

SHAKERS OF THE EARTH

Gregory Benford

1988

Squinting against the slicing sunlight, Dwight Raser shouted, "Lift!"

The excavation crew leaned heavily on crowbars. The heavy-duty winch roared, chains clinked and tightened, dust stirred in the desert breeze—and nothing happened. The crew was already tired from a half day of laborious picking away at the dinosaur vertebrae. They grunted and thrust down harder to free the enormous chunk of pale, sandy fossil.

"Careful!" Mito could not help herself crying out. She reached over and touched Dwight's arm, alarm widening her eyes.

Dwight glanced at her, seeming to be more surprised at this touch from a woman who was normally reserved, compact. "That sucker's heavy, but don't you worry. We'll get it—"

Something broke free at the base of the vertebrae and the winch growled louder. It was mounted on the back of a grimy flatbed truck. Mito watched the big black tires fatten as they took the weight.

Dwight had estimated over three thousand pounds. Why did Americans persist in that antiquated system of units? Mito watched the mass lift with excruciating slowness and translated into kilos. Almost fifteen hundred! How could the winch—

It couldn't. A thick steel-blue bar supporting the chains bent abruptly. The crew scattered—except for one young woman, who held on to her crowbar.

Something snapped. The stony vertebrae lurched, dropped. The woman screamed.

Dust settled as she lay sprawled.

The next few minutes were a fevered blur. Shouts. Attempts to free the woman's leg from under the mass. Recriminations. Angry denials. Sweaty tugs at the crowbars.

Dwight said nothing, just walked around the tilted chunk that had come down to them out of a hundred and fifty million years of pressing silence, and thought. Mito watched him closely, and not merely to distract herself from the contorted face of the woman.

Three young men began digging at the hard-packed soil around her calf, but Dwight stopped them. Instead he told the crew to realign the chains. An angle here, oblique tension there, forces vectoring away from the crushed leg—Mito gained fresh respect for the man's quick competence. She was more at home in cool laboratories and had always felt awe for the rough-and-ready elements in science, the rub of the real.

As the crew got ready their faces were drawn, eyes hollow. If the chunk of massive vertebrae slipped again, it could roll.

The woman lay staring blankly up into the piercing winter sun, shock numbing her. She mumbled incoherently. Mito wondered if it was a prayer.

The crew set themselves, digging in. Mito could see wary flickers in their faces as they calculated where they would flee if something went wrong. Following Dwight's gesture, Mito took hold of one of the woman's shoulders and set her feet to pull. Two men also held the woman. They all looked at each other, nodded, said nothing.

"Lift!" Dwight called again.

This time the massive bulk tilted, escorted by crowbars. The grinding labor of the winch swallowed a chorus of grunts.

The sandy chunk rose a centimeter, two, three—Mito pulled. The woman slid free. They dragged her several meters away and she began yelping with pain.

After a jeep had taken the woman away for a long, jouncing journey into San Ysidro, she stood with Dwight and watched the crew beef up the hoist assembly. Nobody suggested knocking off for the day.

"Damn stupid, that," Dwight said. "Some kinda introduction for you, eh?"

"You said yourself that it is not easy to estimate the weight of such segments," Mito said.

"Well, I screwed that one up pretty bad." He scuffed at the dust. "This baby's sure bigger than that 'Ulltrasaurus' Jim Jensen's been talking about. He found a spine of one a few years ago. They didn't get anybody hurt, though."

The skeleton was mostly uncovered now. The deep trench curved along the brow of a worn sandstone bluff. Dwight's terse report had said it was 140 feet long, bigger than *Diplodocus*, bigger even than the largest of the plant-eaters, *Brachiosaurus*.

Mito said, "A set of vertebrae so massive can easily—"

"Two-inch cold rolled steel, too; just gave way."

"Do not blame yourself. That woman was slow." Her voice must have given away the depth of her feeling, for Dwight turned and looked at her with surprise, something fresh coming into his face.

"Thanks for sayin' so," he said quietly. "But it's my fault."

