THE DESERT THAT WAS AN OCEAN

An ancient bone bed in the Nevada desert holds clues to the West's past — and the Earth's evolutionary puzzle FEATURE BY HILLARY ROSNER

Route 50 across Nevada has long been dubbed "the Loneliest Road in America." But turn off it onto Nevada 361 at Middlegate — population 17 and the only gas for dozens of miles — and 50's near-empty asphalt seems congested by comparison. Here in the back of the back of beyond, cruising past salt flats and lava tubes and mountains cut like sand castles, you might even imagine you're the last human on Earth. Or perhaps the first. Against this otherworldly scenery, it isn't hard to conjure a landscape long before humans arrived.

About an hour southeast of Middlegate lies the entrance to Berlin-Ichthyosaur State Park. Rising from the desert's unpeopled quiet is the ghost town of Berlin, where a blacksmith's shop, an assay office and some tumbledown miners' cabins stand as shaky monuments to a gold-and-silver strike in the early 1900s, and to the lives of those who worked it. A bit farther down the dusty road is a monument to another kind of vanished life, a boneyard from a time not just before humans, but before dinosaurs — 150 million years before *T. Rex*.

Poking out from a hilltop protected by a barn-like structure and scattered among rocks and scree on miles of nearby slopes are the fossilized remains of ichthyosaurs — giant marine reptiles that terrorized Earth's bygone seas.

These bones belong to the species *Shonisaurus popularis*, a sort of super-sized dolphin with paddle-like front limbs and a long tail ending in a fin. Among the largest of the ichthyosaurs, *S. popularis* could reach 40 feet in length, with a 10-foot-long skull, and may have weighed as much as 40 tons. (Mass is notoriously difficult to estimate for extinct creatures, particularly those with no living analog.) Though reptilian, it gave birth to live young in the water.

Discovered in 1928 and partially excavated beginning in the 1950s, these fossils keep an ancient secret — one that Neil Kelley and Nicholas Pyenson are determined to uncover. The two Smithsonian National Museum paleontologists have assembled traditional and high-tech tools, along with a team hailing from three separate institutions. "Something happened here," says Pyenson, 35, Smithsonian's curator of fossil marine mammals. "Is this a graveyard? Is this a murder site? We're trying to figure that out."

The mineralized bones of these animals may also help shed light on a deeper mystery: one that involves their species' origins and the evolutionary forces exerted by our planet's oceans. Throughout Earth's history, all manner of land-dwelling creatures have essentially walked into the sea and transformed, over eons, into something entirely new. *Shonisaurus* — descended from a reptile that walked on land — is among them. What might its skeletons add to the story of life on Earth?

To reconstruct a plausible plot with no witnesses and only spotty evidence, the team must get creative in its investigative tactics. Vertebrate fossils, after all, aren't straightforward research subjects "like pressed plants or microscope slides," says Pyenson. Chasing truth in a pile of timeworn bones demands patience, persistence, and a constant balancing dance between imagination and doubt.

Please see **Fossils**, *page 16*

"Something happened here. Is this a graveyard? Is this a murder site? We're trying to figure that out."

—Nicholas Pyenson, Smithsonian's curator of fossil marine mammals

A ball cap featuring a prehistoric ichthyosaur rests on the dash of a truck on Route 50 in Nevada, near Berlin-Ichthyosaur State Park.
COURTESY NICHOLAS PYENSON/SMITHSONIAN

A team from the Smithsonian Institution's National Museum of Natural History works at Berlin-Ichthyosaur State Park in Nevada, where they're using 3-D imaging to help study fossils found in the prehistoric sea bed.
COURTESY NEIL KELLEY/ SMITHSONIAN

About 250 million years ago, Earth was rocked by the Permian-Triassic extinction. Roughly 90 percent of marine species disappeared. Ichthyosaurs appear 7 million years later.

