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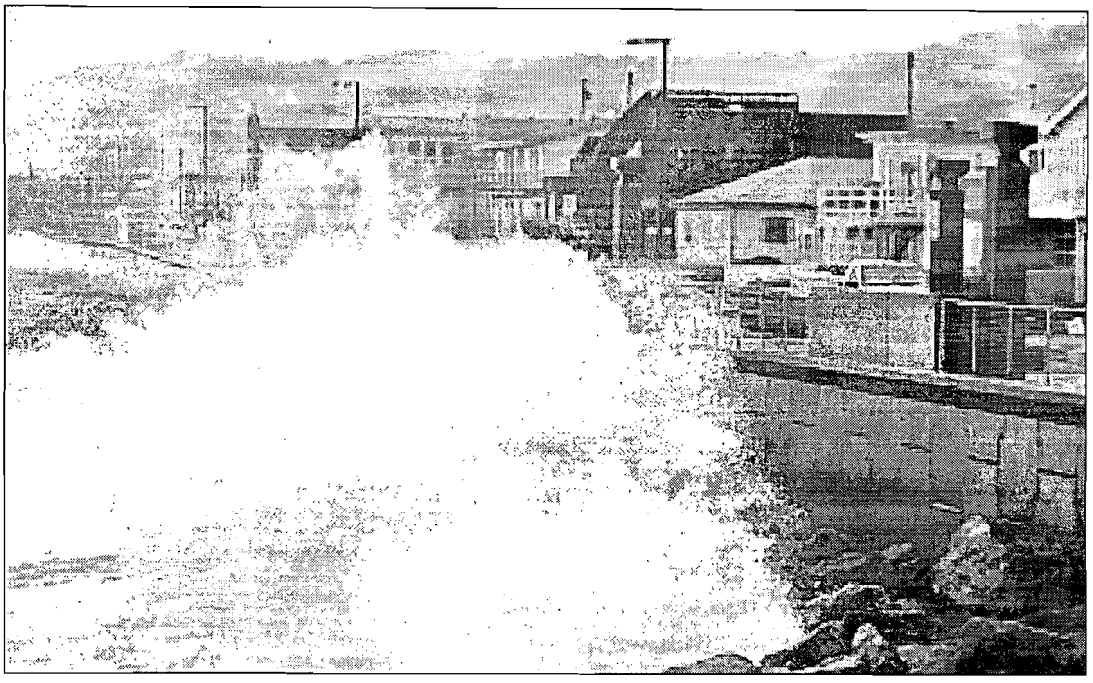
DROUGHT WATCH

Rising sea: 'It's not going to stop'

As oceans surge globally, the Pacific's diminished levels will reverse, experts say.

MATT HAMILTON



PAUL SAKUMA Associated Press

WAVES POUND a sea wall in Pacifica, Calif., in 2010. Ocean levels could rise by 3 feet or more globally by the end of the century, new NASA measurements show.

Here's one trend California is behind on: rising sea levels.

For the last 23 years, ocean levels around the world have climbed by about 3 inches on average, and NASA scientists say the sea will continue to rise as warming temperatures cause ice sheets in Greenland and Antarctica to melt.

But California, and the rest of the western United States, has actually seen ocean levels fall. That's about to change, thanks to a shift in weather patterns, and scientists are sounding the alarm.

New satellite measurements from NASA suggest that ocean levels could rise by 3 feet or more globally by the end of the century. The question faced by scientists and policymakers is not whether oceans will rise, but how fast and by how much.

"People need to be prepared for sea level rise," said Joshua Willis, an oceanographer at NASA's Jet Propulsion Laboratory in La Cañada Flintridge. "It's not going to stop."

If ocean levels are rising, where is the additional water coming from?

Steve Nerem, a scientist at the University of Colorado, Boulder, said that about one-third of the rising sea level is a result of the ocean expanding as it absorbs heat trapped by greenhouse gases and becomes warmer. Another third comes from melting glaciers, and the rest comes from the melting of enormous ice sheets in Greenland and Antarctica.

