Letter from the Desk of David Challinor
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The year 2004 ended with a natural disaster of Armageddon-like proportions, when the submarine earthquake-generated tsunami reached the low-lying shores of Asia in its path. The loss of life and property was on a scale that matched the devastating Chinese earthquakes of the 1920's. This month's letter will consider the mechanism that generated this tsunami and why it caused so much damage.

Although familiar with the term "tsunami," I had not given the phenomenon much thought until the 1950's when I met a fascinating woman who survived one. As a child she was raised in Tokyo where her father published the French language newspaper. She told of going to the beach at Yokohama as a six-year-old with her Japanese nurse in the early 1900's. She recalled watching the ocean suddenly flow rapidly away from the shore, exposing a sea bottom never seen even at the very lowest tides. Her nurse immediately understood what was happening, scooped up the child and ran as fast as she could to high ground. They escaped the huge wave that followed but many others did not. Her story made a deep impression on me and like many other pieces of miscellaneous information, it has remained permanently in my memory.

The 26 December 2004 tsunami was triggered by a massive 9.0 quake (measured as "moment magnitude," not the Richter scale) that lifted parts of the sea floor as much as 5m (16 ft) or more. That sudden movement lifted a volume of water some three miles thick, seven hundred miles long and perhaps fifty miles wide, and sent that much energy through the water, speeding toward unsuspecting tropical shores on a sleepy Sunday morning like a million Pearl Harbors. The epicenter of the quake was near a triple junction, where the India, Australia, and Sunda plates converge, pressuring the water upwards along 700 miles of the deep Java trench where the India plate slides under the small Burma microplate. The epicenter was just south of Simeulue Island, which lies 130km (80 mi) off the northwest coast of Sumatra. The seafloor at the quake epicenter is about three miles below sea level. The extreme depth was an important factor in generating the power of this tsunami because of the enormous volume of the bulge of water forced upwards. By the time the bulge reached the surface off-shore, the wave it created was only about two feet high. Therefore, at sea even directly over the epicenter, one probably could not have detected the wave at all. Although the energy released by the quake is traveling at high speed—over 400 mph—the wave crests are separated widely in the open ocean and can be miles apart. The pulse (the bulge of the water), however, took less than three hours to cross the Bay of Bengal to Sri Lanka—1200 miles to the west. When wave crests are scores of miles apart, they can arrive at a beach 10 to 20 minutes apart.

As the crest approaches shore, especially where the slope of the beach is long and gradual, all of the energy in the original pulse that was distributed about evenly throughout the entire three mile thickness of water becomes compressed as the water depth becomes shallower and shallower. In many cases, there is nowhere for the water to go but up, forming a wave that rises far above the height of an average one. As the ever-rising wave approaches the shore, it sucks the ever-shallowing water into its height, much as one sees surf form on any sloping sandy beach—but amplified. This is important to remember, because if you are at the beach and see the ocean suddenly start receding from the shore, you often have time to run inland to higher ground. When tsunami crests reach shallow coasts, the drag of the sea bottom slows their speed to 20-30 mph. (The energy of the earthquake that is put into the wave becomes stored in the heightening wave, which becomes taller as the ocean depth becomes shallower) Thus, the receding water builds up the forging wave so that when it crashes on the shore it can be as high as 50 feet. The off-shore bottom contour is crucial in determining wave height. The big wave tsunami just described is the most dramatic kind, but other tsunamis caused by submarine landslides, for example, do not always produce such huge waves, but rather—depending on the contours—move landwards like an overflowing swimming pool or a high tide that fails to turn, but keeps on rising.

Perhaps the most catastrophic oceanic event of all happened 65 million years ago before there were any humans to witness it. This occurred when a meteorite estimated to be one or two kilometers in diameter hit the ocean off Mexico's Yucatan Peninsula. The impact created an underwater crater that was discovered only a few decades ago. It is likely that energy, released when the compressed air in front of the meteorite hit the shallow ocean, caused the meteorite to explode, changing it from a solid to a gas instantly. The detritus from the seabed, the vaporized meteorite and the vaporized ocean water lofted into the atmosphere and so darkened the earth that the resulting low temperatures are believed to have been a major cause of dinosaur extinction. The enormous number of craters on the moon illustrate how often it must have been bombarded with meteorites early in its history, yet none seem to have struck it since recorded history.