Fossils, *continued from page 13*

ON A WARM, CLOUDLESS MORNING, Kelley and Pyenson scout the main excavated quarry. An 80-foot-wide slice of rock, now set up as a sort of museum, cradles a smorgasbord of fossils, including some near-complete ichthyosaurs. Dozens of vertebrae, each several inches thick and nearly a foot in diameter, lie alongside scores of rib bones stacked in the rock like fence slats. Jaw fragments show indentations from the reptiles' inch-wide teeth.

It's Pyenson's first time here, and he consults a preliminary digital map the team made last summer. He's dressed in a striped Oxford shirt, orange pants, Chacos, and a baseball cap advertising Great Basin Brewing Company's Ichthyosaur IPA — a nod to Nevada's state fossil. Kelley, a 34-year-old postdoctoral researcher at the Smithsonian and an expert in extinct marine reptiles, wears a T-shirt promoting Built to Spill — an indy rock band — Chacos to match Pyenson's, and a "Yo! MTV Raps" trucker hat. With their identical shoes and scruffy facial hair, the boyish-looking scientists could be paleontology's answer to the Hardy Boys.

And indeed, they've taken on an ambitious case. Earlier this year, Kelley and Pyenson published a paper in the journal *Science*, laying out an expansive research agenda: to explore how top predators in the ocean have changed through the ages, reshaping entire ecosystems. About 250 million years ago, Earth was rocked by the Permian-Triassic extinction — the largest in planetary history. Roughly 90 percent of marine species disappeared. "After that event, ecosystems are built from the ground up," Kelley says. "Everything changes. Things that build reefs change, shellfish change, fish change." It's the first time there's evidence of land reptiles returning to the oceans and thriving; ichthyosaurs appear 7 million years later.

Shonisaurus was the biggest vertebrate yet to take to the water. And ever since, "big predators are continually diving in from land," Pyenson says. "All these big, iconic, beloved critters — whales, dolphins, sea otters, polar bears. Every time it happens, the whole structure of food webs accommodates these great predators, and they have an influence that's disproportionate to their abundance."

Even *Shonisaurus*' form is one that reappears throughout time, says Pyenson: those paddle-shaped forelimbs, for example, and a streamlined body ideal for efficient movement underwater. "When we see that happen in reptiles, and then much later in marine mammals," he says, "it tells us something really important about how evolution works." The demands of the marine environment yield the same structures in completely different creatures. Today's apex ocean predators are simply the most recent rendition of a song that Earth has been singing for a quarter-billion years.

Berlin-Ichthyosaur offers a snippet — a brief crescendo, like a passage from the planet's unfolding ecological score — that will help Pyenson and Kelley illuminate how evolution progresses on a grand scale. Scientists call it "macroevolution," the natural world's version of macroeconomics: a scaled-up picture that explains broad patterns at play over eons.

But first Kelly and Pyenson need to figure out some more basic things, such as just how deep the ocean here was. Charles Camp, the University of California-Berkeley paleontologist who studied and excavated the site for more than a decade beginning in 1954, believed the ichthyosaurs died after stranding on the shores of a giant inland sea. In a slim, trippy volume called *Child of the Rocks*, published in 1981 by the Nevada Bureau of Mines and Geology, Camp imagined what "pioneer astronauts" from a distant planet might have seen had they touched down here roughly 220 million years ago. Standing at the "edge of the muddy tide-flats," he wrote, the visitors would have come upon the stinking carcasses of dead ichthyosaurs "lined up like logs along the shore, and rotting in the sun.

> *One of the carcasses may have seemed fresh as if it had come in on the last tide. Its skin, smooth, only slightly lined and crinkled, would have glistened in the sun. The great head, with its long tapering snout partly embedded in the mud, lay twisted around alongside the body. Rows of pointed and fluted teeth ranged down the sides of its long upper and lower jaws. The monstrous eye, glazed in death, was a foot across, while the body, eight feet thick, lay like a half inflated balloon.*

Camp used his vivid imagination to reconstruct the tragic and compelling scene of one reptile's demise. The poor creature, he wrote, was "churning the water into a froth with his lashing tail and puffing out air from his lungs in great agonized gasps." But there's one crucial problem: Back then, the site was almost certainly much deeper underwater; it wasn't a tideflat.

