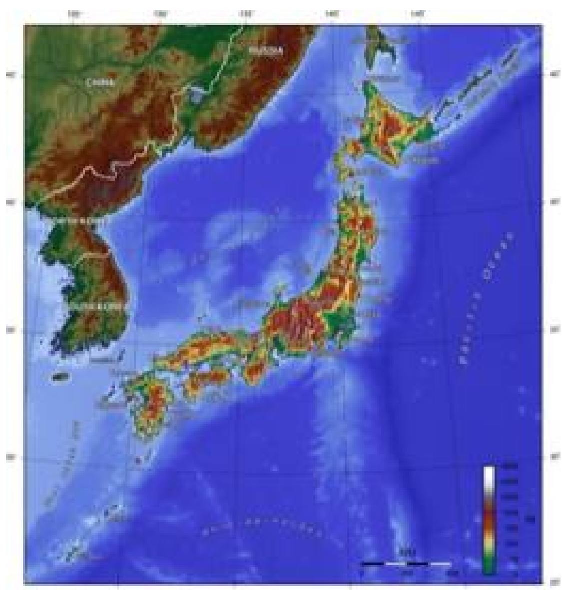
Seeing through the cracks

March 23 2011, By Jennifer Chu



Credit: Wikipedia

While rescue workers in Japan continue their search for missing persons amid the rubble in Sendai and beyond, geologists are sifting through seismic data and satellite images for hints to what caused one of the most catastrophic earthquakes in recorded history. For the past week, scientists around the world have posted charts and maps on blogs and websites to help describe the extent of the quake, and the vulnerabilities that possibly triggered the massive rupture.

So far, data have shown the quake may have redistributed the Earth's mass and moved the planet's axis, increasing its speed of rotation and shortening the day by a fraction of a second. There are also reports that a significant portion of Japan's eastern shoreline dropped off by several feet as a result of motion along a fault line further east where one tectonic plate slid under another. There are reports that the east coast of the island of Honshu may have also shifted to the east as a result of the quake. Scientists observed what may be farther-reaching effects, as the tremor may have also momentarily shifted the position of a large glacier in Antarctica.

Bradford Hager, Cecil and Ida Green Professor of Earth Sciences in the Department of Earth, Atmospheric and Planetary Sciences, says the outpouring of scientific analyses is thanks in part to Japan's extensive monitoring system — a network of thousands of sensors on land and sea that have continuously kept tabs on local seismic energy.

"It's incredible how instrumented this quake is," Hager says. "With a thousand GPS receivers, you can see there's a lot of detail. Having that data will enable us to understand and statistically forecast earthquakes in the future."

It's no coincidence that Japan has one of the most advanced earthquake monitoring systems in the world. The country sits along the "Ring of Fire," a wide arc of active volcanoes and fault lines in the Pacific Ocean that curves around Australia, up along the eastern edge of Asia, and sweeps down the western edge of North and South America. Ninety percent of the world's earthquakes occur along this seismic belt, and Japan experiences approximately 1,500 earthquakes a year.

The massive shock that struck on March 11 occurred within a tectonic zone that typically generates large tremors. Japan lies on two major tectonic plates – the North American plate to the north, and the Eurasian plate to the south. Just south of the Eurasian plate lies the smaller Philippine Plate, and to the east, the massive Pacific plate. Like shuffling in slow motion, these plates shift against each other, creeping along at the rate of almost ten centimeters per year, causing minor or imperceptible tremors.

Leigh Royden, Professor of Geology and Geophysics, says that it's in areas of subduction, where one plate slides under another, where larger earthquakes occur. The titanic tremor on March 11 very likely occurred as a result of stress built up as the Pacific plate slid under the southern sliver of the North American Plate.

"Japan is living on a cauldron of natural disasters, between large quakes, tsunamis and volcanic eruptions," Royden says. "These areas where there's subduction can give rise to mega earthquakes."

Hager says these tectonically active regions usually produce earthquakes in the 7.0 to 8.0-magnitude range. In the past 40 years, there have been about ten earthquakes within this range in the region. It's extremely rare to see a 9.0 magnitude earthquake such as the one on March 11. What's more unusual is that two days earlier, the country experienced a 7.2 magnitude tremor that, at the time, seismologists considered to be the main shock.

"One of the mysteries is what keeps all earthquakes from turning into bigger earthquakes," Hager says. "When a fault ruptures, the local stresses are relieved and get transferred to another fault, so breaking one fault automatically increases the stress levels of other faults."

If those other faults already have built up stress, the added strain could cause them to break in turn, triggering an even stronger earthquake. A map generated by one of Hager's former MIT graduate students may support this theory. Brendan J. Meade, now associate professor in the department of earth and planetary sciences at Harvard University, plotted out the strengths and weaknesses of Japan's surrounding fault lines, and found that the area between the two recent earthquakes contained many stressed, or "locked," faults that were already close to the breaking point. The initial breakage that triggered a 7.2 quake on March 9 could have collapsed surrounding faults in a ripple effect, generating the more devastating 9.0 earthquake two days later.

The March 11 earthquake in turn will continue to shift the balance of stresses along neighboring fault lines, creating aftershocks that may be felt for years, though with rapidly decreasing frequency. However, Robert van der Hilst, Cecil and Ida Green Professor of Earth and Planetary Sciences and director of the Earth Resources Laboratory, says there is always a possibility that an aftershock could break a major fault, setting off another large earthquake. "It is possible that earthquakes in the foreseeable future could indeed relate to what happened last Friday," says van der Hilst. He adds that predicting when such quakes may strike is the "Holy Grail" of earthquake seismology.

While Japan has set the standard for earthquake monitoring, van der Hilst and others want to advance the system to identify signs of tremors earlier. One way is to have even more sensors to monitor signals below the Earth's surface. It is possible that in the future researchers will detect signals that they don't even know exist, but which may be able to alert them to impending shocks. Van der Hilst envisions burying sensors deep within boreholes, much like how oil and gas companies monitor reservoirs, in order to detect significant quake-developing patterns.

"I can imagine in the future there will be more sensors, maybe in boreholes, so you can really listen full-time, like a player of a 4D video game, to see what's going on in the sub-surface beneath a country like Japan,," says van der Hilst.

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