



## Anatomy of a Tsunami

**I**T IS SAID THAT THE WORD TSUNAMI, derived from tsu (harbor) and nami (wave), originated with Japanese fishermen who, upon returning to port after fishing in the seemingly tranquil open ocean, found that the area surrounding the harbor had been destroyed by giant waves. Tsunamis are among the most devastating and destructive of geologic phenomena, as evidenced by the recent event in northern Japan and the Indian Ocean tsunami in 2004.

Tsunamis usually originate along tectonic plate boundaries. The crust, or lithosphere, of the earth is composed of a mosaic-like structure of plates, the positions of which are constantly shifting. There are three types of plate boundaries: convergent, where two plates collide and one is subducted beneath the other; divergent, where the plates move away from each other; and transform, where they slide past each other. By far, the most destructive tsunamis occur along convergent plate boundaries.



Unlike a normal wave, which travels along the surface of the water, tsunami waves travel through the total depth of water. This allows them to reach incredible speeds, up to 500 mph, enabling them to cross an entire ocean in less than a day.

### OTHER CAUSES OF TSUNAMIS

Although most often associated with undersea earthquakes, tsunamis can also be triggered by undersea landslides, volcanic eruptions, avalanches, the melting and breaking of icebergs away from glaciers, and even meteor impact. Scientists have found evidence of an asteroid collision that occurred 3.5 billion years ago and generated a tsunami that swept around the earth several times. It inundated everything but the tallest mountains, drastically altering the configurations of the continents, and eradicating almost all land life that existed at that time.

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### THE "RING OF FIRE"

The Pacific Ocean is encircled by a horseshoe-shaped zone of convergent plate boundaries, which renders it the most tsunami-prone ocean in the world. Also known as the "Ring of Fire" due to the preponderance of volcanoes (over 450), this zone encompasses about 25,000 miles of nearly continuous oceanic trenches, volcanic island arcs, and volcanic mountain ranges.

Tsunamis are typically generated by large, shallow earthquakes with an epicenter on or near the ocean floor. A tsunami is not a single wave, but a series of waves that propagate outward from the site of the initial disturbance.



Geotechnical Engineering  
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### Earth Systems, Inc.

San Luis Obispo  
(805) 781-0112  
Toll free (866) 781-0112

### Earth Systems Global Inc.

Bermuda Dunes  
(760) 345-1588

Beijing, China  
(86) 10-5864-1836

### Earth Systems Pacific

San Luis Obispo  
(805) 544-3276

Hollister  
(831) 637-2133

Milpitas  
(408) 934-9302

Salinas  
(831) 422-8547

Santa Maria  
(805) 928-2991

### Earth Systems Southwest

Bermuda Dunes  
(760) 345-1588

Rancho Cucamonga  
(909) 484-5455

### Earth Systems Southern California

Palmdale  
(661) 948-7538

Pasadena  
(626) 356-0955

Van Nuys  
(818) 901-8075

Ventura  
(805) 642-6727

### Consultant's Corner

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Editor: Margaret McQuade  
(mmcquade@earthsystems.  
com or 805.544.3276)

# The Rose Bowl Renovation Project

## Earth Systems Southern California Provides Key Services

A National Historic Landmark, the Rose Bowl Stadium ("America's Stadium") has had many remodels and additions in its 89-year history. And now, a 152 million dollar Renovation and Improvement Project is underway that will improve public safety and enhance fan experience while maintaining the historic qualities of the stadium. Earth Systems Southern California provided geotechnical engineering design and consultation services during the design phase of the project. Mr. David Murray and Mr. Mark Russell of ESSC, project manager and geotechnical engineer respectively, attended the ground breaking ceremony on January 25, 2011. ESSC's services have included geotechnical engineering investigations, a storm water infiltration study, a geologic hazards assessment, a geophysical survey, and an earthquake ground motion study. ESSC is also providing construction monitoring of micropiles, soldier piles and tiebacks, mat foundations, tunnels, grading, and materials testing and inspection services during the three-year construction schedule.