"There's no beach sand in these rocks," explains Kelley. "These are fine-grained mud rocks that you typically get in deep-water sediments." Jennifer Hogler, a paleontologist who studied the site in the 1980s and 1990s for her doctoral research at UC-Berkeley, concluded there was no evidence for the idea that *Shonisaurus popularis* "frequented intertidal waters or was prone to stranding."

Carefully stepping among the *Shonisaurus* bones, Kelley deals another blow to Camp's theory. The skeletons, he says, look to be belly-up.

Pyenson is intrigued. "Cool!" he responds.

Beached creatures, such as modern whales, usually end up on their bellies. The ichthyosaurs' orientation suggests that they were already dead when they hit the sea floor.

"Unless they were rolled," says Kelley.

"They could be rolled," admits Pyenson.

Asking whether the animals floated or sank or stranded is useful, says Pyenson, "because what we are really asking, whether it be fossil whales or ichthyosaurs, is the process of what happens between death and discovery." That process has spawned a science all its own, called taphonomy — the study of the dead. As biological evidence becomes locked in stone, key information vanishes. Reconstructing that data from other sources is how we ultimately tell the story of lost worlds.

Here, the skeletons' orientation may point to something profound, or it may ultimately prove nothing more than "the physics of centers of gravity," Pyenson says. Where clues are scarce, you gather all you can.

GATHERING THE *LARGEST* CLUES, however — the skeletons of 40-ton animals — is an unwieldy process at best. You can't pick up a giant skull with calipers. "Anything bigger than what you can hold in your hand means that you can't see everything in one glimpse," explains Pyenson, "which has the effect of really limiting your understanding." But Kelley and Pyenson have found a hack: 3-D imaging, or photogrammetry, a relatively new technique for paleontology, which, Pyenson says, lets them "search for patterns that cut through the random vagaries of what taphonomy leaves for us to find." A few years ago, for example, when workers building a new section of the Pan-American Highway in Chile's Atacama Desert exposed a bed of fossilized marine animal bones from roughly 6 to 10 million years ago, Pyenson and his colleagues raced to the scene armed with equipment that would preserve a virtual copy of the excavated site. Time was short: In just two weeks, construction would destroy more than 40 complete or partial skeletons — extinct varieties of whales and other marine animals, includ-

At the Smithsonian's National Museum of Natural History, Nick Pyenson, Randall Irmis and Neil Kelley compare fossils with 3-D prints and images of extinct marine predators to understand the fossil reptiles found at Berlin-Ichthyosaur State Park in Nevada. OLIVIER DOULIERY

ing an aquatic sloth.

The scientists combed the area for clues — in the boneyard, in the rock, in the surrounding landscape. "We were searching for a single good explanation," Pyenson says, "for why we had the cast of characters and the condition they were in." The skeletons, perfectly preserved, lay just meters from one another, piled in four layers that each represented roughly 10,000 years of history. By building 3-D digital models, the scientists were able to observe the skeletons from angles impossible in the real world. "These views gave us the luxury to see every nook, cranny and overhang, and really understand how different bones, and the tangled skeletons of different individuals, were positioned relative to each other," Pyenson says.

The team ultimately concluded that the killer was a toxic algae bloom: a red tide, like those implicated in the recent deaths of Florida's manatees and bottlenose dolphins. Iron eroding from the rocks of the Andes could have caused it. The whales and other animals would have eaten prey contaminated with the poisonous algae, died within hours, and washed up onto the flat sands of an estuary. Over millennia, the scenario was repeated, and the bones became buried in the mud.

Along with the imaging technology, an understanding of macroevolution helped solve the mystery. Throughout history, four-legged animals that return to the water dive in at the top of the food chain. That makes them susceptible to things like toxic algae, whose effects can be magnified the higher up the chain you go.