She saw then that beneath the gruff manner he was tired and sad and yet undaunted. "My dad, he used to say being fast on your feet was one talent nobody could teach you. Maybe so."

A moment passed between them which she was to remember to the end. A crinkling of his eyes, a wryly sour smile tugging at the corners of his mouth. Brooding, assessing blue eyes. She breathed shallowly, as if not to disturb the currents that brushed between them. She had found Americans confusing, but this man held a kind of limpid mystery.

She had always been drawn to puzzles, and a man like this was doubly odd. A westerner in both senses of the word, cowboy/scientist, walnut-brown from years of scouring the rocky wastes, yet also known for his precise, meticulous excavations of great fossils.

He had made this remarkable find by dragging an 8-gauge shotgun through these ranges on a wheeled cart. It fired a slug of soft metal into the ground. The slug flattened and sent out a pulse of sound waves.

An array of microphones lowered down a drilled hole picked up the waves. A computer unfurled their signals into a three-dimensional picture of the sandstone beneath. Sound sped through bone faster than through stone, and the difference in arrival time cast a sharp sound-shadow. Oak Ridge had developed the shotgun technique to find old sites where drums of radioactive waste had been buried. Dinosaur bones were about the same size, and paleontologists had seized upon this happy accident to extend their grasp.

“This sucker’s gotta be ten EEU’s, easy,” he said.

“Uh . . . EEU?”

“Oh, sorry. Field jargon. Equivalent Elephant Units, a little joke. Elephants weigh about seven and a half tons. This guy’s gotta be ten EEU’s—that’s twice the mass of a *Brontosaurus* .”

“What will you name it?”

“Well . . .” He seemed a bit embarrassed. “I figure the ground shook when it came by. How ’bout *Seismosaurus* ?”

She allowed herself an amused smile. Her hair was pulled back in a severe black bun held with a blue clasp, and she wore a tan field jumper. Dealing with men in such delicate professional matters had never been her strong point, and it was best to not give any unwanted signals.

He led her to the tail dig. They climbed down through nearly three meters of sandstone into the cool trench. The beast had apparently died beside a river and had been quickly buried by drifting sand, she remembered from his report. That kept predators from rending and scattering the bones.

This was a wonderful discovery site, deep inside a federal wilderness area, easy to hide and defend from tourist-vandals. Dirt bikers didn’t like the rippling rock formations. This was an upthrust of the Morrison Formation, which stretched across the American west. It held the great herbivores, a massive sheet of rock entombing the classic era of giants. They had found early human fossils here within the first few days of scraping, mere minor newcomers on the scale of deep time.

She sneezed from the dust and knelt to follow his description. He had launched into lecture mode, probably to put her at ease, letting her lapse back into her usual air of formality.

“These re Jurassic rocks, laid down in a river channel that sliced into older basalt. It’s fine-grained sandstone and gray shales with lacings of reddish brown and tan-yellow. Material was mostly unconsolidated, which accounts for the undisturbed fossil.”

It was a beautiful job, stripping away the rock at an inch a day to reveal the smoothly curving, colossal spine.

“These projections, big fat chevrons, see? I figure they helped adjust the weight. Beast like this, carryin’ the load’s a big problem.”

“Thus the hollow bones,” she said.

“Huh? How’d you know that?” A sudden scowl.

“Do not patronize me, my colleague.” She enjoyed the consternation that flitted across his face.

“Okay, let’s cut the socializing. I hoped you Los Alamos types could tell me what I’ve got here.”

“Indeed, I can.” Her visiting two-year appointment under the US-Japan exchange program gave her freedom to pursue eccentric ideas. On impulse she had volunteered for Dr. Baser’s curiously worded request. He had refused to give away any information about the fossil material he had brought to the Laboratory including the fact that some of it was not fossil at all.

She had prepared her conclusions for a more formal presentation, but somehow, standing here in a shaded trench amid the hammer and clang of the continuing work, sweaty even in the winter sun, skin plated with tangy dust—it all felt sharper, pungent, more earthily real, than her antiseptic life amid Pyrex provisions.

