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# *Blindsided by Ferocity Unleashed by a Fault*

**By Kenneth Chang**
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On a map of Japan that shows seismic hazards, the area around the prefecture of Fukushima is colored in green, signifying a fairly low risk, and yellow, denoting a fairly high one.

But since Japan sits on the collision of several tectonic plates, almost all of the country lies in an earthquake-risk zone. Most scientists expected the next whopper to strike the higher-risk areas southwest of Fukushima, which are marked in orange and red.

“Compared to the rest of Japan, it looks pretty safe,” said Christopher H. Scholz, a seismologist at the Lamont-Doherty Earth Observatory at Columbia University, referring to the area hit worst by the quake on March 11. “If you were going to site a nuclear reactor, you would base it on a map like this.”

Records kept for the past 300 years indicated that every few decades, part of the Japan trench, an offshore fault to the east of Fukushima, would break, generating an earthquake around magnitude 7.5, perhaps up to magnitude 8.0. While earthquakes that large would be devastating in many parts of the world, the Japanese

have diligently prepared for them with stringent building codes and sea walls that are meant to hold back quake-generated tsunamis.

Shinji Toda, a professor of geology at Kyoto University in Japan, said a government committee recently concluded that there was a 99 percent chance of a magnitude-7.5 earthquake in the next 30 years, and warned there was a possibility for an even larger magnitude-8.0 quake.

So much for planning. Although Japan's foresight probably saved tens of thousands of lives, it could not prevent the vast destruction of a magnitude-9.0 temblor, which releases about 30 times as much energy as a magnitude-8.0 quake. It was the largest ever recorded in Japan, and tied for fourth largest in the world since 1900. Thirty-foot tsunamis washed over the sea walls and swept inland for miles. The death toll is expected to be more than 20,000, and nearly 500,000 are now in shelters.

 MISSING  The search for people in Minamisanriku last week. Japan's foresight probably saved tens of thousands of lives, but couldn't stop vast destruction.

Hiroaki Ono/Yomiuri Shimbun, via Associated Press

“I was surprised,” Dr. Toda said. “Nobody expected magnitude 9.”

This was not the first time scientists have underestimated the ferocity of an earthquake fault. Many were also caught by surprise by the magnitude-9.1 quake in 2004 off Sumatra, which set off tsunamis radiating across the Indian Ocean, killing more than 200,000 people.

Sometimes, scientists are blindsided by earthquakes because they occur along undiscovered faults. The deadly earthquakes in New Zealand this year; in Haiti last year; in Northridge, Calif., in 1994; and in Santa Cruz, Calif., in 1989 all happened along faults that scientists were unaware of until the ground shook.

“It’s shameful, but we’ve barely scratched the surface,” said Ross Stein, a geophysicist with the United States Geological Survey. In California, for instance, scientists have cataloged 1,400 faults, yet for smaller earthquakes — magnitude 6.7 or less — about one in three still occur on previously unknown faults.

“Humbling,” Dr. Stein said.

That raises a worrisome question: How many major quakes are lurking in underestimated or unknown faults?

The basic dynamics of earthquakes have been understood for decades. Earth’s crust is broken into pieces — tectonic plates — which slide and collide. But the sliding is not always smooth. When the plates stick together, they begin to buckle. Stress builds until the ground breaks and jumps, releasing energy in the form of vibrations: an earthquake. Not surprisingly, places close to plate boundaries are beset by earthquakes, while those far from the boundaries are not earthquake-prone.

The largest earthquakes occur in subduction zones, places where an ocean plate collides with and slides under a continental plate, particularly around the edge of the Pacific Ocean.

But some subduction zones seemed to produce more large earthquakes than others. One explanation was offered in 1980, when Hiroo Kanamori of the California Institute of Technology and Larry J. Ruff, now at the University of Michigan, published a paper that said giant earthquakes occurred more often along ocean faults where the subducting ocean plates were geologically young. The younger plates, like those off Alaska and Chile, were warmer, less dense and harder to push down into the Earth's mantle, their thinking went. Meanwhile, the older, colder and denser ocean plates like those off Java and the Marianas trench in the Pacific would sink more easily and not produce the giant catastrophic quakes.