Although the damage and death from the 26 December tsunami doubtless did not compare with that of the meteorite impact that ended the Cretaceous era, it killed impressive numbers of people with initial estimates hovering around 150,000. Amazingly, no densely populated major cities were inundated by this tsunami, but the figures emphasize the recent rapid population increase in Southeast Asia where, as in the developed world, so many people live along the shore. Had Calcutta, Mumbai or Karachi been in the tsunami's fatal path, the death toll might have been in the millions.

During the XX century, there have been worse natural disasters with drought the most deadly. For example, in 1928 three million people in China alone were thought to have died as a result of the drought that year. India with its teeming population is estimated to have lost 3.2 million people from droughts in 1900, 1942, 1965, 1966 and 1967. Floods, too, cause enormous death tolls and China, as might be been expected, was the hardest hit this past century with a toll of 6.2 million. Even earthquakes have been more deadly than any single tsunami; three in China (1920, 1927 and 1976) each killed more than the December 26 total. Put in perspective this tsunami was indeed deadly, but it was by no means the most lethal natural disaster of the past 100 years.

The relative rarity of tsunamis inundating the coasts of the Indian Ocean meant that there were virtually no coordinated warning systems in place. In fact the earthquake had been precisely recorded at seismic facilities in both India and Sri Lanka, but scientists had no way of predicting the path or even the genesis of a tsunami. They would have needed carefully spaced pressure-sensitive recording devices sunk along the major fault lines of the area that would automatically alert them to the speed and direction of the submarine pressure bulge. The governments of India, Sri Lanka, Burma, Thailand and Indonesia have now started cooperative efforts to create such a warning system.

One footnote to this disaster and to other similar ones is the long-standing myth that dead bodies are a dangerous threat to the survivors. My colleague, Neal Smith at the Smithsonian Tropical Research Institute in Panama, alerted me to several articles on this topic; the most recent one, published in the Pan American Journal of Public Health, was written by Oliver Morgan of the London School of Hygiene and Tropical Medicine. He points out that epidemics that cause high death rates are generated only from relatively few diseases, such as cholera, typhoid, anthrax and formerly plague and smallpox. The pathogens causing infectious diseases cannot survive for long in a corpse. Therefore, the survivors themselves are a far more likely source for a post-disaster epidemic. Sadly, this myth has led to the mass burial of victims before they have been properly identified. The reasons, in addition to disease, for the officials' panic in disposing of numerous dead are complex and seem to encompass all cultures—it will be a hard myth to dispel.

Can there be bright side to a disaster of this magnitude? In very guarded terms the answer is "yes." We can be thankful that we are living on a dynamic planet, whose ever-shifting plates float on a sea of molten rock (magma). There is no evidence yet that any other body in our solar system has such a geological equivalent, and it is quite possible that having this seemingly rare characteristic may have allowed life to evolve on earth. We know, for example, of the bizarre life forms that live along the active vents in the abysmal depths—crabs, worms and even fish. Some scientists think that these vents were the loci for life. The concept that surface plates slide under each other and are thus forced down into the bowels of the earth is only about 50 years old. I clearly remember a talk by Tuzo Wilson, the eminent Canadian geophysicist, at the Museum of History and Technology on the hot new topic of plate tectonics that he gave in the early 1970's; what is now generally accepted came like a bolt from the blue. The earth's surface is constantly renewing itself—mountains form, volcanoes spew mineral-rich material into the atmosphere, which eventually settle on the earth's surface to produce the fertile soils from which we benefit. We humans are recently evolved, short-lived mammals and it is hard for us to encompass the truly big picture; thanks to astronomers and geologists measuring time in light years or geological eras (e.g. Cambrian, Triassic, etc.), many lay people are beginning to grasp the inevitability or even the necessity of such temporarily destructive earthquakes, volcanic eruptions and meteorite collisions as an integral and essential phenomena for the sustenance of our planet. The humility engendered by such thinking should prove a welcome antidote to our arrogance and hubris.

The earth has existed for a few billion years and theoretically should continue to support life (although not necessarily human) for another few billion until the sun burns out and our solar system collapses. Trying to contemplate these time scales is daunting, but it does cause us to stretch our minds and rejoice in our ability as humans to grapple with the inevitable disasters that are beyond our control; they will continue to bedevil those of us who could be its victims.

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