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Living on a Fault Line

A year after the tsunami, scientists fear that another monster earthquake might one day strike Sumatra, triggering a fresh inundation by the sea. How frightened should we be?

BY SIMON ELEGANT | MALIGI

The village of Maligi on the west coast of the Indonesian island of Sumatra seems idyllic—two dozen houses strung along a palm- and casuarina-covered strip of land, on one side the crashing waves of the Indian Ocean, on the other a rippling river mouth. When a rare group of visitors appears in the bright mid-morning sunlight, a dozen children chase after the car, laughing and waving.

"So many kids," American geologist Charles Rubin mutters gloomily as he waves back. "They don't have a chance."

"Nope," agrees fellow geologist Kerry Sieh, also waving and smiling. "They'd all be killed. There's just nowhere to run here. It's water on both sides."

"If they knew what was coming, they might be able to climb the coconut trees and survive," Rubin continues, "assuming the tsunami wasn't too high, say in the four-meter range. They need to build platforms on the trees and maybe cut steps in the tree trunks. They need information. You should give them one of your posters, Kerry."

Sieh nods. A professor of geology at the California Institute of Technology, he probably knows more than any person on the planet about how and why earthquakes and tsunamis happen so often, to such deadly effect, in this part of the world. Sieh and his colleagues on this field trip know how many lives have already been saved by posters and other efforts to educate those who live in a 2,000-km-long danger zone running from Aceh on the northern end of Sumatra to an island off its southern tip called Anak Krakatau, or Child of Krakatau. And they'd like to save some more.

For Sumatra is at risk. In the space of just three months at the beginning of

2005, two giant earthquakes rocked the region. A tremor on Dec. 26 produced a tsunami that knocked the earth off its axis and killed nearly a quarter of a million people. Then, on March 28, came another huge earthquake, this time farther south. There was no large tsunami generated by that temblor—dubbed the Nias quake after the island off the Sumatra coast that was worst affected—but over a thousand islanders died. After two such devastating blows, the inhabitants of Sumatra might be forgiven for assuming that nature will leave them in peace. It probably won't. Sieh, 54, and other scientists are warning that the island's troubles are not over. It isn't as though anybody needed a reminder, but the Oct. 8 earthquake that leveled large swathes of Pakistan and Northern India, leaving some 73,000 dead and millions homeless, could be a small taste of what is to come in Sumatra.

Even by Indonesia's chaotic standards, 2005 was a tough year. First came the gargantuan task of cleaning up and rebuilding after the tsunami—a job rendered more challenging by incompetence, bureaucracy and corruption. Then came the sudden eruption of bird flu that constantly threatened to explode into a major epidemic, and fresh bombings in Bali, which sent the country's tourism industry into a tailspin. But such problems would pale in the face of yet another monster earthquake striking Sumatra. That could kill hundreds of thousands of people. Such a quake, moreover, might trigger not just another tsunami but force a volcano to erupt, as happened with Mt. Talang, which was jolted out of an almost 40-year slumber by the Nias temblor.

How sure can we be that another catastrophe is coming? A combination of historical, geographical and geological research accumulated over some 12 years of painstaking field and laboratory work emphatically suggests that a section of the coast several hundred kilometers long, and populated by more than a million inhabitants, is threatened by the possibility of another shock. "There has never been a more certain geological prediction," Sieh declares. "There will be another gigantic earthquake and tsunami south of the equator off the west coast of Sumatra. It could be tomorrow or it could be in two decades from now, but there is no doubt that it will happen and that if the towns and villages along the coast aren't prepared, many, many people will die again."

Given Sieh's past record, his warnings have to be taken seriously. Sieh didn't foresee the scale of destruction and death wrought by the Aceh earthquake and tsunami. But he and a group of Indonesian and American colleagues had long been warning of the dangers of a massive shock off the coast of Sumatra. They concentrated most of their efforts on the communities inhabiting the string of islands that lie off the coast, an archipelago that sits virtually on top of the epicenter of both the Dec. 26 earthquake and the Nias event. After the December temblor, Sieh warned that a second one was coming. Just three weeks before the Nias shock, he told a reporter that "other parts within the section of this fault should be

considered dangerous," and that the possibility of an imminent tremor was a "major issue." He had just finished preparing a new version of the poster he and his colleagues had been using to alert the islanders to the signs of a tsunami. "The poster was going to press the morning we heard news of the second quake," Sieh says ruefully.

The two shocks were triggered by ruptures in what geologists call the Sunda megathrust, a 3,000-km-long "subduction zone" where two tectonic plates—the vast interlocking sections of the earth's crust which together form the planet's surface—have been butting heads for millions of years. That produces the forces making Sumatra the most active seismic and volcanic region in the world. Under the Indian Ocean 200 km off the west coast of Sumatra, the leading edge of the Australian plate is pushing itself into and under the heavier, higher Sunda plate, an area that encompasses Sumatra.

