Introductory note by author:

My name is Sheldon Breiner. I am a resident of the town of Portola Valley, CA which sits astride the main trace of the San Andreas fault. I am chairman of a committee of five all of whom are geologists or geophysicists, most from the nearby USGS. We advise our town council on earthquake and landslide topics. My PhD thesis from nearby Stanford was on the subject of earthquake prediction. Thirty years ago, I made a simple seismograph that recorded earthquakes from Italy, Chile, Japan, Hawaii as well as California. Using the same design (Zollner horizontal pendulum), we had one assembled for our recently constructed Town hall, adjacent to the San Andreas fault. The seismograms are online for the previous days' event, if any, and can be viewed at http://www.portolavalley.net/index.aspx?page=303

I have occasionally sent out a blog about earthquakes on our local YahooGroups site (for the audience of 1,700 from our town and Woodside) A collection of installments of "Fault Lines" from Feb-Mar 2011 appears below.
(sent out to Portola Valley residents via PVForum on Yahoo Groups)

Installments of "*Fault Lines*":

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A Brief History of the San Andreas Fault

The San Andreas fault system represents the contact between two of the major tectonic plates of the earth's crust, namely, the Pacific plate on the West and the North American plate on the East, each extending for thousands of miles. The fault is actually a wide zone with many associated faults, some named, some not and some more active than others. In Portola Valley, it splits into two segments: the Woodside trace on the West and the Trancos trace on the East, about 400 feet apart. The historically active displacement has usually been only along the Woodside trace. At certain places, the fault does not break cleanly, but "feathers" along the trace, which it does at the old Town Center location, breaking at many small places each at an angle to the principal trace in a manner geologists call *en echelon* faulting.

The San Andreas fault, named after the San Andreas Lake just north of the Crystal Springs reservoir where it was first mapped, is known and respected by us primarily because of its association with large earthquakes up and down California. Seismologists predict that we are overdue for a major earthquake on the Hayward and the San Andreas faults. These cataclysmic events originate on the fault or on one of the faults which comprise the fault system which includes the Hayward and Calaveras faults in the East Bay, all three of which merge just north of Hollister.

The rocks more than several tens of miles on either side of the fault and greater than 20 miles deep along a stretch of 200 miles, are moving more or less continuously at about 2 inches per year, through a process called tectonic creep. This happens at depth because the rocks at that depth and temperature are rather soft – as rocks go – and move easily. When the surrounding rock mass below and adjacent to this locked-up block has moved enough, and when the dragging stress at the bottom and sides of this block is great enough, this sticking gives way and there is a sudden shearing along the fault - yes, an earthquake. The greater the length of the fault that is involved, the larger is the earthquake.

After the slip has taken place, the area just on either side of the fault is then put under a new stress from this major slip which gradually over hours, weeks and months results in many smaller (than the original) earthquakes which we call 'aftershocks' until the new stress picture attains equilibrium. These aftershocks do not occur at the original location, but rather all around it. Around Hollister (and other such creep locations), aftershocks also occur after 'silent' tectonic creep events.

Earthquakes like this happen once every 75, 100 or even 200 years or so and happens throughout the West including sections of the San Andreas fault from the Gulf of California to northern California and everywhere in between.

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"There is a 60% probability of a major earthquake on the San Andreas in the Bay Area in the next 30 years"

The following is a comment on the story by Sarah Trauben in the *Palo Alto Online*, January 26th,, 2011 about the above forecast issued by the US Geological Survey. Consider this to be "*Seismology101*."

See http://www.paloaltoonline.com/news/show_story.php?id=19846&e=y

At a depth of 20 miles or more around here, rocks under such temperatures and pressures at such depths act like frozen oatmeal, that is, they are ductile, not brittle and have no strength. So, the tectonic pressures at this junction of these plates do their job causing the two sides of the fault to slide past each other day-n-night at a rate of between 1.5 and 2 inches/year. The rocks from about 15 miles to the surface are good ole brittle, hard rocks as we know them. These brittle rocks are 'locked" up waiting for the shear stress in the transition region between the underlying, already moving ductile rocks and overlying stationary brittle rocks to cause the latter to move, suddenly, as an earthquake.

(This is why all earthquakes in this region always originate at a depth from a few miles to about 12 miles, but not deeper. Ductile, soft rocks at depths of 20 miles or deeper do not break; they sort of flow like silly putty.)

The more the underlying rocks have shifted since the last major temblor, the greater the stress and the larger the earthquake. Since 1906 the two sides of the fault down deep have already moved past each other perhaps 15 feet; in 1906, the local fault shear was about 6 feet. The next major earthquake *might* be a repeat of what happened in 1906 which involved displacement along the San Andreas fault from Hollister (which I previously cited as keeping up with the underlying shifting) to some point near Point Arena, a distance of perhaps 250 miles. Since the resulting earthquake magnitude is proportional to the length along the fault that experiences displacement, this might cause an earthquake of M 7+ or greater, a very large earthquake, indeed.

No one knows yet what it is that causes the locked-up section of the fault to finally break loose. It is fair to characterize the stressed volume as about 20 miles deep, maybe 20 miles wide and 250 miles long. When one section finally gives way, the shear itself propagates, causing the whole length of stressed fault to go. Say, would a whole lot of

WD40 do the trick?? Or should we do the opposite and squeeze epoxy along the fault to defer the temblor for the next generation to deal with? Hey, they're a whole lot smarter than we.

