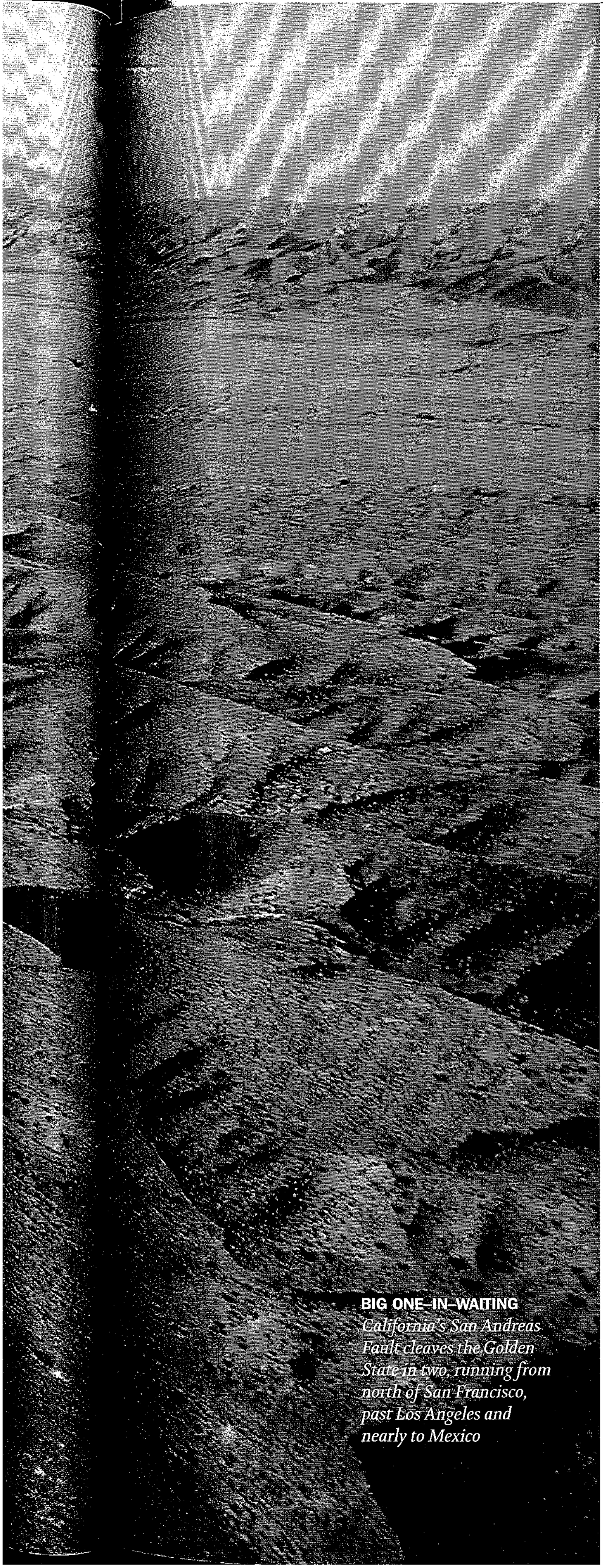


BIG ONE-IN-WAITING *California's San Andreas Fault cleaves the Golden State in two, running from north of San Francisco, past Los Angeles and nearly to Mexico*

LLOYD CLIFF—CORBIS

Dance of The Land

The theory of plate tectonics is a planetary operating manual

"STRANGE AS IT MAY SEEM," PHYSICIST Richard Feynman wrote in his 1985 book, *Six Easy Pieces,* "we understand the distribution of matter in the interior of the sun far better than we understand the interior of the earth." That curious neglect of the world beneath our feet in favor of the cosmos beyond may be hard-wired into our DNA. We are an exploring species, and the things truly worth exploring always seem to be *up there* rather than *down there.*

Need proof? Consider that while we've gazed at the stars and speculated about their origins for millennia, we didn't even realize that the Earth wasn't flat until 500 years ago, or one-tenth of 1% of human history. Indeed, human beings have been able to fly machines above the ground for longer than we have had an inkling that there is anything below that ground other than solid rock. Even in the geography of mythology, people of widely different cultures have always believed instinctively that the skies belong to the gods, and the realms beneath the ground are the domain of darker forces. After all, tidings from the Underworld—arriving chiefly in the form of hot lava or unsettling tremors—were almost invariably bad.

