tread." It is Africa's most famously fossil-rich area, in the heart of the Sahara's hyperarid Ténéré region, a desert within a desert. Although I've never felt so much as a drop of rain in Gadoufaoua, my team made a fossil discovery there years ago that's a reminder of how much wetter the area once was. It wasn't a dinosaur at all but rather history's largest dinosaur-eating crocodilian, *Sarcosuchus*. We took to calling it "SuperCroc," a nickname that has stuck in the media.

We left from Agadez, where we deposited fossils between digs. In front of us, a roadless expanse of rock gave way to a majestic but daunting dunescape, unfolding as far as the eye or drone could see. Experienced local guides are essential in such terrain, where sinkholes of unexpectedly soft sand can mire vehicles driven by even veteran Saharan hands. Our large dump truck, loaded with 1,000-liter tanks of water, was prone to sinking. Digging it out became a familiar routine, extending what could be a single day's journey to Gadoufaoua into three.

You know you've arrived at Gadoufaoua when you see the fossil bones, tinged red with iron, scattered in every direction among low rocky ridges. We were looking for species that lived alongside SuperCroc, in the early Cretaceous, some 110 million years ago. Out first target was *Ouranosaurus,* a 30-foot-long, sail-backed herbivore. My team had encountered one years before and had covered it, to protect it from wind erosion, until we could someday return. We found it again before long, a gorgeous row of planklike bones as tall as a human and arranged in an array, like a peacock's fantail. It was the first intact bony dinosaur sail ever discovered, and studying it will help solve the mystery of what biological purposes these protrusions served.

To make up for our initial delay in Agadez, we worked deep into the night excavating *Ouranosaurus,* relying on generator-powered lamps. Although the work was exhausting, round-the-clock excavation has its perks in the heart of the Sahara. Nighttime temperatures plummeted to half the day's 125-degree high. Insects attracted by our bizarre desert light show retired before midnight. All told, we would pack out two tons of *Ouranosaurus* fossils in just three days.

Gadoufaoua hides its secrets under drifting, shifting sand: You might walk right past a hidden skull one year only to spot it the next. On an earlier visit, we had discovered a patiolike stretch of exposed sandstone that was packed, to a jaw-dropping degree, with the embedded bones of raptors, turtles, fish, and more—what paleontologists call a microsite. As I returned to Gadoufaoua, among the foremost questions on my mind was whether the microsite would be buried under deep sand, and if it wasn't, how we might carve it up and collect it.

I held my breath as I neared the spot and saw a towering dune. But miraculously, just yards away from it, the microsite was exposed. And soon it was surrounded by awestruck paleontologists on their hands and knees, marveling at the sandstone-bound menagerie. We used a rock saw with the largest diamond-covered blade we could find to slice down, about six inches, into the bone patio, hoping to cut it into bricks we could carry out in our usual field jackets. But would the slabs separate cleanly?

When the first one did, with little more than the tap of a chisel, my team whooped. I felt like Michelangelo at first, then like Darwin aboard the H.M.S. *Beagle,* knowing a million bones of unknown species were ours for the collecting.

Painstakingly removing rock or sediment from around fossil treasures like these might require years of lab time. But there at Gadoufaoua, one of my team members submerged a block from the microsite in water, and we discovered to our amazement that the sandstone matrix softened instantly—meaning this trove could be freed with minimal effort back at the Fossil Lab. The thrill of that realization helped power us through six long days transforming the bone patio into 10 tons of jacketed slabs.

When the slab came loose with little more than the tap of a chisel, my team whooped. I felt like Michelangelo at first, then like Darwin aboard the H.M.S. *Beagle*.

Top left: Spanish paleontologist Noelia Sánchez Fontela peers at sediment with a loupe at a site called Gadoufaoua, where exposed rock dates to the early Cretaceous.

Bottom left: This fossilized ungual, or claw bone, once belonged to a sauropod on the Irhazer Plain. When the dinosaur was alive, in the Jurassic period, a claw as big as this fossil would have protruded from the bone.

Top right: Labels on fragments of one of a sauropod's trunk (or dorsal) ribs will aid reassembly. Prepping fossils to ship to Sereno's lab in Chicago required diligent logging and packaging.

Bottom right: A logo on one of the team's Land Rovers dates to the first Saharan expedition that Sereno led, in 1993. Fifteen vehicles made up the caravan during the most recent Niger mission.

Grace Kinney-Broderick, then a field assistant and fossil preparator in Sereno's University of Chicago Fossil Lab, brushes off a sauropod tailbone while members of the team's security detail look on. Truck-mounted guns were a precaution against bandits.

WE HEADED TO our final site with only two weeks left in the field, feeling the pressure. Three years before, we'd come to this place, some 120 miles east of Agadez, after investigating a passage I'd read in a 1950s monograph. Its author, French geologist Hughes Faure, described an isolated site where he had found saber-shaped teeth, like those of the *T. rex*-esque Egyptian predator *Carcharodontosaurus*. With some effort, we had found his site and, along with it, plenty more teeth, confirming Faure's understanding of the beds as late Cretaceous, some 95 million years old.