How much ice is actually melting in Greenland and Antarctica?

During the last decade, Greenland's ice sheet lost about 303 gigatons of ice on average each year, while Antarctica's ice sheet lost about 118 gigatons annually on average. One gigaton is a billion metric tons.

Why did California's sea level fall during the last few decades?

Waters off the coast of the western U.S. have had lower surface temperatures, largely because of the Pacific Decadal Oscillation, or PDO. This pattern of wind, ocean current and temperature variations can bring warm or cold phases for several years — or even decades. Since 1998, some scientists say, we have experienced a cold phase that

has counteracted the effects of climate change and prevented sea levels from rising.

Will California's sea levels always be lower than elsewhere?

No, and scientists say a reversal in the Pacific Decadal Oscillation could cause sea levels to catch up to increases seen elsewhere. According to JPL's Willis, current measurements indicate that a switch in the PDO already occurred.

"We can expect accelerated rates of sea level rise along this coast over the next decade as the region recovers from its temporary sea level 'deficit,' " Willis said.

Does this have anything to do with El Niño?

Yes. Some climatologists think of El Niño as a short-term phenomenon that lies on top of the more longterm temperature fluctuations associated with the Pacific Decadal Oscillation. Warmer PDOs are more conducive to El Niños.

What are we supposed to do about rising sea levels?

The key word stressed by scientists: planning. Tom Wagner, cryosphere program manager for NASA, said communities along coastal zones should factor in the increase in sea levels when considering major infrastructure projects such as a water treatment plant or power plant. Rising sea levels could mean more erosion or flooding associated with a storm surge, he said.

What's the likelihood that sea levels stay the same or actually fall?

Don't count on it. Over the next century, the sea may rise between 1 1/2 and 3 feet or possibly more, said Eric Rignot, a research scientist at JPL and a professor at UC Irvine. And ice sheets react to warming by