It was the search for worldly riches—gold, diamonds, oil and coal—that first prompted people to probe ever so slightly beneath the surface of our planet. What they found, usually a layer of soil or sand followed by solid rock, was assumed until the 20th century to represent the entire nature of the earth's interior. But in the past 100 years, humanity's knowledge of the world that lies beneath the surface has increased considerably, thanks to a handful of visionary scientists. Today we understand that many of the seemingly disparate natural disasters treated in this book—earthquakes and volcanoes, landslides and tsunamis—are all linked, each phenomenon the reflection of a planetary architecture whose forces are great enough to move continents, raise mountain ranges and drain oceans dry.

The scientist who revolutionized our view of geology was a German meteorologist, Alfred Wegener, who was only 30 when he wrote to his fiancé in 1910: "Doesn't the east coast of South America fit exactly against the west coast of Africa, as if they had once been joined? This is an idea I'll have to pursue." And he did just that, researching geologic and fossil records in university libraries all over Europe.

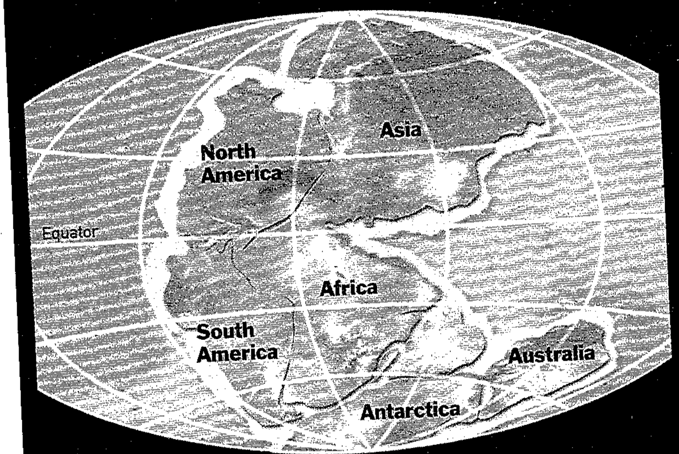
Some of Wegener's findings amazed him: remains of *Cynognathus,* a 9-ft.- (2.7 m-) long Triassic-era land reptile, had been discovered in two narrow strips of land, one in South America, the other in central Africa. When these continents were fitted together like jigsaw pieces, the two strips lined up perfectly. Another set of bands, in which fossils of the freshwater reptile *Mesosaurus* had been found, seemed to connect seamlessly across the lower latitudes of South America and Africa. A third dinosaur, *Lystrosaurus,* was found only in three strips traversing Africa, India and Antarctica, and these bands formed a single brushstroke when the shapes of those continents were linked.

For Wegener, the conclusion was clear, if mind-boggling: all the world's continents had once been joined in a single landmass, which he called Pangea, Greek for "All Earth." That giant landmass, he posited, had gradually broken apart, in a process he called "continental drift." Of course, the fossil evidence that Wegener used to support his theory had not gone unnoticed by other scientists. Yet in an example of how tenaciously mainstream scholars will cling to orthodoxy, geologists and paleontologists had explained these anomalies by hypothesizing a series of "land bridges," causeways that once linked continents across the world's oceans. The fact that there was little evidence, aside from a few well-known examples, that such bridges had ever existed seemed to bother no one.