“I respect your intentions,” she said, wishing her tone was not naturally so stiff; a liability of her strict Japanese upbringing, perhaps. “Still, I would have appreciated knowing exactly what I was given to analyze.”

He chuckled. “I wanted straight scoop, no preconceptions.”

“I knew the scrapings had to be old, of course. Very old.”

“How?” His bristly eyebrows knitted together with suspicion. “Somebody leak it?”

“I ran isotope tests. There is a high concentration of uranium.”

“Um. Guess it maybe could’ve concentrated in the bones. . . .”

“Not ‘maybe’—it did. Scintillation counters do not lie.”

“Uh huh.” Noncommittal, eyes giving nothing away.

“You gave me some standard fossil material, yes?”

He grinned. “Sure. Know which ones?”

“Samples 3, 7, and 11 through 16.”

“Bingo.” His grin broadened.

“The signatures were clear. Silica, pyrite, calcite—they had intruded into the bone, replacing the organic matter.”

“Standard fossil process, right. I took those samples from the outer segments of the sacrum, pelvis, ribs.”

“And the others?”

He smiled slyly. “Not so fast. What’d you find?”

“Very well. Collagen.”

She could have laughed at the blank expression on his face. “What’s that?” he asked.

“A protein.”

“Um.” He peered up at the rectangle of blank blue sky, then gave her a guarded look. “What else?”

“No, it is your turn. I suspect you merely gave me fossil samples which had been contaminated—correct?”

“Huh? Contaminated how?”

“By your assistants’ handling. Flecks of skin. Human dander.”

He shook his head strongly. “Nossir. We took pelvis bones, femur, some spine. Real careful.”

“Hollow bones, all?”

“Right. Drilled ’em in vacuum. You got the samples straight from the vac box, believe me.”

She felt a strange prickly sensation rush across her skin. A chilly breeze? Here? “How . . . how did you pick the sites for drilling?”

“Most of this fossil was formed by the usual process. Organic molecules were leached out by ground water, then the interstices filled—with quartz, mostly. But the biggest dinosaurs evolved hollow bones to help ’em keep their weight down.” He gave her a look of respect. “You looked that up, right?”

“Of course. I became suspicious.”

“Look, I’ll come clean. It looked to me like the quartz intrusions had sealed up the pores and connections in some of the bones. There was stuff inside—hard but lighter.”

“Those were the other samples.”

“Right. I figured maybe the solids had trapped some bone in there, preserving it. Real bone, not stuff replaced by minerals. The bones didn’t crack, see, so the inside might still be chemically intact. Hell, maybe there’s even marrow.”

His face had a pensive, almost shy quality. His eyes seemed to plead with her. She had enjoyed playing this game with him, but now there was a tingling in her, a shortness of breath, and she could constrain it no longer.

“I found collagen, yes. Then I performed a thirty-element analysis. Twenty-eight of the elemental abundances matched modern bone to within five percent.”

“Ah. Close.”

“Very.”

His mouth twisted in sudden speculation. “So if bone hasn’t evolved a whole lot since the Jurassic.”

“There is more. I found twelve other proteins. Clear signatures.”

He blinked. His mouth made an **o** of surprise, then closed.

In the long silence that hung between them she heard, as though coming hollowly down a distant tunnel, the clatter and muted mutterings of the restless human energies around them, delving deeply and with patient persistence, seeking.

“You thinking what I am?” he asked, eyes glinting. “I believe so. The protein will be broken, of course, by thermal damage.”

She was surprised at her voice, still restrained and professional and not giving away a hint of the quickening in her body, of her attraction to this man mingled with the suddenly apparent idea he had begun. He must be thinking along the same lines, or he would not have asked for so specific a series of

tests.”

The air held a savor of tingling possibility.

“We’ll want to be careful.”

“Indeed.”

“People’ll say it’s sensationalistic.”

“I expect so.”

“But we don’t want to get scooped, right? Got to be fast on our feet, like my dad said.”

She stepped nearer him and caught a heady scent, a sweaty musk that hung in the dry air. Looking up at him, she knew exactly what he was thinking behind his shy smile. His head blotted out the sun. She said quietly, “We can try.”