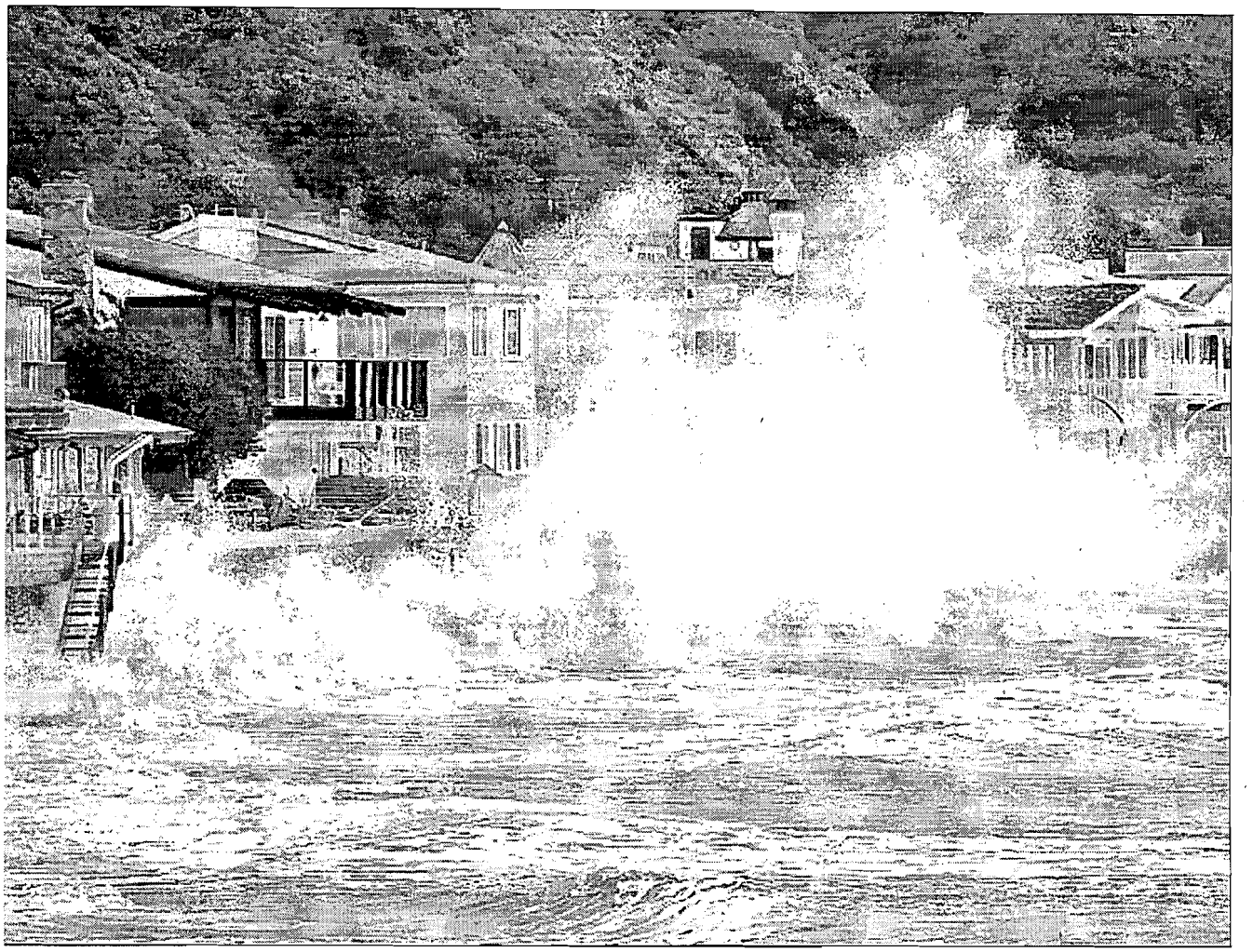
melting faster and faster. Any reversal of the inevitable ice melt "would take centuries," he said. "Some of the measurements collected by NASA are an important red flag on what's about to come." matt.hamilton@latimes.com Twitter: @MattHjourno

EARTHQUAKE WATCH

A new Ventura tsunami scenario

Floodwaters would hit areas once thought to be out of reach, a study suggests

RONG-GONG LIN II



AL SEIB Los Angeles Times

WAVES POUND near homes in Ventura,during a winter storm in 2010. A new study focuses on a hypothetical scenario in which a magnitude 7.7 earthquake strikes nine miles under the Earth's surface northeast of Santa Barbara, creating a tsunami.

In recent years, some scientists have been warning that Ventura County is at greater seismic risk than previously thought.

Now, a new study has found that a major quake in the area could pose a heightened tsunami threat.

A study by UC Riverside and U.S. Geological Survey scientists published Tuesday said tsunami floodwaters could reach points in the Ventura vicinity beyond the area currently marked in California's official tsunami inundation map. Tsunami wave heights could approach 20 feet in the Ventura Harbor and Channel Islands Beach area near Oxnard.

A California Geological Survey official said the agency would study the report. The agency is creating a second edition of tsunami inundation maps after publishing the first version about six years ago.

The latest study comes amid new focus on the earthquake faults that stretch deep under the Santa Barbara and Ventura areas. Previously, some seismic experts thought that the faults in the area posed only a moderate threat. But research in recent years suggests they are connected in a way that could cause a magnitude 7.7 to 8.1 earthquake.

The latest study focuses on a hypothetical scenario in which a magnitude 7.7 earthquake begins nine miles under the Earth's surface, under the mountains northeast of Santa Barbara.

The earthquake starts on a deep fault — the Lower Red Mountain fault — then moves to the shallower Pitas Point fault under the Pacific Ocean. The quake thrusts up the earth north of the fault, lifting up the seafloor permanently and creating a tsunami.