Both the Aceh earthquake, which at a magnitude of 9.3 was the third most powerful ever recorded, and the one near Nias island, resulted from the sudden release of built-up pressure along the Sunda megathrust, scientists say. But each of those earthquakes released pressure only in one segment. And each *increased* pressure on nearby segments that remained locked. In scientific language, British geologist John McCloskey spelled out the consequences in the journal *Nature* in April: "Calculations show that stresses imposed by the second rupture have brought the megathrust closer to failure."

How can such definite forecasts be made about earthquakes, whose occurrences have been notoriously impossible to predict? "Because of the research that has been done in Sumatra over the last 12 years we now have data for three full cycles of seismic activity in this segment dating back a thousand years," Sieh explains. "That is unique. In no other comparable zone have we been able to assemble anything like such detailed data." Three different strands of research have been woven together. First, the skimpy (sometimes non-existent) historical record was consulted for evidence of past seismic activity. Then current seismic activity in the region was observed from global-position-system (GPS) monitors that Sieh and his team have been installing on the islands since 2001. The sensors, which are capable of measuring earth movements as small as a few millimeters, have allowed scientists to build up a detailed picture of the state of the megathrust under the string of islands on which they are positioned. The data collected during and after the two recent earthquakes was particularly revealing. "One of the monitors we put in place just before the Nias quake caught the biggest vertical movement caused by an earthquake ever recorded—a 15-meter uplift," Sieh says. By the time the whole system is up and running in 2007, it will have cost about $1 million, all raised from research grants, and will boast a string of 40 GPS monitors.

Lastly, and most importantly, Sieh and his Indonesian colleague Danny

Natawidjaja have spent more than a decade examining coral reefs at the islands off the west coast of Sumatra. Using hydraulic chainsaws, the men hacked out cross-sections of huge coral heads that, like the rings on a tree trunk, can provide a remarkably accurate chronological record of past seismic events. The islands lie at the edge of the Sunda plate and are pulled downward 5 cm a year by the force exerted by the Indo-Australia plate. When the built-up pressure is suddenly released in a huge earthquake, the islands—and the corals growing on them—spring back upward by as much as five or ten meters. That usually pushes the corals out of the water, causing them to die and marking for scientists the moment of the tremor. Using this coral calendar, Sieh and Natawidjaja were able to detail a surprisingly consistent cycle of quakes. The segment of the megathrust facing the coast's biggest city, Padang, has recorded three mega-earthquakes in the last seven centuries, they say, first in about 1360, then around 1605 and finally in 1797 and 1833, a pair of tremors that are classed together as one because the second quake was triggered by the first. "That gives us a cycle that averages out at 220 years," says Sieh. "If we calculate from 1797, that would mean that we are due for another quake any time now. And then there's the added pressure on the fault from the two quakes in Aceh and Nias."

Sieh is careful to avoid making any exact prediction about when a new disaster might occur. And some other geologists have raised questions about the sense of urgency and imminent danger that Sieh conveys. Even Sieh himself is quick to say that earthquake prediction is "voodoo science." But the quiet Californian believes that both the historical evidence—"look how quickly Nias came after Aceh: five of eight gigantic quakes that occurred in the last century have been followed by earthquakes of similar or larger magnitude"—and the momentum of the research data points to something happening sooner rather than later.

Who would be most at risk? Sieh and his colleagues are principally concerned about the effect of a quake and tsunami on Padang, a city of nearly 1 million inhabitants strung along a beach halfway down Sumatra's west coast. Several factors add to the worry. One is population size. Banda Aceh, where the tsunami penetrated 8 km inland at some points, killing an estimated 90,000 people, has only a third of Padang's population. Then there's geography: 50% of Padang's population lives within 5 km of the shore. The death toll wreaked by a tsunami hitting Padang could dwarf the 169,000 dead and missing in Aceh, Sieh warns.

A group of Indonesian and German scientists are in the process of installing an early-warning system off the coast of Sumatra consisting of pressure sensors on the seabed and sonar buoys to detect changing wave heights. The system is expected to be fully functioning by 2008 and scientists say that they will be able to tell within 15 minutes of an earthquake whether a tsunami is imminent. When it is finally in place, the system will provide an invaluable extra warning mechanism. But Sieh and

other scientists point out that a tsunami would take half an hour or less to reach Sumatra, making preparations for a speedy and orderly evacuation critical. As yet, though, there doesn't seem to be any sense of urgency in Padang. The city government has set up an Earthquake and Tsunami Command Post. But despite the grand name, the reality is a small shack on the beach that features a hastily drawn map of the city with arrows representing escape routes. Budiman, the 60-something retired civil servant appointed to man the post, says the danger has been exaggerated. "People in Padang should not worry too much," he says with a reassuring smile, as he sits in the post smoking a clove cigarette. "The possibility that a tsunami will hit is very low."