Pyenson hopes Berlin-Ichthyosaur will ultimately prove as scrutable as the whale bone bed. Inside the Ichthyosaur shelter one morning, Holly Little, Smithsonian's "paleoinformatics specialist," prepares the eons-old fossils for their 21st-century moment, carefully sweeping away dust with brooms and brushes. Meanwhile, Jon Blundell readies a series of cameras and laser scanners, mounted on tripods that he'll carry around the site. The lasers capture millions of data points that essentially describe the surface of the objects with sub-millimeter accuracy; photogrammetry uses algorithms to combine exhaustive, overlapping digital images into a high-resolution 3-D model. The result can be easily manipulated and examined on a computer, aiding the hunt for clues. Blundell, who describes his background as "nerd," has also helped make other 3-D scanned models, including an image of President Obama, and — as part of an ongoing project — a replica of the space shuttle *Discovery*.

In addition to making massive objects easier to examine, digital 3-D models can bring fossilized bones and other rare objects to a wider audience, allowing researchers around the world swifter and longer access. Bones from fossil digs too often end up virtually reburied in museum basements. Many of the *Shonisaurus* bones that Camp excavated from Berlin-Ichthyosaur still lurk in cartons at the Nevada State Museum. "A few paddles are on display, but then there are boxes full of wrapped-up bones sitting undisturbed," Pyenson laments. Who knows what mysteries might be solved if more eyes could scrutinize those bones?

POWERFUL AS NEW TECHNOLOGY can be, paleontology still relies on tools that would have been familiar to Berlin's miners. Outside the fossil shelter, under a sun growing fiercer by the hour, Randall Irmis supervises a sort of geological scavenger hunt. He's building yet another bridge to the past, this one using information gleaned from the rock record. With picks and shovels, Irmis and his team dig a trench up a hillside — surveying the rock at different levels, above and below the quarry, measuring its layers and taking home samples to test for concentrations of isotopes, or different forms of chemical elements. That will help determine how the bone beds formed. "It's pretty low-tech," says Irmis, a 33-year-old paleontologist at the University of Utah and the Natural History Museum of Utah who has been involved in the discovery of a half-dozen extinct reptile species. He and Pyenson were housemates during grad school at UC-Berkeley.

In addition to containing clues about ichthyosaurs, the dirt and stone at this site can help tell the broader story of Nevada's prehistoric past — the movements of its land and water as well as their inhabitants. The region's famous "basin and range" topography consists of mountain ranges of very old rocks separated by valleys of very young rocks. It's caused by plate tectonics. "Forty million years ago, Nevada was half the width it is today," Irmis says. "It's been pulled apart to almost twice its original width just in the last 30 million years." The Pacific plate used to move underneath the North American plate. But now it moves side to side — a switch that put extreme tension on the western side of North America, pulling it apart "like a Snickers bar," as Kelley says, and leaving chunks of rock separated by thinner layers. Nevada's mountain ranges reveal the layers of many eras of the deep past — timelines of geologic history scrawled across the region's stark scenery.

The geological slices found at Berlin might help explain how these particular ichthyosaurs died, or how they ended up preserved as fossils rather than decomposing like most corpses, their mineral components recycled to the sea. Or they might offer answers to questions we haven't yet asked.

But visualizing long stretches of change over time, across a physical landscape, is a tricky endeavor. Pyenson calls it "the mind-fuck of geology." To imagine what the area around Berlin looked like during the age of the ichthyosaurs, you need to time travel back to a very different planet. The Mesozoic era lasted from 248 million to 65 million years ago. Trying to fathom that timespan is daunting, and the familiar trick of picturing Earth's 4.6-billion-year history as if it's 24 hours on a clock seems unhelpful: It minimizes the scale, and therefore the scope, of our awe. "To grasp the face of evolution, we don't need to speed up the film, we need to slow it down," marine biologist Richard Ellis writes in his book *Sea Dragons*. "We must not be misled by the idea that a million years is a mere blink of the eye." One million years is a long, long time. Ichthyosaurs roamed the planet's oceans for roughly *150 million* years. The fossil record of whales, by comparison, is only about 50 million years old.