Tsunami waves then spread northward and southward. Santa Barbara itself is largely protected from tsunamis by coastal bluffs, but parts of the Ventura and Oxnard areas are particularly at risk — especially in neighborhoods around the ports at sea level.

"Ventura and Oxnard have lower-lying topography. That region is flatter than other regions around it," said Kenny Ryan, lead author of the study and a geophysics graduate student at UC Riverside. "It's kind of a bad place to have a tsunami propagate into, because a tsunami can propagate into lower-lying lands easier than they can steeper ones."

The study includes a map showing areas outside of the state's tsunami zone that could be at risk of tsunami floodwaters. Some of the new areas now labeled at risk appear to be sparsely populated farmland. Other areas are close to the state's existing tsunami line.

Such a magnitude 7.7 earthquake in the Santa Barbara and Ventura County area would be a rare, devastating temblor for California. There have been only a handful of such earthquakes to strike California since it became a state: the magnitude 7.9 earthquake on the southern San Andreas fault in 1857, a 7.8 temblor in the Imperial Valley in 1892, and the great San Francisco earthquake of 1906, also a 7.8.

Given how the devastating magnitude 9.0 earthquake and tsunami was to Japan in 2011 — and how surprising it was to scientists — it is important to consider how to prepare for such rare earthquakes, said study coauthor David Oglesby, geophysics professor at UC Riverside.

"I think it's worth investigating," he said. "Certainly you can't rule this event out.... We wouldn't simulate it if it wasn't plausible."

The most surprising thing about the study, Oglesby said, was how the tsunami wave initially moved south from the fault and then turned sharply east toward Ventura.

The main reason for that is the western part of the tsunami strikes deeper water first, and begins moving faster than the tsunami's eastern flank.

Like a rowboat where an oar on one side starts moving faster, the entire tsunami alters course and heads straight toward Ventura.

The study was written with Eric Geist, a U.S. Geological Survey tsunami modeler, and Michael Barall, an expert in the development of fault modeling software, in addition to Ryan and Oglesby.

It was funded by the Southern California Earthquake Center, which receives money from the U.S. Geological Survey and the National Science Foundation.

The study was published in the journal Geophysical Research Letters, a publication of the American Geophysical Union. ron.lin@latimes.com Twitter: @ronlin

'Ventura and Oxnard have lower-lying topography. That region is flatter than other regions around it.'
— KENNY RYAN, study author and geophysics graduate student at UC Riverside

(ALL THE CLIMATE AND CULTURE THAT'S FIT TO BLOG)

Ventura stands on deep, dangerous fault system: VC Star

KITSTOLZ@YAHOO.COM • JANUARY 5, 2014 • DISASTER, PRESS ISSUES, THE LAND, VENTURA COUNTY

Several new studies funded by the Southern California Earthquake Center have identified Ventura as a hot spot for geological activity, with a fault running directly under downtown potentially far more dangerous than previously believed.

If the fault ruptures along its length and involves other faults, it could cause a major earthquake and massive damage, with the possibility of a strong local tsunami, researchers say.

Here's a story on the front page of the Ventura County Star about the "high hazard" the city and the region face from a network of earthquake faults.

My editor at the paper gave me a go-ahead to attend a scientific conference last month, and added a pretty wonderful graphic, and made this story free to the public on line for at least a day, all of which show it matters to the paper and all are facts for which I'm grateful.

But I hope this story doesn't get a whole lot bigger.

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VENTURA EARTHQUAKE FAULT MORE DANGEROUS THAN PREVIOUSLY THOUGHT, GEOLOGISTS SAY

Several new studies funded by the Southern California Earthquake Center have identified Ventura as a hot spot for geological activity, with a fault running directly under downtown potentially far more dangerous than previously believed.

If the fault ruptures along its length and involves other faults, it could cause a major earthquake and massive damage, with the possibility of a strong local tsunami, researchers say. The Ventura research was presented at an American Geophysical Union conference last month in San Francisco.

