Taking Seismic Science into the Third Dimension

3D Models Help Predict Shaking Vulnerability in Your Neighborhood

By Tania Larson

During the Loma Prieta earthquake in 1989, 42 people were killed when the Cypress Structure, the freeway approach to the Bay Bridge from Oakland, Calif., collapsed. But it wasn't just the strength of the earthquake that contributed to its fall. There were factors beneath the Earth's surface that made this location particularly vulnerable to earthquake shaking.

Remember the parable of the wise man who built his house upon the rock and the foolish man who built his house upon the sand? Well, the principle is still true today, and a new tool from the USGS is taking it to a whole new level. The USGS has created a 3D geologic map and seismic-velocity model of the upper 30 miles of the Earth's crust in the greater San Francisco Bay Area and much of Northern California.

"The new 3D model is a result of the long and productive collaboration between the California Geological Survey and USGS," said California state geologist John Parrish. "Its usefulness will be to test and predict the intensity and effects of shaking in future earthquakes and to build safer structures. This will be cost saving and life saving for residents of the Bay Area, now and in the future."

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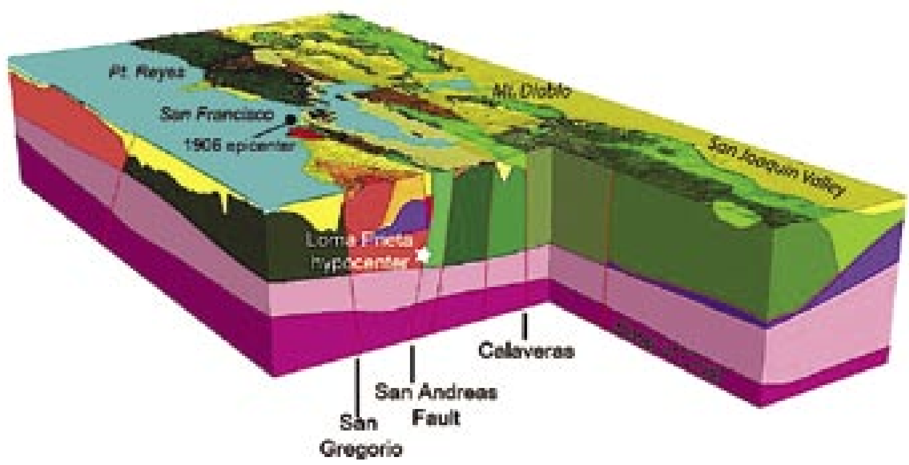
— Tom Brocher



Oblique view, looking from the southwest toward San Francisco Bay: The corner of the 3D Geologic Model has been cut away to show faults (red lines), basins (yellow) and other geologic rock units (various colors). By incorporating geologic features, scientists have created a powerful new tool to help protect people and their investments by showing where earthquake shaking is likely to be more intense.

Most loss of life and property damage during earthquakes stems from the effects of strong ground shaking, and scientists have shown that how long and how strongly a building will shake is directly influenced by the properties of the Earth beneath it. The Loma Prieta earthquake provided the first set of recordings of the levels of shaking on a wide variety of geologic materials, including soft, unconsolidated sand and clay.

These records clearly documented that ground shaking is much more violent on the soft sediments around the Bay margins than on bedrock. They also showed that differences in the Earth's crust can affect how seismic waves move through the ground. For example, at least two properties of the Earth's crust worked together to cause the collapse of the Cypress Structure. First, the structure was built on loose soils that shook much more strongly than surrounding regions on stronger ground. And second, there were variations in the thickness of the Earth's crust between the hypocenter and Oakland that actually focused energy toward Oakland and downtown San Francisco.

The 3D model is an important scientific advancement that combines 100 years of surface geologic mapping with decades of research into the seismic properties of rocks. It also incorporates information from boreholes and variations in the Earth's gravity and magnetic fields. In creating the model, scientists broke the upper 15 to 30 miles of the Earth's crust into irregular shaped blocks bounded by faults, making it a "fault and block" model. Since seismic waves can bounce off faults, bend and be focused as they cross faults, and be trapped and amplified in buried basins, the inclusion of subsurface faults and basins provides important information.