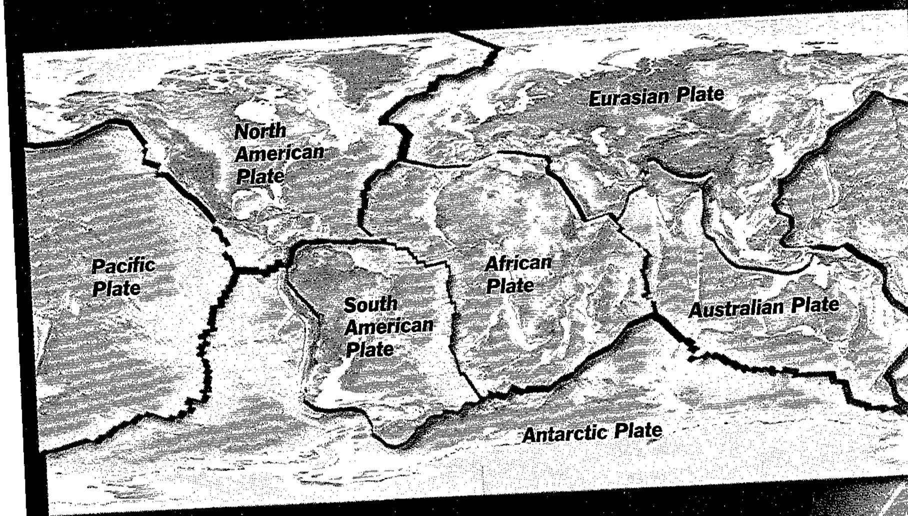
What did bother nearly everyone, though, was the prospect that a young outsider—a mere weatherman, no less!—could upend the finely wrought theory of land bridges. "Utter, damned rot!" howled the president of the American Philosophical Society. Any person who "valued his reputation for scientific sanity" would dismiss such a theory out of hand, agreed a leading British geologist. When Wegener died, on an expedition to

PANGEA: ONE WORLD

All the planet's landmasses were once concentrated in a single supercontinent, Pangea (Greek for "whole earth"), which began breaking up around 225 million years ago



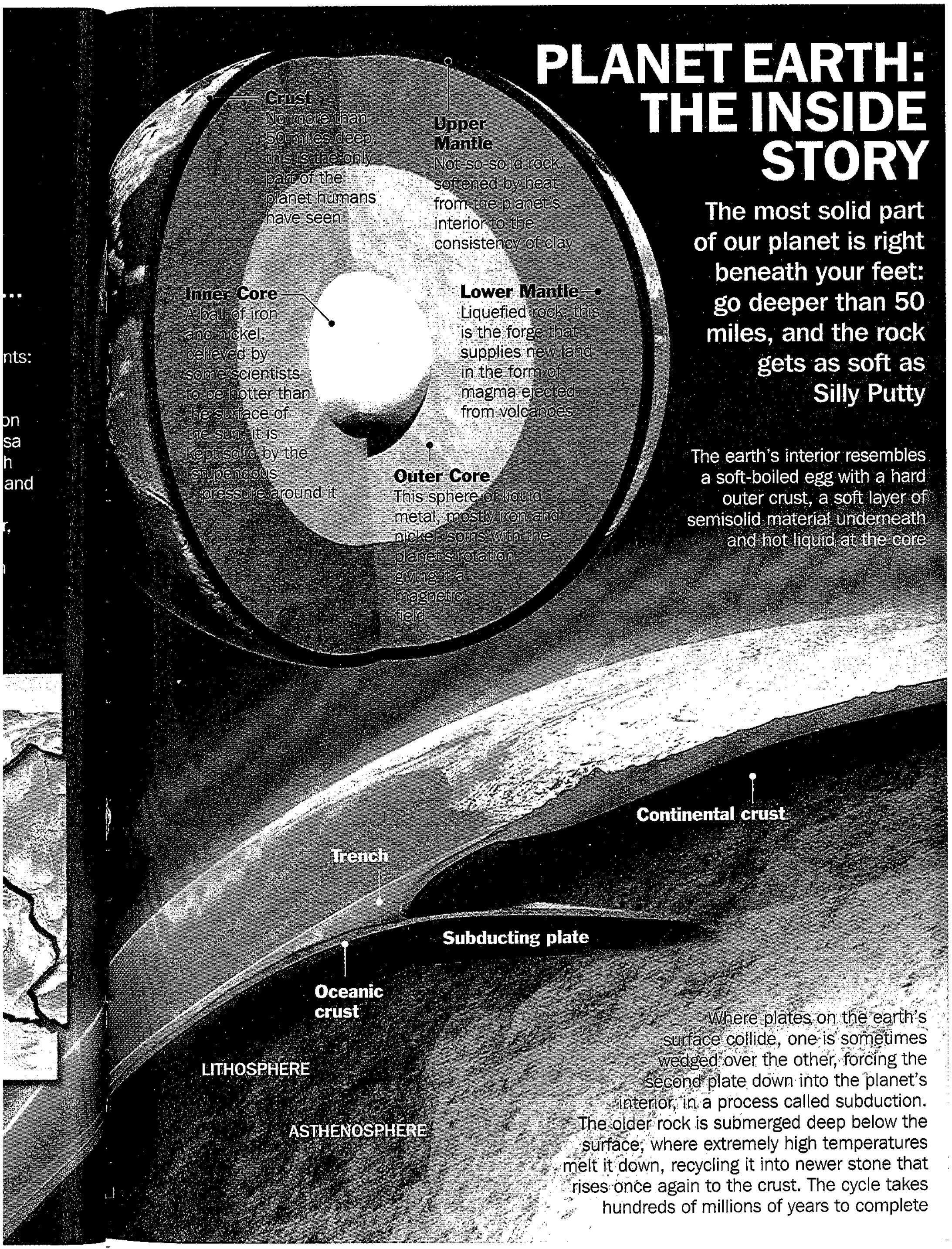
ONCE UNITED ... As of 200 million years ago, there were two continents: Lauraisa and Gondwanaland. Around 130 million years ago, Lauraisa cleaved into North America, Europe and Asia. About 70 million years later, Gondwana-land calved into South America, Africa, Australia and Antarctica