The walls of the command post feature photographs of the only other major initiative taken by the Padang city government: mass prayers at which local cleric and businessman Boy Lestari led three hour-long chants imploring God to spare the city. "There is no better way to prevent a tsunami from happening but to bring yourself closer to Allah," says Lestari, who doesn't believe in the scientists' forecast. "No scientist can predict when a disaster will strike. It is in the hands of God. As long as the sounds of people chanting still reverberate on earth God will postpone the doomsday even, let alone a tsunami."

Padang's mayor Fauzi Bahar says his administration is taking steps to prepare the city's population for a tsunami; including classroom drills for students and the distribution of leaflets showing the location of places of refuge such as tall buildings. But he says that regular evacuation drills and other such practices have a downside: they "add to people's anxiety and fear. That's why I reduced the volume of the alarms so that people aren't too scared. In March, when people's concern was at the highest, there was an exodus of 60% of people from the city. How long can you live that way?"

Some Padang residents have already decided they won't. Real estate agents say that the prices of homes near the shore have halved since the beginning of the year, while the value of buildings on higher ground has shot up. The Nias quake and several heavy aftershocks in early April sent tens of thousands of Padang residents scrambling for the hills, causing massive traffic jams on the main roads leading out of the city. One of those caught in the congestion was 64-year-old Walini. The mother of six was attending a ceremony marking the seventh month of pregnancy for her youngest daughter. "Dishes and glasses flew into the air and we ran out of the house petrified," she recalls. "It lasted less than one minute, but it felt like forever for me." That was enough for Walini, who decided on the spot to abandon her home of nearly 50 years and move her entire family to a rented house on higher ground. The 30-minute drive took three hours because of the crowds fleeing the city. "Since the Aceh earthquake the sound of the waves in my old house kept me awake all night," says Walini. "Now, after moving, I can sleep again."

Mujono, who heads the neighborhood association that covers Walini's old house, says that 15 out of the 60 families that used to live there have moved out. Some people ran as far as Solok, 60 km away. But they were forced to flee back to Padang the next day, Mujono says, after a nearby volcano suddenly erupted. He shrugs. "You can't escape."

Others in the city are less fatalistic. A group of academics, doctors and businesspeople have set up the Tsunami Alert Society. The group aims to educate the populace about the dangers of an inundation and organizes training and equipment needed to minimize the potential loss of life. "Our target is to get people to realize that living in Padang means they have to know what to do if there is a tsunami," says Febrin Anas Ismail, dean of the Engineering Faculty at Andalas University in Padang. "Just like when you are about to fly on a plane, you should know that you have to fasten your seat belt and so on."

So far, the group has carried out three evacuation drills, one of which saw 3,000 people walk to high ground in half an hour, about the time scientists estimate it will take before a tsunami hits if an earthquake comes. "Our aim is to carry out a general evacuation drill for the whole city by the end of the year," Febrin says. The group's members say they have received nothing from the local government except permission to carry out the drills. "The government prefers to calm people down rather than prepare them for the worst," says civil servant Hediyanto Husaini. "There's no sense of emergency despite the scientists' serious warnings. They won't do anything until people get killed in hundreds of thousands."

Calf-deep in a muddy field outside the village of Maligi north of Padang, Charles Rubin and two colleagues are doing their best to make sure that never happens. They hope to use the geological record to measure the size and frequency of previous tsunamis that have hit the west coast of Sumatra. Rubin raises a meter-and-a-half-long steel shaft above his head and plunges the sharpened end downward. As a score of curious villagers watch, he twists the shaft and then slowly extracts it. About a meter of the pole is cut away, leaving only a semi-circular channel, now filled with a cored-out column of earth. Using a pocket knife, Rubin scrapes the round surface of the core flat, exposing a cross-sectional view of the field's geological history for the last thousand or so years. In between two layers of pulpy dark-chocolate-brown peat is a distinct band of grey about two centimeters wide.

"This looks like sand to me," Rubin says excitedly. "It's definitely a candidate for dating." He pokes gently at the grey material, its flaky granular composition visibly distinct from the compost-like peat around it. Carbon-14 dating will determine to within about 50 years when the sand was laid down. If it coincides with one of the big three Padang earthquakes in the past 700 years, Rubin and his team will seek to calculate the size of the tsunami from the thickness of the band of sand.

"If we can find out how big the past tsunamis were, then we can go a long way to letting people living here know what to expect," Rubin says with satisfaction. "We may even discover they were all only in the one- or two-meter range," agrees Sieh. "Or even that there were no tsunamis at all after the earthquakes. Wouldn't that be wonderful?" It would. But for Sumatra's long-threatened people, the past portends a worrying future.

With reporting by Zamira Loebis/Padang

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