Sitting around the campfire one evening, I mentally strip this spot of its contemporary features: first the SUVs, picnic tables and composting toilets, and then the piñon pines, sagebrush and Mormon tea plants. I erase the biting red ants underfoot and the scorpions scurrying in the shadows. I try to ignore the constellation of REI tents on the desert floor and instead focus on the dazzlingly starry sky above — though even this would have looked different to the ichthyosaurs.

In a camp chair beside the rising smoke, Irmis — another boyish-looking scientist with scruffy facial hair and a baseball cap — tells me that the trench revealed layers of limestone interspersed with the layers of mud that Kelley described earlier. "You think about an

At the Natural History Museum of Utah, Fred Lacy cleans part of a fossilized humerus bone of a *Shonisaurus*, top, that was found during a dig at Berlin-Ichthyosaur State Park. Above, the museum's paleontology curator, Randy Irmis, holds a fossilized *Shonisaurus* tooth. KIM RAFF

Paleontologists from the Smithsonian, University of Utah and University of Nevada in one of the quarries in Berlin-Ichthyosaur State Park in Nevada, where scientists believe hundreds of the prehistoric reptiles may be buried.
COURTESY NEIL KELLEY/ SMITHSONIAN

> **"You want to look out for the *Shonisaurs*. You're a little snack for them."**
>
> *—Paleontologist Randall Irmis, imagining what life would have been like in a Triassic era sea*

ocean environment; it's got to be fairly quiet to get mud deposited, but it's got to be warm enough and fairly close to the surface to get calcium carbonate." Back in the Triassic, when *Shonisaurus popularis* crammed the seas of the American West, eastern Nevada would have formed its coastline. Despite a distance of 200 miles to land, Irmis says, the ocean here was relatively shallow, maybe a few hundred feet deep.

The sea Irmis is describing was part of Panthalassa, also called the Proto-Pacific, the "super-ocean" that once surrounded the mono-continent Pangaea. Much of that land mass floated in the Southern Hemisphere — meaning that our fire pit, at roughly 38 degrees latitude, sat in a very different part of the globe. Back in the Triassic, this same spot was at 5 or 6 degrees latitude, in the tropics.

"So we could be floating peacefully in a calm, warm sea," I venture.

"Except for the giant reptiles swimming around you," Kelley says.

"Yeah, you want to look out for the *Shonisaurs*," says Irmis. "You're a little snack for them."

DURING THE YEARS that Charles Camp worked at Berlin-Ichthyosaur, he excavated about a half-dozen quarries. One is the sheltered bone bed; another lies partway up an adjacent slope. But Camp worked before the days of GPS. Though he made meticulous drawings, his directions left much to interpretation. Part of the team's goal is to relocate some of Camp's quarries. They're certain that the fossil trove has barely been touched.

On a search for Quarry 4 one afternoon before I arrived, Cornelia Rasmussen, a doctoral student in Irmis' lab, found a tantalizing piece of jawbone embedded in the rock. A few days later, we set off to take a better look. We scramble several hundred yards up a steep hillside covered in scree, to where the ichthyosaur jaw lies in the shadow of a juniper. It's about 10 inches long, with perfectly preserved indentations from its teeth. The creature's whole jaw might have been three to five feet long. More of its skeleton is likely buried not far beneath the surface, somewhere on this same hill.

Partly to keep from slipping down the slope and partly to dodge the blazing sun for a moment, I crouch in the shade of a piñon. At my feet, a mess of reddish rock shards stretches up and down the hill. "How can you possibly pick out something like a jawbone — or any fossil — when it all looks so similar?" I wonder aloud. No sooner have I uttered the words than I begin to distinguish fossils all around me. I start picking up some of the smaller ones, and soon I have handfuls of bones — bits and pieces of ribs encased in limestone. Paleontologists call these fossils "float" — bones that erosion and weathering have left exposed on the surface rather than buried beneath the soil. But these seemingly trivial rock scraps can be crucial pieces of the prehistoric puzzle. They're the glass shards from a backwards-gazing crystal ball.