"We have a multiplicity of concerns about Ventura," said Thomas Jordan, who directs the USC-based center.

"The Ventura fault that runs right through downtown is a very active structure, and Ventura County is an area with many big thrust faults, including San Cayetano, Red Mountain and Pitas Point.

"If you have a 7.3 out in the desert where there's nothing but a small Marine base, it's no big deal. But if you put a magnitude 6.3 in the middle of a city, there's hell to pay, and the fault in downtown Ventura is capable of a lot more than that."

Using holes drilled about 75 feet deep in a corner of the Ventura College campus, as well as sounding methods at various sites along Day Road in Ventura, researchers found evidence in the layers of stratification of a large earthquake 770 to 1,020 years ago.

The earthquake made a scarp — a fold in the Earth like a fold in a rug. Over hundreds of years, deposits from floods covered and smoothed it out. Today, it's a

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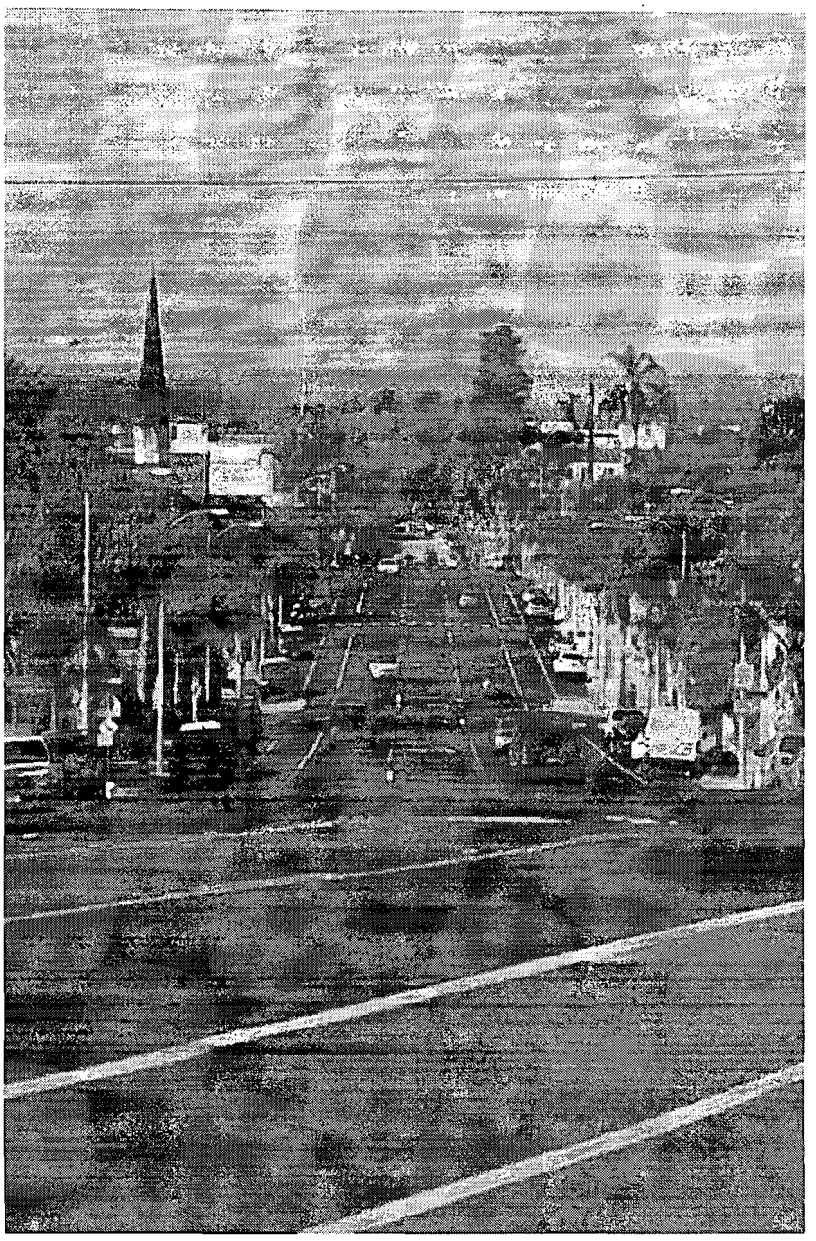
gentle slope more or less along Poli Street and Foothill Road, not far from the base of the hills overlooking Ventura.