2050

Sixty-two years, she thought. Sixty-two years of trying, of steadily carrying forward their dream. Did they guess then how far it could go? Mists shrouded the decades . . . she couldn’t remember.

“Dr. Nakawa?” a young man asked at her elbow. She recognized him: Flores, the microtech specialist. He had made some of the first DNA reconstructions that proved out. That had been a decade ago at least—yet his face was still unlined. Molecular tinkering nowadays corrected many of nature’s flaws.

“I was just resting.” The pain had passed.

“Your husband is already out in the canyon. He said—”

“I know—hurry up.” She made a fierce, comic frown. “He’s been pacing around since dawn.”

She let the man lead her through the hushed carpeting of the executive offices, past labs and workshops and big work bays. The place had a spruced-up sharpness, part of the half-century observance. She recognized some of the equipment, vastly better than the bulky stuff they had used decades ago to do the first detailed protein chain readings.

The sign over an impressive entrance said *HELICAL LIBRARY*—a bit of romantic dash, unusual for the bureaucracy-heavy Park Service. She reminded herself that after today she would take some time to browse in there. The flood of new data and ideas made research resemble trying to take a drink from a fire hose, but she was damned if she wouldn’t try.

That had been the analogy she and Dwight first used in their grant proposals: the DNA library. For the *Seismosaurus* they had millions of copies of the same book—DNA segments—but each copy had only a page or two left in it. Worse, the pages weren’t numbered. The blind rub of millennia had ripped out all but a few of the *Seismosaurus* genetic plans.

The trick lay in realizing that each fragment of DNA they found was a book with different pages left. Find enough books, compare the pages, stitch and splice and edit . . . and they could eventually patch together a complete book.

As Dwight often said, after all the talk about molecular groups and amino acids, the library analogy *felt* right. Even a congressman could grasp it.

The young man opened a door—and the fragrance and noise and buzz of the crowd hit her. She blinked at the sudden sun glare. Here were familiar faces, grins, hands to shake, 3D cams doing zoom-shots. She made perfunctory greetings, smiled a lot. Then they fell away from her as the officials performed their best function, brushing people off. She walked a bit unsteadily through a stand of gum trees, shielding her eyes against the slanting morning light.

“Mito!” Dwight called. He was with a small group of technical people, all carrying field equipment and communicators. She waved and hurried to his side.

“It’s almost here,” he said. “Ready?”

Then the tech types were talking, checking, reassuring, and she never answered. They all fell silent.

Through the moist air they could hear now the snapping of small trees. A strange, hollow bellowing. And the steps. Long, heavy blows, like a boulder bounding endlessly down a mountainside. Regular, stolid, remorseless.

She had never quite become accustomed to the sight. It was more like a moving jade-green hill, not a living thing at all. Human intuitions of size failed in the face of the great muscle slabs, the smoothly sliding hummocks of fat.

But the hammer blows of its broad, clawed feet belied its grace. The bountiful tail held over eighty vertebrae, tapering to a long, slender whiplash. The beast did not drag such mass, though. The tail arched smoothly upward, pert and buoyant. This weight balanced precisely the pipeline neck which swiveled with lazy grandeur, carrying the head aloft to browse among the tallest palms.

The improbability of the sight always struck her first. This most massive of land creatures moved with measured, easy elegance. A great deal of its brain dealt with balance and movement because it did not need the sharpened senses and low cunning of the hunters.

They all stepped back involuntarily as it approached. A technician whispered to her, “Don’t worry, ma’am, we’ve done this a thousand times. It’ll stop right over there.”

Of course, Mito thought, of course. But if everybody’s so sure, why are they whispering?

She stepped back anyway, taking Dwight’s arm.

The lumbering immensity halted exactly at the right spot. Then a crane lifted the two of them to the prepared chairs perched securely on the broad, leathery back. As all this happened it was as though Mito was two persons, one experiencing the heady swirl of smells and sounds, the other abstractly recalling the many hard struggles and failures they had seen through decades past.

