

The Scarred Earth

Tsunami-spawning quake leaves geophysical changes **BY MADHUSREE MUKERJEE**

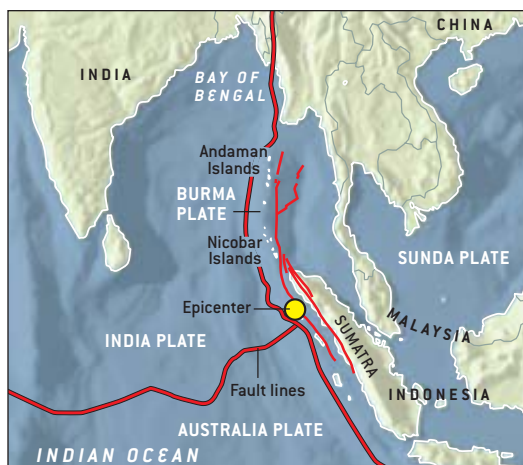


SUBMERGED: Part of the Indonesian city of Banda Aceh, on the northern tip of the island of Sumatra, was wiped away, as seen in these satellite images before the tsunami (*top*) and after (*bottom*).

A year of death and destruction wreaked mostly by humans ended with nature flexing her own muscles, to terrifying effect. A section of the earth's crust hundreds of kilometers long tore off its moorings, slamming into the seawater above. The resulting tsunami traveled at 700 kilometers per hour to rear up like a hydra onto shores, sweeping away some 225,000 lives and millions of livelihoods across 12 nations. Now, as broken-hearted survivors turn to piecing together the remnants, scientists are scrutinizing the oceanic and island terrain to determine how the crust has changed and to gauge what further horrors the earth may have in store.

The magnitude 9.0 earthquake was the largest ever recorded in the region and the world's biggest since a 1964 Alaskan quake. The underground tear started 100 kilometers off the coast of Sumatra, on the western edge of the Burma plate. This "sliver" plate, a long, thin section of crust that reaches southward from Myanmar (Burma), pushes over and against the India plate to its west at the rate of 14 millimeters a year; on December 26, 2004, the Burma plate jerked westward and upward along an incline by perhaps 15 meters.

According to an early reconstruction by seismologist Chen Ji of the California Institute of Technology, the earthquake initially displaced 400 kilometers of crust 20 kilometers below the seabed. The tear very likely continued farther north but too slowly to generate seismic waves. (Long ruptures produce very low frequency seismic waves that are difficult to measure and interpret.) "Our preliminary tsunami modeling indicates the length of the rupture was significantly larger than the estimates the seis-



COLLIDING PLATES: The Burma tectonic plate lurched west over the India plate, uplifting the seafloor and triggering the December 26, 2004, tsunami.

mologists are putting up,” remarks Frank Gonzalez of the National Oceanic and Atmospheric Administration in Seattle. In any case, the earthquake shook the bottom of the sea along a ridge aligned north to south, sending up-raised walls of water barreling mainly east and west.

On reaching gently sloping coastlines the tsunami slowed down, shoaled and rose many meters to descend on unsuspecting humans. It first bulldozed coastal towns in Sumatra and, farther north, washed clean over several of the Nicobar Islands, leaving in places only a handful of survivors clinging to treetops. Sloshing within the confines of the Andaman Sea to the east, it carried off vacationers in

Thailand. The westward wave traveled across the Indian Ocean as swiftly as a jet plane, striking India and Sri Lanka. Six hours later it claimed lives on Africa’s shores and kept on going until it had circled the globe and dissipated.

At the same time the tsunami scoured the planet, the earthquake permanently altered its shape. Because the plates pulled tight and snug over one another, the earth’s crust became more compact. Calculations suggest that, like an ice skater drawing in her arms, the contraction made the planet rotate faster, by perhaps three microseconds. And because the ocean bottom near the epicenter thrust upward, the planet’s water now has less room, causing the sea level to rise by about a millimeter.

More locally, the earthquake and its aftershocks changed the shape and orientation of virtually the entire Burma plate and the lands it supports—in particular, the Andaman and Nicobar islands. The two island groups are the peaks of an undersea mountain range, raised by the scraping up of soft sediments as the plate’s leading edge pressed down and forward against the India plate. After the earthquake, some of the Nicobar Islands seem to have sunk, and one island, Trinkat, has split into three pieces, with fish now swimming around once idyllic, palm-fringed villages.

The western edge of the Burma plate has risen a few meters—exposing coral beds around the tiny island of North Sentinel—whereas the eastern edge has dropped. According to Survey of India, a government mapping department, the main town in the Andaman-Nicobar region, Port Blair, has shifted by a meter and sunk by 25 centimeters. Such tilting is to be expected, notes Joseph Curray of the Scripps Institution of Oceanography in La Jolla, Calif.: one undersea ridge south of the Nicobars was once, he suspects, a piece of Sumatra that sunk in the distant past. “Sooner or later Banda Aceh will subside” and disappear into the ocean, he concludes of the Sumatran city.

“Sooner” for a geologist usually means “later” for other humans: the earthquake and its aftershocks, Curray believes, eventually ruptured and released stress along the entire western edge of the Burma plate, making other massive jolts unlikely for a century. Large quakes could still be expected along the eastern edge, he warns: the Burma plate, drifting northward around 25 millimeters a year, tends to stick and unstick against the plate to its east in motions that produce “strike-slip” earthquakes. Such earthquakes probably would not result in tsunamis, because they would cause the water column above mainly to shear, not to lift.

But Kerry Sieh of Caltech suspects that an increased risk of a tsunami-spawning earthquake prevails south of the epicenter, where the rupture did not propagate. Sensitive measurements of the region’s contours will be necessary to resolve this question.

Seismometers, tide gauges and other detection instruments now being deployed will make the next tsunami, if not the next earthquake, come as less of a surprise. Still, the coastal areas of Asia face future challenges: cyclones and their attendant surges will take an increasing toll as global warming disturbs weather systems. The devastated communities should ideally be rebuilt on high ground far from shore, where they would be protected by mangroves from the ever rising ocean. But for millions of the poor in crowded countries, such safety may never be possible.

Madhusree Mukerjee, reporting from Kolkata, India, is author of The Land of Naked People: Encounters with Stone Age Islanders, a book about the Andamanese.

WHEN OLD WAYS TRUMP NEW WAYS

Days after the tsunami, an Indian coast guard helicopter flew 50 kilometers west of the town of Port Blair in the Andaman Islands.

There, hovering over North Sentinel Island, it found itself targeted by two-meter-long arrows: evidently the inhabitants are Paleolithic hunter-gatherers who choose to live in isolation. They are one of four groups of Andaman aboriginals, all 500 or so of whom appear to have run to high ground after they felt the earthquake.

“Our forefathers told us,” explains one tribesman, “that when the earth shakes, the sea will rise up onto the land. They said we should run to the hills or get into a boat and go far out to sea.” The Andamanese had a lead time of less than an hour. So while people in the information age groped through phone books to issue a tsunami warning that never arrived, those in the Stone Age had packed up their children, baskets, nets, bows, arrows and embers and run for the hills.

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