 FOUND  Japanese soldiers carried a body from the rubble in Minamisanriku. Toru Yamanaka/Agence France-Presse — Getty Images

And yet the Pacific plate off Japan is 130 million years old, one of the oldest, and it generated a magnitude-9.0 counterexample. “It is not nearly as straightforward as I thought in the beginning,” Dr. Kanamori said.

Dr. Scholz of Columbia said the recent quake in Japan fit with a theory that he and Jaime Campos of the University of Chile developed in 1995. By their theory, the colliding tectonic plates off Fukushima were stuck, and should have been producing earthquakes. But the absence of spectacular earthquakes in the near historic record disagreed with their theory, and led Dr. Scholz to believe that something unknown was relieving the stress.

“Now we know we were wrong about that” and right in the first place, he said. “It does agree with the theory.”

Dr. Scholz said that patches of the Pacific plate off Fukushima become stuck as the plate moves under Japan. In the more modest earthquakes of the past 300 years, just one patch would break free. This time, he said, the patches ruptured together, producing a more cataclysmic quake. “The past 300 years, that hasn’t happened,” Dr. Scholz said. “So if you’re going to use the past history to extrapolate the future, the last 300 years wouldn’t have predicted the recent earthquake.”

Most regions of the world have less historical data than Japan, making it even harder to judge the earthquake patterns. Haiti is a prime example.

Even the notion of an earthquake fault — a long crack in the earth — is not quite as certain as it once was. Near Landers, Calif., seismologists had identified three faults, each capable of a magnitude-6.5 quake. Then, in 1992, an earthquake shook along all three faults at once, at a magnitude of 7.3.

“This is a controversy through the field right now,” said Peter Bird, a professor of geology and geophysics at the University of California, Los Angeles,, “whether we can say we know the names and lengths of the faults.”

 TOSSED  The tsunami had brought a ship inland from the docks in Kamaishi. Roslan Rahman/Agence France-Presse — Getty Images

In Japan's history, there does seem to have been a precedent for the recent quake, but it took place more than a thousand years ago. A text known as "Nihon Sandai Jitsuroku," or "The True History of Three Reigns of Japan," described an earthquake in July 869 and a tsunami that flooded the plains of northeast Japan: "The sea soon rushed into the villages and towns, overwhelming a few hundred miles of land along the coast. There was scarcely any time for escape, though there were boats and the high ground just before them. In this way about 1,000 people were killed."

These were the same plains that were submerged this month. Analysis of sediments left by the 869 tsunami led to an estimate that the earthquake had a magnitude of 8.3.

Brian F. Atwater, a geologist at the United States Geological Survey, said that a similar situation exists in the Pacific Northwest. Only in the past couple of decades have scientists realized that the seismic conditions of the Cascadia trench off Oregon had the potential to produce a huge earthquake. Warning systems have been built. Evacuation plans have been drawn up.

Another worrisome subduction zone is the 2,000-mile Java trench in the Indian Ocean. Few earthquakes occur there. The ocean plate there is old, so Dr. Kanamori's 1980 observations would suggest little likelihood of a great quake.

But Robert McCaffrey, a research professor of geology at Portland State University, said he no longer believes that geophysicists can distinguish dangerous subduction zones from the not-so-dangerous ones. "We just don't have a long enough earthquake history to make models of subduction," he said.

The only relevant characteristic, he said, is the length of the fault, and he sees the potential for a magnitude-9.6 earthquake in the Java trench. Indonesia, which has not built extensive sea walls and warning systems, would likely be very hard hit.

"That's my biggest fear," Dr. McCaffrey said.

Over the weekend, Dr. Scholz reread his 1995 paper and found that Java's recent quiet did not fit with what his theory predicted. "It must be missing a very big one," he said.

***A correction was made on March 23, 2011****: An article on Tuesday about the challenges of accurately estimating seismic hazards described incorrectly the Java trench in the Indian Ocean, where few earthquakes occur. The*

*ocean plate there is relatively old, not young, and therefore, as the article noted, is less likely to produce a great quake, according to a theory held by some scientists.*

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