From the proteins in its bone marrow, long before they knew its DNA, she and Dwight had shown that the *Seismosaurus* was a milkmaker. She turned and watched this mother’s brood ambling along nearby, munching small saplings. They were a mere two meters high, tails pointed nearly straight up, perky and alert. One cooed for its mother. Mito knew that today the moving mountain under them would not pause to give suck, however. The control relay rode like a silvery helmet atop the square head, giving carefully programmed orders.

The cheering from below fell away and behind them. Walking was a slow, grave rhythm. The young ones skipped ahead, calling to each other. They were moving appetites, stripping leaves and bark from the copse of gum trees. These babies grew quickly, evolution’s best way to offset against predators, but there were none such here.

“You okay?” Ralph asked, concern deepening the furrows in his face.

“I am indulging in memories.” She smiled at the passing broad expanse of the canyon as it opened toward the Kansas plain.

“Remember the first ones?”

She laughed. “I thought we would never get one to survive.”

“It was you who saw what they needed.”

“No, I merely carried it out.”

“Nonsense. They had milk but no mothering. And you were the only one on the whole team who had the guts to mother something like a calf with claws.”

She beamed. “All that would have amounted to nothing if you had not suggested feeding them stones.”

He shrugged. “*That* didn’t take guts.”

Even the babies needed stomach stones to crush tough leaves and pine needles, a staple of their diet after the first month. In their antiseptic cages the babies had no way to find any pebbles. Such simple points had eluded the brainy genetic engineers.

Park Service HQ helicopters hissed overhead, but their directives, relayed through the silvery helmet, did not completely offset all natural impulses. Feeding had to be constant, automatic. The beaked jaw was so powerful it could bite into a fat redwood and mash it to pulp in a sawmill of blade-sharp teeth. To work the vast jaws and support the massive skull, thick slabs of muscle worked over an arc of bone back down the thick neck. The cheeks bunched and flowed, chewing perpetually below eyes protected by horned ridges. It fed quickly, not even breaking stride. Its life was a perpetual odyssey, browsing four hundred kilos of leaf and needle a day.

Dwight pointed. “River comin’ up.”

Her composure slipped along with her smile. “Are you—”

“Just watch. This doll knows her limits.” One of the freshly carved rivers that had remade Kansas rushed and frothed at its banks. The *Seismosaurus* slowed, apparently working through its slow calculations. Then it waddled into the water. The pipeline neck rose in lofty disregard of the torrent. Currents lapped and swirled higher, higher—and held a meter below their carriage chairs.

“See?”

Dwight always had more confidence in physical matters than she did. “*Her* head is up there. What does she care if her back gets wet?”

“Ummm. Rest easy. Feelin’ okay?”

Though the pains had returned to her lower abdomen she gave him what she hoped was a sunny smile. “Wonderful.”

The beast showed no concern for the churning river. The sauropods were proving to be astonishingly versatile. They were true land animals, not the pond-loungers envisioned earlier. In the nineteenth century the first discoverers of the huge fossils had thought they were an extinct variety of whale-like reptiles. Bulk was their best defense. Challenged, they could deliver a massive, rib-crushing blow with the strong

hind legs or tail.

The young ones crossed the river at a shallows farther down, then raced to join their mother. Swaying, Mito let the summer heat claim her. They worked their way into some undulating hills crowded with the new fast-growth olive trees, which their mount gulped down with gravelly grunts of relish.

They met a *Brachiosaurus*, russet-red among the shifting silver-greens of the olives. It thudded around a rocky ledge, surprising the humans, but provoking no reaction from the *Seismosaurus* .

Neither beast displayed hiding behavior, Mito noted abstractly. Only once had any of the sauropods shown a fighting stance, when surprised by a holoprojection of a model *Tyrannosaurus* . It had reared onto hind legs like an elephant, claws extended.

The *Brachiosaurus* was like a smaller edition of their mount, with folds of fat and ribbed colorings of pink and blue. Over the last half-century fossil-hunters had found organic traces of nearly fifty species, and a dozen now walked the earth. The most startling differences among them were the vibrant splashes of oranges, burnt-yellows, milky blues and rich browns that each species displayed as soon as they were weaned, as their reproductive patterns took hold. Mito watched the *Brachiosaurus* approach, appreciating the contrast of colors, when suddenly a powerful explosion jarred her.