... PANGEA DRIFTED INTO DIVISION Terra firma is a figment of the human imagination: the seemingly solid surface of the earth is made up of more than a dozen vast plates floating above the liquid rock of the planet's interior and butting up against one another at tectonic convergence zones

PLANET EARTH: THE INSIDE STORY

The most solid part of our planet is right beneath your feet: go deeper than 50 miles, and the rock gets as soft as Silly Putty



The earth's interior resembles a soft-boiled egg with a hard outer crust, a soft layer of semisolid material underneath and hot liquid at the core

Where plates on the earth's surface collide, one is sometimes wedged over the other, forcing the second plate down into the planet's interior, in a process called subduction. The older rock is submerged deep below the surface, where extremely high temperatures melt it down, recycling it into newer stone that rises once again to the crust. The cycle takes hundreds of millions of years to complete

Greenland in 1930, his theory of continental drift commanded about the same level of academic respect that speculation about the Bermuda Triangle does today.

One reason Wegener could be ignored was that he offered no theory as to how or why continents could move, like plows in a field, through the apparently solid surface of the planet. The explanation would have to await Harry Hess, a Princeton geologist who served as the commanding officer of a naval transport during World War II. Hess's ship was equipped with an early version of sonar, and Hess ordered that the equipment always remain on, thus compiling thousands of detailed readings about the contours of the seafloor. Among his first discoveries was the Mid-Atlantic Ridge, a vast mountain range that bisects the ocean, reaching almost from pole to pole. Hess and his colleagues would later discover that this ridge is one small part of a global chain of mountain ranges, mostly undersea, that stretch around the earth like seams on a baseball, and that many of these ranges consist of extinct or currently active volcanoes.

Taking core samples from these volcanic ranges, the geologists found that the rocks on top of the mountains were relatively young, just a few million years old, whereas rocks found on the slopes were older by tens of millions of years, and stones recovered far from the peaks were geologic senior citizens, hundreds of millions of years old. Their conclusion: new rock was continually bubbling up from somewhere inside the earth and was being ejected and pushed outward in the form of volcanic lava all along this line of ridges. The planet's surface, they reasoned, is actually composed of a series of giant plates that are continually moving, bearing continents and seas with them.

Today scientists believe the earth's crust is made up of 11 major segments, vast and solid, along with about 20 much smaller pieces, that float on a layer of molten rock that has the consistency of Silly Putty. The plates are called tectonic, from the Greek root meaning "to build," because they are continually building and reshaping the planet's surface while constantly jostling against one another like rafts crowded into a small pond. Along the boundaries where they meet, earthquakes and volcanoes are especially common.

When tectonic plates collide, one of three things occurs: they push each other upward to form mountain ranges, like the Himalayas; they push each other downward, which is how ocean trenches are formed; or they grind against each other, creating regions of instability. The last is what is happening where the two largest plates in the world, the Pacific and the North American, meet. One line between these two pieces of the planet's jigsaw skin is the San Andreas Fault, which gashes California for more than 650 miles (1,046 km). The two plates are moving so inexorably in opposite directions that the state's late seismologist Bruce Bolt once quipped, "In 30 million years, Los Angeles will become a new suburb of San Francisco."