[a pic of the slope from the paper]



Note: Researcher Judith Hubbard, who graduated from Harvard in 2012, gave me a couple of charts that illustrate literally at a deeper level what is going on, and encouraged me to use them, so here are two profiles that show how deep the Ventura fault was thought to be in 1982 and how deep we think it goes today.

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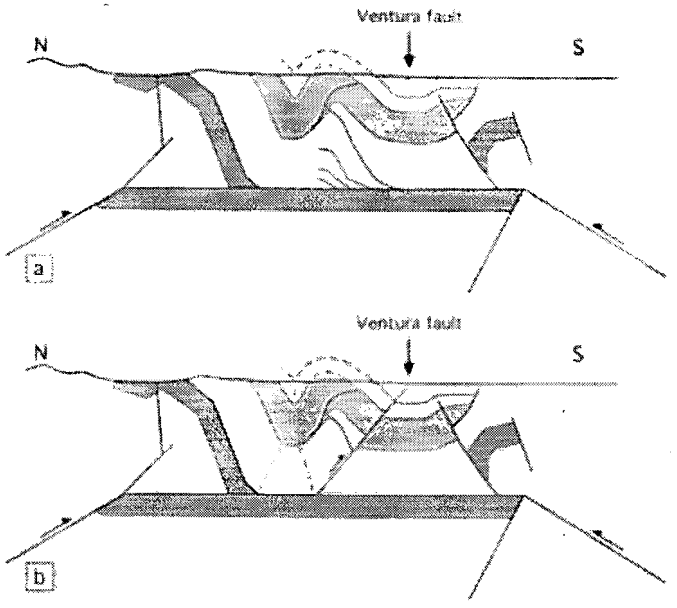

Figure 4: Schematic cross sections showing alternate models for the Ventura Avenue anticline and Ventura fault. (a) Cross section after Yeats (1982a) and Huftile and Yeats (1995). The Ventura Avenue anticline is a north-vergent detachment fold lifting off of the Sisar Decollement; secondary faulting in the interior of the anticline is well constrained by well data. The Ventura fault is a minor bending-moment fault in the syncline at the southern edge of the anticline. (b) Interpretation of Hubbard et al., (2011; 2013), modeled in part after Sarna-Wojcicki and Yerkes (1982). The Ventura Avenue anticline is produced as a consequence of shortening on the Ventura fault, which is a steeply dipping thrust fault rising from the Sisar Decollement. Slip on the blind thrust ramp to the north is partitioned between the Lion backthrust and the Ventura fault. See Sarna-Wojcicki et al., (1982) and Yeats (1982). (from Hubbard et al., 2013).

You can barely see a crack in the top graph: in the bottom it links with a whole floor of faults.

To continue with the story:

The earthquake made a scarp — a fold in the Earth like a fold in a rug. Over hundreds of years, deposits from floods covered and smoothed it out. Today, it's a gentle slope more or less along Poli Street and Foothill Road, not far from the base of the hills overlooking Ventura.

The earthquake that made this slope was anything but gentle, found researchers James Dolan, a USC professor of geology, and Lee Mcauliffe, a graduate student working with Dolan.

"You're talking about moving a whole chunk of the Earth's crust in a few seconds," Dolan said. "We're talking 6 meters of uplift and 10 meters of displacement. That's very, very energetic. You simply

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don't see that in earthquakes of less than 7.5" magnitude.