“What—” Dwight jerked around, alarmed.

The great tail curled high above them. Fierce bellows boomed. The tail descended, a blur that abruptly sent forth a hammer-hard crack.

The *Brachiosaurus* jerked, daunted. Its massive feet pounded as it turned, a sight which brought laughter from them, and then it beat a hasty retreat.

“Protecting its grazing rights,” Mito said.

“And here I always thought it used that tail as a weapon.”

“The best weapon is one you do not have to use.”

Dwight blinked as their mount gave a loud parting shot. “Damn impressive.”

“You see what this means? We humans thought we were the first creatures to break the sound barrier. But a great whip like this—it must, yes?”

He thought a moment. “Suppose so. The dinos beat us to it by 150 million years.”

What she most loved about her life was the way surprises abounded. To bring true a deep human dream, to conjure forth the great lizards again, would have been quite enough, even without the cornucopia of amazements that followed.

Who would have guessed, she thought, that the sauropods’ pursuit of mass as a defense against the meat-eaters mould in the fullness of time give them immortality? The quest for sheer weight had led them to the efficiencies of hollow bones. Cradled in those chambers, the dinosaur genetic heritage slumbered for over a million centuries . . . while the solid-boned meat-eaters’ legacy trickled away, the helical chains besieged by the salts of ground water. Finally, the meek did inherit the earth.

The stabbing pain returned, catching at her breath.

They rose over the last line of slumped hills and there before them spread the center of the park. The

fresh, glittering river rapids lay like a string of whitewater jewels in a verdant setting. Dinosaurs grazed all along the broad, lush plain, their splashes of color like gaudy ornaments. Amid the fields of tan wheat and stretching orchards were discreetly positioned cameras, observers, elite guests. Even the grandest class of all dinosaurs could spook and run, given provocation, as more than one trampled specialist had learned.

As they descended along a slow-sloping hillside, something strong and dark welled up in her. Perhaps it was the ancient sway of the great beast, or her mounting suspicions about the pain that had ebbed and returned in her now for days. Medicine had prolonged life in the best possible way: lengthening the robust days, then ending them with a sudden, sure collapse. There was little to do at the end, which was a final kindness. And if she kept her serene outer glaze, Dwight would not guess and worry until the last possible moment.

So long as it fell after *this* day, she reminded herself. A happy accident, that the Park could open at the half-century mark, and that they had both labored into this era. They could have been caught beneath the blundering incoherence of one of the first rebirths, crushed by the malformed beasts made in the first few years of experiments. Several of the unwary had been.

But no. Now the immense mass beneath them had been harnessed with skill and love.

As they descended a cheer rose all down the ample plain, thousands of voices giving them greeting. The sky itself swarmed and lit with the new electro-display she had heard about but never witnessed.

KANSAS SAUROPOD PARK

OPENING CEREMONIES DEDICATED TO

MITO NAKAWA AND DWIGHT RASER

THEY OPENED OUR PAST

It was a dazzling iridescent display. The letters loomed across the pewter sky bowl, yellow cascading into orange.

“Y’know, I still wish we’d patented the *Seismosaurus* DNA,” Dwight said.

She laughed; he could always make her do that.

With a sudden swelling of emotion, she felt herself let go of all her concerns. This might be the last of days but it would certainly be one of the greatest. Her heart thumped with love of the man next to her, and with love for the rough beast beneath them, slouching into their strange world.

As she made ready to depart, it was arriving, brought forth from the pressing solemn silence of a million centuries, into a territory free of the predators its kind had borne for so long. Humans might tinker all they would, but they could not with any genetic certainty reconstruct the great *Tyrannosaurus*, or any of the rest of that blood-drenched legion which had bedeviled these vast, simple creatures.

She grasped Dwight’s hand and drew in a breath containing scents unsensed for longer than humans had walked the world.

They would evolve, of course. But this time they would have a shepherd.