While team members Jahan Ramezani (at left) and Vincent Reneleau handle lunch dishes, Sereno finds a patch of elusive shade alongside the kitchen tent.

We might have left with nothing more than teeth if not for a serendipitous visitor to our camp. He wore a black trench coat, *cheche* head wrap, and sunglasses, with a Tuareg sword slung over his shoulder. His name was Abdul Nasser, and he offered to take us to a bigger bone field. As he led us deep into one of the Sahara's great ergs, or sand seas, over and between dunes, our Land Rover struggled to keep pace with his Honda motorbike. It was feeling like a fool's errand until Abdul pulled up alongside a thigh bone as long as I am tall. It clearly belonged to a skeleton; in every direction, there was more bone.

With little daylight and fuel, we were able only to note the GPS coordinates of the place, called Jenguebi, and grab a few jaw pieces we assumed were from *Carcharodontosaurus*. But assembling the jaw back in Chicago, I realized the teeth and tooth sockets were all wrong. They belonged instead to the sail-backed predator *Spinosaurus*. It was the first record of one of these water-loving beasts found so far inland—and I suspected it was a new species.

Our return trip to Jenguebi took us back across the erg. We hopscotched among rocky areas, each smaller than the last, as we traveled deeper into it. We set up camp near where we found the jaw pieces, and we'd been there no more than an hour when my colleague Dan Vidal, a seasoned paleontologist from Spain, came running toward me, eyes gleaming.

"It's here!" he said. "The skull!"

I found much of my team gathered around a toothy snout jutting up from the rock. These were the first *Spinosaurus* remains found in place in more than a century. My colleagues stood, mesmerized, as the significance of the find sank in. Some even wept. A few hours later, Dan found me again. This time he held an unfamiliar, boomerang-shaped bone. It was a head crest, we realized, but a strange one, projecting upward to a degree never seen in predatory dinosaurs. And where the crest of an Egyptian *Spinosaurus* is a ridge, this one was shaped like a scimitar.

On coals made from kindling, the team's Tuareg guides boiled water for tea in the evenings. Knowledgeable local guides were key to the expedition's success.

While the team excavated the skull, Dan, our

Veteran fossil hunter Agali Bazo, curator of a small natural history museum in the oasis town of Ingall, visits the site that the team nicknamed Sauropod Island.

photogrammetry expert, documented the emerging skeleton with digital photos—a much faster process than in my early career, when we'd have photographed a few key fossils and I'd have stood over others, doing shaded drawings. That evening, on a laptop in the tent, he presented us with a 3D image, made from the stitched-together photos, of the skull of our new tall-crested *Spinosaurus*. The team was awestruck.

It wasn't our last spectacular find at Jenguebi. A few days later, an 11-year-old boy from a Tuareg family camped nearby offered to show us fossils he'd seen while wandering with his goats. Navigating complex terrain he knew by heart, he led us to site after site, some with little more than a lonely bone fragment. At the last site, however, was an impressive set of bones and teeth. The latter's saber-like shape left no doubt we had found Africa's first partial skeleton of a carcharodontosaurid. After cleaning and assembly, it will provide a first ever look at Africa's line of these colossal predators.

We returned to Agadez haggard, dirty, and triumphant, with fossils filling two 40-foot containers. On a truck scale, the results of our efforts weighed in at 55 tons, twice what many of us had estimated. I, meanwhile, was 32 pounds lighter. I was also elated, leaving Niger for Chicago and knowing that, in a matter of months, our fossils would soon make the same trip.

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Then one last hurdle arose, suddenly and unexpectedly, a few months after our return. A military coup toppled the elected government of Niger, putting the shipment of the fossils on hold.

FOR NEARLY TWO YEARS, the fossils from our expedition remained in limbo. Then this spring, I traveled to Niamey, Niger's capital, where I signed an agreement that will at last bring the fossils to Chicago. It also provides for their staged repatriation, and it establishes a blueprint to develop two new Nigerien museums to house them, along with an institute to train the country's next generation of museologists, archaeologists, and paleontologists. These initiatives will be overseen by NigerHeritage, a foundation I established in 2016.

I first came to Niger for its fossils, for high adventure, and for the stark beauty of its landscapes and sunsets. But I've returned again and again because of my deeper motivations as a paleontologist—because I know that the significance of my work isn't ultimately measured in new species but by the impact those discoveries can have on the future of a nation.

On the eve of our expedition, I had goaded my young team members by telling them this would be their chance to write a new chapter in Earth's history, something they'd have few opportunities to do in a lifetime. We now have troves of images, video, and data from the field, and we have presented findings to conferences and journals, including a paper on the remarkable tall-crested *Spinosaurus* species. Soon we will have the bones for close study, along with geologic samples to reveal their age. Next will come an outpouring of discoveries related to the *Carcharodontosaurus*, a dozen new sauropods, a digging raptor, an armorless croc, a giant "SuperFish," and other new species. We are poised to write that chapter, introducing others to Africa's lost dinosaur worlds, daring them to imagine what still lies beneath the surface. ▯