Craig Nicholson, a geophysicist at UC Santa Barbara, pointed out that the 1994 Northridge quake was 6.7 in magnitude. A 7.5 would be about 30 times as strong as the Northridge quake, which caused about $40 billion in damage, according to Nicholson.

EXAMINING DATA, HISTORY

Dolan cited new studies by Judith Hubbard, a structural geologist now at Nanyang Technological University in Singapore, and Tom Rockwell, a geology professor at San Diego State University. Hubbard used oil industry data to help find and profile the Ventura fault. Rockwell used old photos to identify uplifted plateaus along the coast north of the city.

Both have deepened geologists' understanding of the Ventura fault system.

"Previously, there had been some debate as to whether the Ventura fault was capable of generating large earthquakes or whether it was a surface feature and not much of a factor," Dolan said. "What this study and other studies ... are showing is that these are large displacement events. That means many meters of slip, which indicates that this fault is capable of an earthquake well in excess of a 7" magnitude.

Hubbard spent four months analyzing seismic profiles of the Ventura region provided by the oil industry. The profiles, based on sound waves sent miles below the surface by explosions, provide records of stratification in rock.

Scientists believe that the longer and deeper a fault runs, the more risk it poses. Previous study of the Ventura fault estimated it extended about 1,000 feet

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below the surface. Hubbard's results show it extends at least 7,500 feet below.

This means it likely connects to numerous other faults in the region, extending north toward Santa Barbara along the Red Mountain fault, out to sea along the Pitas Point fault, eastward along the San Cayetano fault and southward along the Lion fault.

Note: Hubbard stressed that maps that show faults at the surface, which don't appear to connect, are misleading in the Ventura basin, because we don't see what's happening below. Here's a graph of hers that uses oil rigs to give a sense of the Ventura fault's depth.

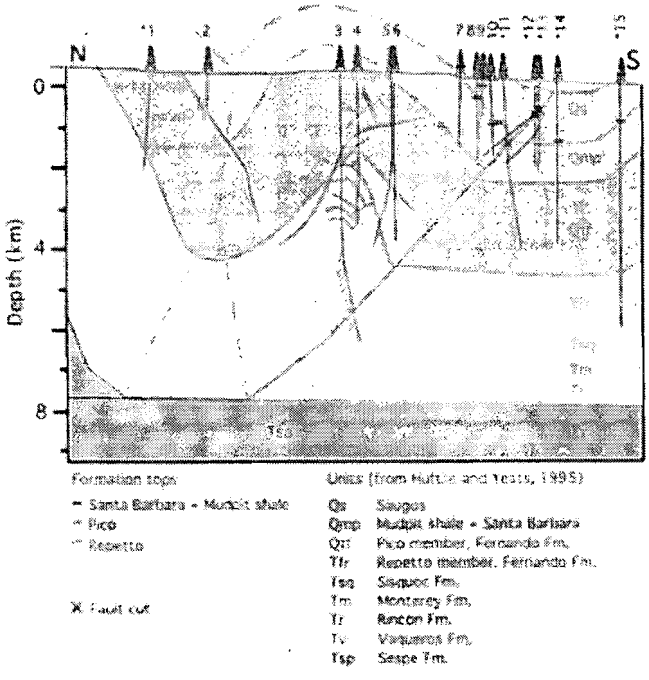
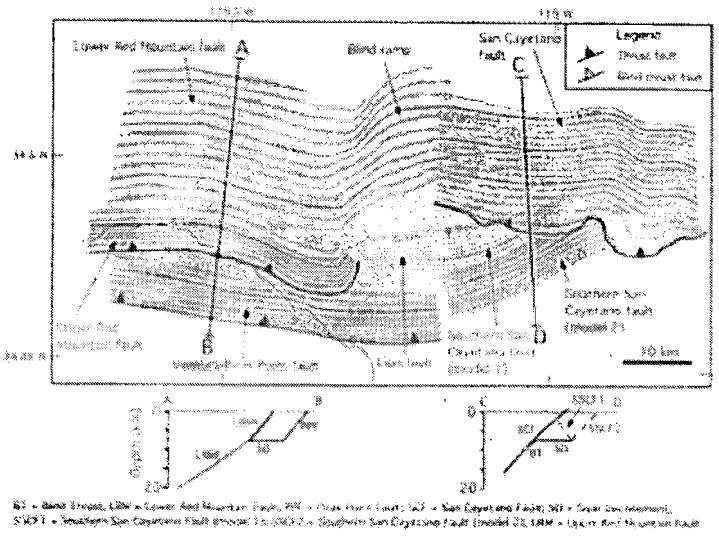