By pulling all of this information together, the model developers have created a powerful new tool for earthquake science. "We expect this new 3D model to revolutionize our ability to forecast the location of 'hotspots' — where shaking occurs most intensely — throughout the Bay Area," said Tom Brocher, USGS seismologist and co-developer of the model. "For the first time, we have a tool that allows us to forecast the strong shaking likely to be produced by large Bay Area earthquakes on a neighborhood-by-neighborhood basis."

In addition to helping researchers forecast strong ground motions that may damage buildings, essential infrastructure and levees, the 3D model will help locate earthquakes more accurately; predict where destructive liquefaction of the ground may occur; and model permanent ground deformation that may be produced by earthquakes, including ground subsidence that could cause flooding. The 3D geologic map was also built with the flexibility to serve other needs in the future. Researchers are already using it to study what happens when the crustal plates that meet in California move slowly past each other, and future refinements will help scientists study groundwater movement and toxic contaminant dispersion.

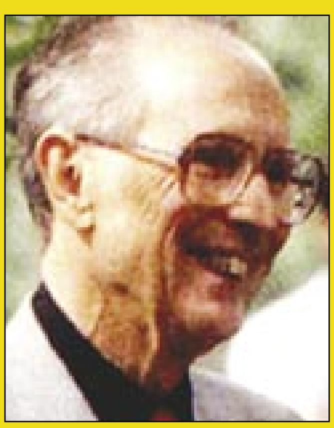
This information will help not only scientists, but residents, lawmakers and building designers. Chris Poland, president of Degenkolb Engineers, said, "The 3D velocity model will provide a much more detailed definition of the intensity of shaking."

With more detailed information, builders will have a better idea of how to tailor construction to fit the location, protecting people and their investments.

"There are hundreds of billions of dollars of new construction each year in high seismic regions," said Poland. "The more we can design for the proper amount of strength and durability, the more we can achieve cost efficiencies, perhaps in the billions, while giving people greater safety during a large, damaging earthquake."

USGS developers of the model include Thomas Brocher, Robert Jachens, Russell Graymer, Carl Wentworth, Bradley Aagaard and Robert Simpson.

USGS Earthquake Scientists — A Nationwide Notion of Pride



Jack Townshend

Title: Special Projects Coordinator, USGS Geomagnetism Group

Location: Fairbanks, Alaska

Length of service with the USGS: 33 years

I remember the magnitude-9.2 Good Friday earthquake in Alaska on March 27, 1964. I was chief of the U.S. Coast and Geodetic Survey's Geomagnetic and Seismological Observatory at the University of Alaska, Fairbanks (The Observatory was transferred to the USGS in 1973.)

The house my family and I lived in was on the observatory grounds. We were 300 miles from the earthquake's epicenter, but I remember feeling the shaking and hearing the observatory's earthquake warning alarms. I rushed to the instrument room and saw red ink splashed all over the place. Visual seismographs used at the time had inkwells, and the instruments had been shaken off their piers. The magnetic instruments were also askew. I called in the staff, and a few hours later, we had most of the instruments back up and working.

Later that night, I made a decision to do a preliminary intensity assessment in the Anchorage area. I managed to get on a flight chartered to fly doctors from Fairbanks to Anchorage to assist with medical care. We couldn't land until daylight because the airport tower was down and much of the runway was damaged. When we finally landed, I flagged down a car and driver and asked for a ride into town. The driver was a chief flight engineer with a major airline whose commercial jet had been grounded because of damaged runways. He volunteered to drive me around Anchorage and outlying areas to assess the damage and take photos.

After assessing the damage from the ground, we stopped at a useable airstrip, and I asked for a piloted plane to survey the landscape even further out and from the air. I was told that if I could find a pilot, they would lend me an airplane. Fortunately, I had a pilot with me! We flew around for a few hours taking photos and assessing the damage until the FAA restricted the airspace we were flying and instructed us to land.

The results of this and subsequent assessment trips were published by the Alaska Division of the American Association for the Advancement of Science, 1964 Proceedings of the Alaskan Science Conference held at The University of Alaska in Fairbanks, titled, Preliminary Intensity Evaluations of the Prince William Sound Earthquake of March 28, 1964, U.T.