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WHY WE'RE ALL LA SURFERS

First-Hand Plate Tectonics
BY PETER STARK

BIG HISTORY PROJECT



I WAS SQUINTING INTO THE BRIGHT SUNLIGHT REFLECTING OFF THE GLACIER, AND MY FRIEND RAY, THE PHOTOGRAPHER, WALKED A SHORT WAYS AHEAD, A TALL SILHOUETTE AGAINST THE BRILLIANT SNOW AND ICE.

THE WIND BLEW SO HARD it made us stagger and the gale's force bowed the rope that linked the two of us and the guide ahead like a giant strand of spaghetti. A reddish ridge of earth protruded from the glacier and puffs of steam swirled and kicked from its far side. We were now nearing the place where fire mingled with ice.

All of sudden Ray disappeared. He vanished so quickly I couldn't understand what had happened, as if a magician had touched him with a wand. Puzzled, I looked again ahead of me along the rope. I realized he hadn't entirely disappeared.

Rather, Ray had suddenly become really short. Only his head and shoulders poked above the glacier's shimmering surface. I now understood that he'd fallen into a crevasse. His legs dangled underneath him in a deep crack in the glacier that probably dropped far down toward volcanic depths below.

"Ray!" I shouted, as the wind ripped away my words. "Climb out!"

I'm an adventure writer. Magazines send me to wild and faraway places. When a magazine asked me to write an article about Iceland, I jumped at the chance and

COVER: The Kawah Ljen crater lake in Java, Indonesia

THIS PAGE: Writer Peter Stark (right) and guide, Olifur, survey the Icelandic landscape near the Mid-Atlantic Ridge

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invited Ray along to take photos. While planning the trip, I learned that Iceland is known as the land of “fire and ice” because it’s dotted with big glaciers and live volcanoes. Far in the center of the island, the fire and ice — the glaciers and volcanoes — mix together in dramatic and sometimes explosive fashion. Getting to that spot became the goal of our trip. That journey would change the way I think about our planet Earth.

The Earth is a ball of hot, molten rock and minerals covered by the thin outer “crust” of cooled rock on which we live. Giant “plates” of this cooled crust float like rafts or islands over the molten ball of the Earth’s interior. In perpetual — but very slow — motion, most of the plates move only about one inch per year. In other words, we’re all lava surfing...very, very slowly. But where they meet along the plate edges, all sorts of crazy things oc-

cur. The huge plates scrape past each other sideways. They dive under each other. And in places, the constantly moving plates get snagged on each other, causing tremendous pressures to build. When this tension suddenly releases, things happen way, way, way faster than one inch per year.

My travels have led me to those plate edges in different parts of the world.

ABOVE: An adventurer negotiates a crevasse on the Hofsjokull Glacier in central Iceland

Some of the bizarre phenomena I've witnessed are similar to what scientists observed and experienced during the last century in formulating the theory of plate tectonics.

A NECKLACE OF ISLANDS

Before going to Iceland, I'd spent some time in Indonesia. When I looked at a map of that country, I noticed its hundreds of islands strung out like a 3,000-mile-long necklace of pearls draped in the ocean below Asia. I wondered: "Why is it shaped in such a perfect arc?"

I hadn't been there long when I started to get an answer. My wife, Amy, and her father, Rags, and I were staying in a little hotel on the Indonesian island of Bali. We were eating dinner one evening beside the small swimming pool. I looked up from my plate of rice and fish and my mango smoothie and noticed that the water in the swimming pool was sloshing back and forth, as it does when you slide around in a very full bathtub. But no one was in the pool!

"I think we're having an earthquake," I remarked.

"No we're not," they replied.

The motion was almost too subtle to feel. But when I pointed to the pool, they finally believed me.

Earthquakes strike that island necklace of Indonesia almost constantly — usually they are small and subtle. But occasionally huge quakes, including massive undersea tremors that trigger tsunamis, occur as well.