Mr. Murray and Mr. Russell (left to right) at the Rose Bowl project ground breaking



Micropile load testing

The lineage of Rose Bowl Stadium can be traced back to January 1, 1890, when the Valley Hunt Club in Pasadena staged a parade of flower-decorated horse and buggies and public games including foot races, tugs of war, and a jousting tourney of rings. An audience of 2,000 watched the event, which was dubbed the Tournament of Roses. The site was called Tournament Park and it was home to annual college football games, chariot races, ostrich races, and even an elephant-camel race. By 1920 the facilities at Tournament Park were deemed unsafe to host the growing number of attendees on New Year's Day and so in 1921, the horseshoe-shaped Rose Bowl stadium was built on 10 acres of land previously purchased by the City of Pasadena. The new stadium had a seating capacity of 57,000 and was designed by Myron Hunt. Besides the New Year's Day football games, the Rose Bowl has hosted other major events through the years: the cycling events during the 1932 Summer Olympics in Los Angeles; the soccer competition during the XXIII Olympiad in Los Angeles in 1984; six Super Bowls; the 1994 Men's World Cup soccer games; and the 1999 Women's World Cup soccer games. During the three-year construction time table for the renovations and improvements, the stadium will continue to host football games and other events. ■

## Earth Systems Holds Annual Technical Seminar

The Earth Systems' technical seminar was held February 25, 2011 in Pismo Beach, California. The two-day seminar is held on an annual basis to provide information regarding new developments in the fields of geology, geotechnical engineering, geophysics, environmental assessment, and materials testing, as well as changes in industry practices, building codes or governmental requirements. Geoprosessionals from Earth Systems' offices throughout California attended the seminar. Topics included geophysics, forensic studies of damaged structures, environmental remediation, and use of shear pins for projects affected by landslides or lateral spreading. Contech Construction presented information regarding the use of geogrids for subgrade stabilization and new pavement construction. ■

## The Kitchen Sink



A MATHEMATICIAN, A PHYSICIST, AND AN ENGINEER were given a red rubber ball and told to find its volume. So the mathematician measured the diameter and evaluated a triple integral. The physicist filled a beaker with water, put the ball in the water, and measured the total displacement. And the engineer looked up the model and serial number in his red-rubber-ball table.

AT THE GREAT CENTENNIAL EXHIBITION IN PHILADELPHIA, Pennsylvania in 1876, inventions and curiosities were displayed in 67 buildings spread across a square kilometer. Eight million people paid 50 cents each to view such new wonders as Bell's telephone, Edison's telegraph, the Otis brothers' steam elevator machine, a refrigerated railroad car, a soda fountain, and a typewriter. From France, the first completed part of the Statue of Liberty, the 50-foot high right arm and torch, arrived and was on display.

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### Anatomy of a Tsunami *continued from page 1*

The highest tsunami wave ever recorded was related only indirectly to an earthquake. It occurred on August 9, 1958, in Lituya Bay, a tidal inlet on the northeast shore of the Gulf of Alaska. An earthquake loosened an estimated 40,000 cubic yards of rock from a mountain ridge along the bay. The rock dropped 3,000 feet into the inlet, generating a local tsunami that reached a height of 1700 feet above sea level.

#### NOT ALL EARTHQUAKES GENERATE TSUNAMIS

Whether a tsunami will occur following an earthquake depends upon several factors: the strength of the earthquake, the type and direction of the earthquake's motion, and the topography of the ocean floor. Usually, it takes an earthquake with a Richter magnitude of at least 7.5 to trigger a major tsunami. The type of fault movement is also very important. When fault movement is vertical, the upward shift in the sea floor displaces large volumes of water, potentially triggering a tsunami. Where fault movement is horizontal, little if any vertical displacement of water occurs and tsunamis are much less likely.

The water depth and the topography of the ocean floor play a role in the eventual impact of a tsunami upon the shoreline. While traveling through open ocean, tsunamis can be less than a foot high and often go undetected by ships. As they approach the shore, the waves are slowed by friction with the ocean floor, causing the top of the wave to move faster than the bottom. This can result in a dramatic increase in the wave height. Often, however, tsunamis are expressed as surges of water similar in appearance to a rapidly rising tide. A sudden receding of the ocean can be a warning sign of an impending tsunami.

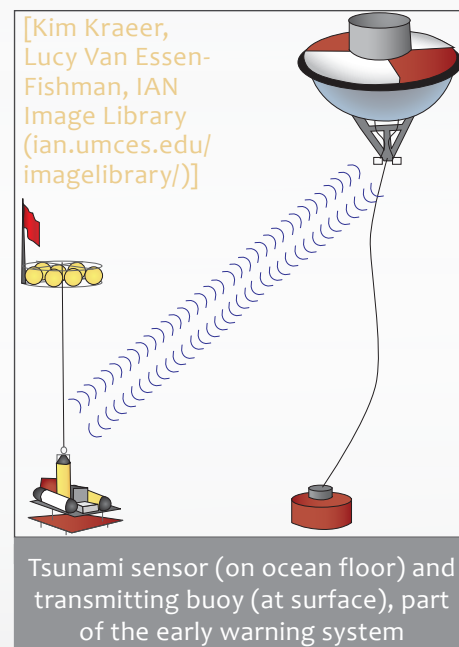
#### TSUNAMI RISK ALONG THE CALIFORNIA COAST

Much of California's coast is characterized by steep bluffs which provide protection from the damaging effects of tsunamis. Exceptions are the low-lying coastal plains around Los Angeles and Orange Counties, some areas near San Francisco, harbors, and places where major rivers meet the ocean.