Figure 5: There are several observations that suggest that the Ventura fault extends to depth beneath the Ventura Avenue anticline, supporting model B in Figure 4. This cross section of the Ventura Avenue anticline shows the locations of fault cuts in wells, stratigraphic picks, and dipmeter data that are consistent with the projection to depth of the Ventura fault at a dip of ~ 45-55°N. (from Hubbard et al., 2013).

And here's one that maps various basin faults at depth, showing how closely they lie.



1253 BT = Blind Thrust, LRM = Lower Red Mountain Fault, PPF = Pitas Point Fault, SCF = San Cayetano Fault, SCF1 = Southern San Cayetano Fault (model 1), SCF2 = Southern San Cayetano Fault (model 2), VRM = Upper Red Mountain Fault

1254 **Figure 18:** Upper panel: Contour map of the faults in the Ventura region. Note that we

1255 depict two alternative interpretations for the Southern San Cayetano fault (models 1 and

1256 2; discussed in the text). Lower panel: Schematic cross-sections (AB and CD) illustrating

1257 the fault geometries to the west and east of the Ventura fault.

Sorry! Perhaps the edtor was right. Back to the story:

Hubbard's study estimated that terraces along Highway 101 north of Ventura, which thousands of years ago were beneath the sea, were raised by 16 to 32 feet per earthquake.

"This much uplift would require large earthquakes (magnitude 7.7 to 8.1) involving the entire Ventura/Pitas Point system, and possibly more structures such as the San Cayetano fault," Hubbard wrote. "Due to the local geography and geology, such events would be associated with significant ground shaking amplification and strong regional tsunamis."

'HIGH HAZARD' SEEN

Rockwell has documented four earthquakes along the Ventura/Pitas Point faults in the past 7,000 years, most recently about 1,000 years ago. Rockwell estimates earthquakes strike there every 400 to 2,800 years, but the long intervals are not entirely good news. It suggests a fault rupture will occur over a greater length and may involve more than one fault.

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Ventura County has few large earthquakes in its historical record. A well-documented earthquake in 1812 damaged several missions along the Central Coast, including the San Buenaventura Mission. A second earthquake later that year caused a tsunami that struck Goleta, Santa Barbara and Ventura, according to historical records compiled in the late 1970s by the California Division of Mines and Geology.

Using sonar and seismic instrumentation, Rockwell has been working with graduate student Gulsen Ucarkus, a researcher at the Scripps Institute of Oceanography, on an undersea survey of the Ventura-Pitas Point fault system as it moves offshore. He also is working with Steve Ward, a professor at UC Santa Cruz, on this fault's potential to cause tsunamis. Also in the works is a model of the potential for ground shaking.

"If you look at the national hazard maps ... you will see an extremely high hazard in the Ventura basin," Lucile Jones, a nationally recognized seismologist with the U.S. Geological Survey, said at last month's conference. "It's a confluence of faults that are moving very rapidly, and there's probably a lot of buried faults that we can't see, too, in such a fast-deforming basin.

"You're one of the hot spots in California."

And here's a link to the paper's excellent interactive graphic — with comments apparently from Lucy Jones, independent of my reporting — which the paper kindly encouraged sharing.

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