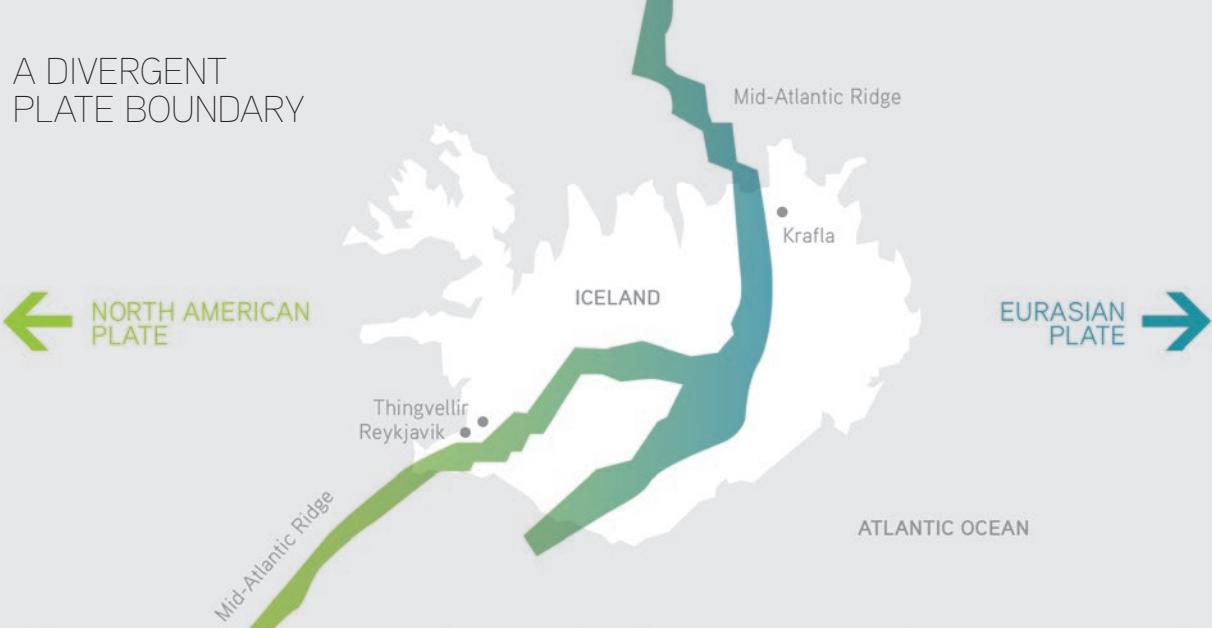
I found more evidence of what might be happening with that Indonesian island arc when we climbed a volcano, called Mount Marapi, on the island of Sumatra. Few people climb this volcano. It was difficult to see from below just how active it might be above. We hired a young man from a nearby village who could lead us to the top. Off we went in the rainy darkness before dawn, clambering for hours through dripping, misty rain forest. Finally, the green rain forest ended and we topped out at nearly 10,000 feet on the broad, ashy-gray summit that looked like the surface of the Moon and was scattered with big gray boulders.

The guide led us across the top, its flat, ashy surface gently pocked by that morning's raindrops, until we reached the center.





A DIVERGENT PLATE BOUNDARY



"Take care," the guide said, and pointed over an edge.

We inched closer and poked our heads over. There was the most incredible hole in the Earth I'd ever seen, as wide across as several soccer fields and impossibly deep, falling far away to a bottom I couldn't see. Every 20 or 30 seconds a huge gray huffy blast of foul-smelling smoke and steam and ash came belching out of that rocky shaft and billowed past our faces into the sky. It made me dizzy to look over the rim.

Then I looked back around me at the big boulders lying on the summit plateau. I had assumed they'd lain there for years,

if not centuries, since the last big eruption. I now noticed that they'd made craters in the ash, disturbing the rain-pocked surface. Right then I realized that the volcano had erupted just since that morning with its lava bombs falling out of the sky onto the summit. It was more than active — it was really active — and it felt like we were standing beside a direct hole down to the molten interior of the Earth.

"This thing could erupt again at any moment!" I said to Amy. "Let's get out of here!"