Nearby, Paige dePolo, an undergraduate from the University of Nevada, is assembling another pile of float. Pyenson and Matt McCurry, a research fellow from Australia, head toward us, each carrying an armful of fossilized bones. They could belong to the same individual as the skull, or represent additional ichthyosaurs. "The story isn't nine individuals dying," says Pyenson, visibly pleased by the glut of fossils here. "It's hundreds."

Berlin-Ichthyosaur's jawbones in particular intrigue Pyenson. Some contain teeth, and others don't, making him wonder whether *Shonisaurs* lost teeth as they aged and their diets changed. "This is something we see with a lot of big ocean predators," he says. "They go through different ocean niches as they grow."

He and Kelley are also debating the timing of the ichthyosaurs' deaths. How closely together did they happen — over hours? days? weeks? longer? And how long did the bones linger on the ocean floor before they were buried? Partly from studying the digital model of the boneyard, they already have one theory for how some of the bones came to their final resting place. "A good analogy is how the corner of a hockey rink sometimes accumulates clusters of pucks, over the course of time," says Pyenson. "Ichthyosaur vertebrae start off as a wrapped package of pucks on their side, and then slowly unroll, until they collect together again, given enough time." The process is a clue to the oceans: It suggests passive currents making "very organized structures from basic units."

BECAUSE IT'S EASY TO IMAGINE all sorts of crazy scenarios based on strange fossils, paleontologists must remain vigilant about evidence. What does the geology say? What do the bones say? Which explanations make sense based on the evidence, and which are pure speculation? "Complexity is really challenging to keep in your head," Pyenson says, "and then you're always playing this game of, like, 'Is what I'm seeing connecting to what I think is going on in my head, which may just be a fantasy?' "

One such story is in part what propelled the team to Berlin-Ichthyosaur in the first place. A few years ago, a husband-and-wife paleontology team proposed a new theory for the Nevada boneyard: 100-foot-long, hyper-intelligent, narcissistic cephalopods with a taste for ichthyosaur.

"Giant Kraken Lair Discovered," a press release blared shortly after Mark and Dianna McMenamin of Mount Holyoke floated the idea at an annual geologists' meeting in 2011. An article on Livescience.com explained the McMenamins' theory that the "markings and rearrangement of the *S. popularis* bones suggests an octopus-like creature either drowned the ichthyosaurs or broke their necks" before purposefully depositing their vertebrae into a pattern like the suckers on a squid's tentacle. "The researchers," the article said, "suggest this pattern reveals a self-portrait of the mysterious beast."

The evidence for this idea? There isn't any, save for the way the skeletons' arrangements appeared to the two observers. "It is a case of reading the scattered bones as if they were tea leaves able to tell someone's fortune," paleontology blogger Brian Switek wrote on Wired.com.

But though the kraken theory may be more science fiction than science, it invokes a broader truth about our quest for knowledge. Humans are a storytelling species. In science, those stories must be based on evidence. But even when they are, we often get them wrong. New ideas, new theories, new evidence, new techniques — all of these prod us forward, and we modify our understanding as we go.

Scientific inquiry is a process of constant revision. And as any writer will tell you, revision is where the most interesting things surface. Dinosaurs, we once thought, were lumbering, tail-dragging reptiles. Now we've come to believe that they were warm-blooded, carried their tails off the ground, and often came with feathers. Who knows how future discoveries will change the narrative?

Shonisaurus popularis has a real story, a concrete series of events that happened millions of years ago. But to recreate it, we must cast back across vast spans of time, assembling clues from each new lead we unearth. Luckily, technology improves and dirt shifts: There will always be another bone that pokes up from the ground and entices us a little way farther down the path to the truth. □

Hillary Rosner writes about science and the environment for *Wired*, *National Geographic*, *Scientific American* and other publications. She lives in Boulder, Colorado.

This story was funded with reader donations to the High Country News Research Fund.