The next unknown: What lies under the plates? Exploration of this interior frontier began in 1936, when Danish scientist Inge Lehmann used seismographic readings to deduce that earth's center consists of two concentric cores: a 1,300-mile (2,092 km) -thick liquid outer core and a solid inner core about 750 miles (1,207 km) in diameter. Both sections are composed mostly of iron and nickel, and it is these two nested spheres (especially the liquid outer core, which spins with the earth's rotation) that give the planet its magnetic field.

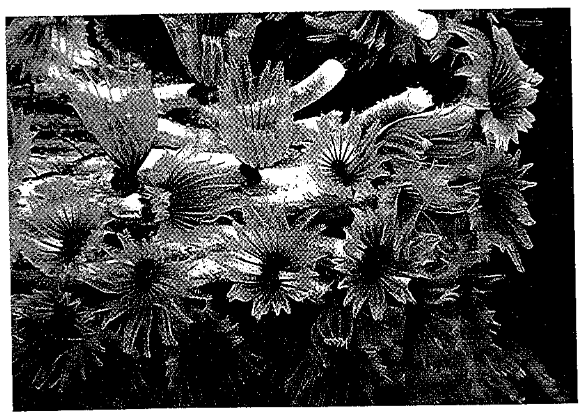
Lehmann built on earlier seismograph readings indicating that surrounding the core is a "mantle" layer of rock, 1,800 miles (2,896 km) thick, that is softened by the heat from the outer core. The mantle begins immediately beneath the 20-to-50-mile- (33-to-80-km-) thick crust, the earth's outermost layer. The mantle is the source of new volcanic rock, which causes ocean floors to spread, continents to drift and tectonic plates to collide. It is also the destination for older rock that is sucked back into the deepest part of the mantle, closest to the hot core, where it is melted and in effect recycled into new rock that bubbles back toward the surface. In a cycle that takes hundreds of millions of years to complete, the reconstituted rock is then ejected back through the crust by volcanic activity.

Further confirmation of the planet's tectonic architecture came from deep beneath the sea. In 1977 a team of scientists operating the submersible *Alvin* near the Galápagos Islands some 1.8 miles (2.9 km) beneath the ocean's surface discovered hydrothermal vents on the ocean floor, where billowing flows of hot water were emerging from cracks in the seabed. Like geysers aboveground, hydrothermal vents occur when seawater seeps through fissures into the crust and is heated by hot reservoirs of magma to some 350°F to 750°F (176-399°C), until it bursts back up through the oceanic crust. (Water that hot would boil on land, but at the extreme depths at which the vents are located, the pressure of the surrounding ocean water raises the boiling point.)

The hot water that pours up through the vents is rich in minerals; when it mingles with the cold seawater, the minerals separate, in a process known as precipitation. Then they crystallize, often forming a chimney-like structure that surrounds the vent. Reflecting the enormous power that creates them, chimneys can grow very quickly, up to 30 ft. (9 m) in 18 months. The vents that spout water most heavily laden with minerals appear deep black and have been dubbed "black smokers"; other vents are "white smokers."

Unique life-forms, including giant tube worms and spider crabs, were soon discovered, thriving near these smoking vents on the ocean floor. Unlike any other sea or land animals, they are sustained by energy that is not derived from the sun in some manner. Instead, they harbor within their bodies large aggregations of bacteria that sustain themselves by turning the mineral sulfides pouring from the vents into oxygen—in short, by chemosynthesis, rather than by photosynthesis. These bacteria, in turn, provide nutrition for their hosts.

Thanks to this ongoing cascade of discoveries, Wegener's bold hypothesis was largely accepted by scientists by the 1960s. But there is much to learn. Humans have walked on the moon and sent probes to Mars but have never ventured more than a few miles beneath the surface of their home planet. More than 25 years on, Feynman's ideas still ring true: If our world were an apple, we have yet to pierce its skin. ■



GRACE UNDER PRESSURE *Above, colorful tube worms flourish near hot vents more than two miles (3.2 km) under the sea, in a sunless world. At right, a black smoker at the bottom of the Mid-Atlantic Ridge, a tectonic convergence zone, billows with heated, mineral-rich, recycled seawater*

RIGHT: RALPH WHITE—CORBIS. LEFT: JURGEN FREUND—NPL—MINDEN PICTURES