EARTH'S OFTEN VIOLENT HISTORY

This got me interested in knowing more about plate tectonics, the theory that scientists developed after observing seis-

mic events like volcanoes and earthquakes, studying data like the fossil record, and minutely examining maps. Maps tell amazing stories of the Earth's dynamic and often violent history, and plate tectonics is a kind of language to read the stories hidden in maps.

When I studied a relief map of Indonesia that showed mountains and valleys on land and undersea, I noticed a huge ocean "trench" — the deepest underwater valley you can imagine, nearly five miles deep — running alongside the island necklace.

Why that arcing trench? Plate tectonics taught me that Indonesia's necklace of islands traces a distinct seam in the Earth's

ABOVE: A satellite image of Iceland and a map showing how the island straddles the North American and Eurasian plates



THE 2004 INDIAN OCEAN TSUNAMI

1250 KM

LENGTH OF RUPTURE ALONG
THE TECTONIC PLATE BOUNDARY

150 KM

WIDTH OF RUPTURE

725 KM/H

SPEED OF WAVES DURING
TSUNAMI

15 M

TOP HEIGHT OF WAVES

475 MEGATONS
OF TNT

ENERGY EQUIVALENT OF THAT
RELEASED BY THE SUMATRA-
ANDAMAN EARTHQUAKE
THAT CAUSED THE TSUNAMI

ABOVE: A village near
the coast of Sumatra
after the tsunami

DATA: Australian
Bureau of Meteorology,
U.S. Geological Survey

crust where two huge plates collide. The Australian Plate is shoving northward at two inches per year and diving beneath — subducting — the Eurasian Plate. This diving creates a deep crease in the Earth's crust, the Sunda Trench. As the Australian Plate dives and melts into the Earth's interior, it allows lava to well up to the surface in a necklace of active volcanoes along the seam, one of them the belching vent of our Mount Marapi. You can imagine how that the incredible pressure of two plates colliding shakes Indonesia with near-constant earthquakes, small and large, and occasional mega-quakes, like the 2004 undersea quake and tsunami off Sumatra.

Diving plates also shove up mountain ranges from below, like shoving a spatula under a sheet of raw pie dough, which is why Mount Everest, already at 29,035 feet the world's tallest mountain, grows an inch or two taller every year.

Sometimes I try to imagine what the plates are doing directly under my feet. This is something you can do, wherever you live. Centers of continents, like the center of a raft, tend to be more stable than a subduction zone on a coast. But not always. I live with my family in the interior of the North American Plate, in Missoula, Montana. This is not so far from Yellowstone Park. All those famous geysers are actually boiling up from a "hot spot" where a massive bubble of lava pushes close to the Earth's

surface from deep beneath the crust and boils water that's flowing underground. The North American Plate is sliding over that huge lava dome. (I'm lava surfing even while I'm writing this.) Over millions of years, as the Rocky Mountains slid over the Yellowstone Hot Spot, it melted and crumbled a wide channel right through the mountain ranges, like a hot pan melting lumps of butter, and snow and rain flowed off the Rockies into the channel to form a river.

This channel both helped and nearly killed early European explorers of the West. Trying to find a pass through the Rocky Mountains to reach the Pacific Ocean, they got funneled into this channel — today called the Snake River Valley — and paddled their canoes down its river. Too late, they discovered that the river eventually left the channel and flowed straight into an ancient ocean trench, now on dry land, created by the Pacific Plate diving under the North American Plate and then cut deeper by the river. Huge rapids smashed the explorers' canoes and trapped them in the canyon bottom. Here they nearly starved to death.