The most likely sources of a tsunami-generating earthquake that would affect California are the major

subduction zones south of Alaska and the Aleutian Islands, and the Cascadia subduction zone off the Mendocino coast in northern California. The Alaskan and Aleutian subduction zones have ruptured numerous times during the last 100 years, most notably producing the magnitude 9.2 Alaska earthquake of 1964, which generated a massive tsunami that resulted in 123 deaths, thirteen of which were in California. The Cascadia subduction zone is a 750-mile long offshore fault system that extends from northern California to southern Canada. The last major rupture occurred in 1700, when a magnitude 9.0 earthquake generated a tsunami that reached the coast of Japan. Some geologists speculate that a large earthquake on the Cascadia fault system may be due; many experts consider a significant rupture along this system poses the biggest tsunami threat to the coast of California, with the first destructive waves able to reach some coastal communities within 30 minutes. Ironically, the San Andreas fault, which is generally considered to be the state's most dangerous fault, is not likely to generate a tsunami, in part because it is a strike-slip fault that typically produces horizontal rather than vertical motion.

Although we cannot prevent the occurrence of a tsunami, loss of life from such an event can be minimized by increasing public awareness and improving early warning systems. Those who live in or visit coastal areas should learn to recognize the signs of an impending tsunami, and international efforts are needed to improve early warning systems, especially for those tsunamis that could reach our coastlines in minutes rather than hours. ■

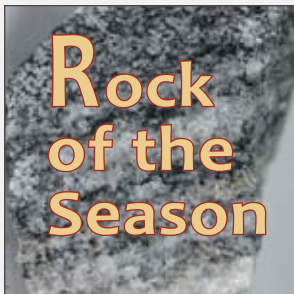




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## Serpentinite

**N**amed for its resemblance in appearance and texture to snakeskin, serpentinite rocks exist worldwide and largely consist of serpentine minerals, a series of magnesium-rich silicate minerals. Serpentinite rocks are formed through forces like heat, pressure, and hydromineralization on igneous and sedimentary rocks. Of the many types of serpentinite in the serpentine group, the three most common are antigorite, chrysotile and lizardite.

Chrysotile is a form of asbestos. Because of qualities such as heat resistance and sound absorption, it has had many industrial applications for over 150 years. Its use is now limited, due to the health hazards of inhaling asbestos fibers that have been released into the air. If serpentinite is found in its natural state where major earthwork is planned, testing for asbestos content is

recommended. In 1965, California designated serpentine as its state rock. Legislation is pending to remove it from this status because of the asbestos-related health concerns. But it turns out that serpentine has potential health and environmental benefits. It has the ability to chemically fix carbon dioxide into the solid mineral magnesium carbonate, and thus it may be possible to use it to sequester carbon from greenhouse gases. Also, serpentine grasslands and outcrop areas are a haven for native plant communities. The grasslands and outcrops are formed in areas where low density serpentinite has worked its way up through weaknesses such as fault zones in the Earth's crust. The soils derived from the rock are poor in plant nutrients and rich in heavy metals, and are shallow and easily erodible. Native plants have adapted to these inhospitable conditions. In California, the Tiburon Indian Paintbrush, the Santa Clara Valley Dudleya, the Fountain Thistle, the Black Jewelflower and the Dwarf Rattlesnake Plantain grow on serpentine grasslands and outcrops, which are also host to spring wildflowers like California's orange poppies.



Mariposa growing on serpentine outcrops on Figueroa Mountain, CA

From antiquity to modern times, serpentinite has been used to make ornamental, decorative, and ceremonial objects. Lizardite, named for its type locality on the Lizard Peninsula, Cornwall, England, is the predominant type of serpentinite present in serpentine marble. Antigorite is the variety of serpentinite most often used in jewelry making.

In some Native American cultural traditions, serpentine is associated with the southern direction and represents heat, magnetism, and transformation. ■

*"You can't wring your hands and roll up your sleeves at the same time."*

*—Pat Schroeder, former congresswoman*