FIRE AND ICE

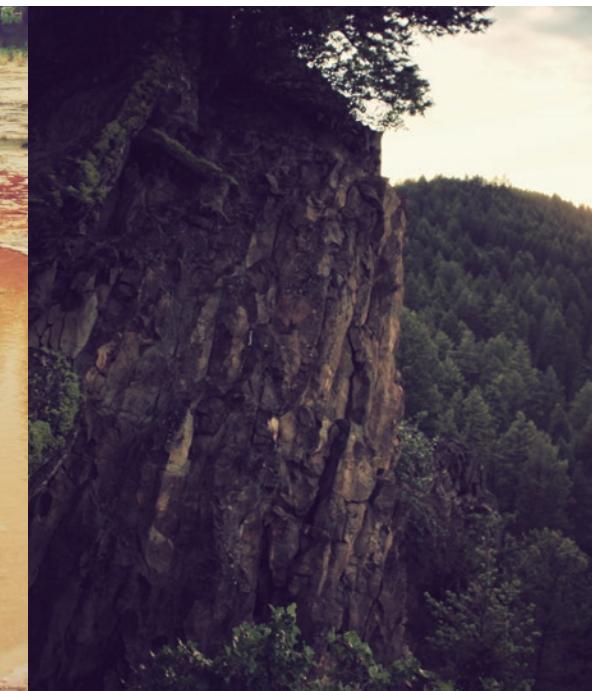
The explorers had stumbled into the deepest canyon in North America — a mile and a half deep, far deeper than the Grand Canyon — which they called "The Devil's Scuttlehole" and today is known as Hells Canyon of the Snake River. The

LEFT: Emerald Pool at Yellowstone National Park, Wyoming

RIGHT: The Yellowstone River and the Calcite Springs overlook at Yellowstone National Park



The deepest canyon in North America was called “The Devil’s Scuttlehole.” Today it’s known as Hells Canyon.



It looked like another planet extending in the distance — rippled plains of lava, a strip of desert where sand and dust blew.

ABOVE: Peter and Ray's view from atop the Mid-Atlantic Ridge



stunt rider Evel Knievel brought notoriety to a nearby section of the Snake River Canyon when he tried to jump it on his rocket-powered motorcycle, didn't make the gap, fell out of the sky, and landed by parachute in the canyon bottom.

Iceland, where I traveled with Ray, is almost the opposite of a subduction zone of the type that formed Hells Canyon and the Rocky Mountains. I learned Iceland sits directly atop a giant seam where two plates are not colliding or diving but spreading apart. Known as the Mid-Atlantic Ridge, here lava wells between two plates, adding to their edges and creating a string of undersea volcanoes. Iceland is where some of the volcanoes rise above

the Atlantic Ocean but it lies so near the North Pole that glaciers cover parts of it. Thus our goal: to reach a spot where volcanic fire mingled with glacial ice.

That's where Ray was dangling in an icy crevasse. Fortunately, Ray carried a pair of skis in his arms. The skis and the rope tied to his waist snagged on the crevasse's lip and prevented him from falling farther down into the crack. He quickly pulled himself out before the guide and I had to rescue him. We staggered onward into gale and into ice crystals pelting our faces.

Finally we stepped off the glacial ice and onto the reddish ridge. We clambered up it. From the top, there was a spectacular

sight. It looked like another planet extending in the far distance — rippled plains of solidified lava, a strip of desert where sand and dust blew in the gale, huge glacial sheets, distant mountains. At our feet, below us, lay a small blue lake sparkling in the sun surrounded by hillsides of reddish earth and patches of glacial ice. Everywhere around the lake steam sprung from the Earth — from the hillsides, from the shores, from steaming vents in the glacier itself.

We'd arrived at the spot where fire mixes with ice. We now stood directly atop the Mid-Atlantic Ridge. Here, the Earth was new.

IMAGE CREDITS

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Peter Stark and guide, Olifur,
near the Mid-Atlantic Ridge in Iceland
© Raymond Geyman

Hofsjokull Glacier in central Iceland
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Early morning at the Mount Bromo
volcano, East Java, Indonesia
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Halmahera, Indonesia
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A true-color satellite image of Iceland
captured, January 2004, courtesy
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Response Team at NASA GSFC

The Mid-Atlantic Ridge in Iceland,
U.S. Geological Survey

A village in Sumatra photographed from
a relief helicopter, U.S. Navy
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Peter Stark's expedition looks
out from atop the Mid-Atlantic Ridge
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