In some sense, therefore, the amount of accumulated displacement since the last major earthquake drives the probability, the timing and the possible magnitude of the next Big One. As the article says, the Big One could come in the next five minutes—or maybe 50 years.

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Peripatetic Cities

There has been a little known move under foot to bring Los Angeles and San Francisco closer together - not just closer, but adjacent. Really.

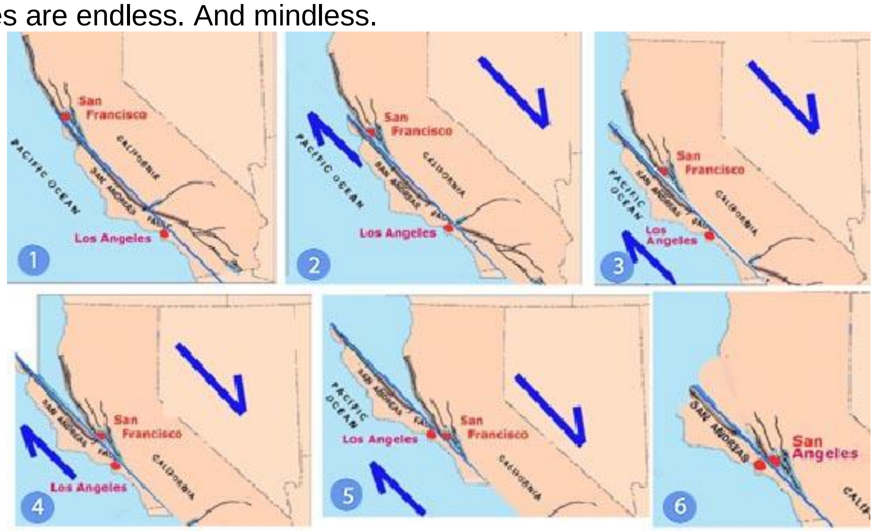
Everyone's heard about the San Andreas fault system and knows that it cuts right through the state from the Imperial Valley to the Mendocino coast. The land on the west side of the fault is moving north at the rate of two inches per year with respect to the land on the east. Incredible as it seems, if one had stood on Portola Road at the Town Center looking towards the Western hills, the land you are looking at will have moved to the right a distance of as much as 300 miles!

The intriguing observation about all this is that Los Angeles is on the west side of the San Andreas fault and San Francisco immediately east of it. Assuming our Design Committee does not rule against it, then the two cities will soon be next to each other. (How soon? Get out your calculator: 400 miles moving at two inches per year.) What does that mean to all of us?

There will be no more going "down South. Interstate-5 will be used to grow sod. The fog in S.F. will clear the smog in L.A. Rodeo Drive will be the main street of Mill Valley and Malibu and Big Sur will merge, both spiritually and actually. Did you ever wonder why some freeway stubs seem to end in mid-air? And you, with such little faith in our city planners.

Mmm, will it be named San Angelisco or Los Francisco?

The effects of this inexorable union of our beloved cities of San Francisco and Los Angeles are endless. And mindless.



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The Earthquake Game

Want a simple method to estimate the distance to the epicenter of the next local earthquake? It's a helpful distraction and may actually put you at ease when it happens, as you play this earthquake game.

When lightning strikes, the electrical discharge and the clap of thunder originate at the same time. The lightning flash is seen almost instantly because it travels very fast, whereas the sound travels much more slowly. You can tell how far away the lightning occurred by counting the number of seconds from the flash of lightning to the arrival of the first clap of thunder, and then multiplying that number by 1100 feet (the distance sound travels in one second in air at sea level).

It is similar with earthquakes. Like lightning and thunder, there are two types of waves created by an earthquake traveling within the crust of the earth. The fastest one, like a sound wave which you feel first, of course, is called the P (primary) wave; the other, which you feel afterwards, is called the S (secondary) wave. The P wave is rather abrupt, sometimes like a sonic boom (if you are close). The S wave is more noticeable, slowly rolling, lasts much longer and does most of the damage. Actually, a third wave, called a Rayleigh wave is often felt as a rolling wave traveling even more slowly than these 'body' waves and is only on the surface.

Since these waves travel at very different speeds (locally about 2.5 miles/sec. and 1.5 miles/sec., for the P and S waves, respectively). The further one is from the epicenter, the longer the time interval. If you have your wits about you and sufficient awareness to estimate when you first felt the earthquake (the P wave), start counting seconds (don't bother looking at your watch—just estimate) until you feel the large rolling S wave. You are now prepared to estimate – without the aid of a calculator -- the distance to the epicenter. Some simple math applied to these numbers boils down to this handy formula: **multiply by 4 the number of seconds between the onsets of the first earthquake wave (P) and the slow rolling wave (S) to compute the distance in miles to the epicenter** (the point on the ground surface just above the actual earthquake focus). Unfortunately, you cannot tell the direction from whence it came, unless you compare stories and times with two other (widely paced) friends in the area.

You can then compare your estimate with the location later reported in the news. This is fun, simple and, allows you to practice seismology in your own kitchen -- without a license and or access to the Internet -- when you play the *earthquake game*.

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How to Profit from the Coming Earthquake

Everyone agrees that it's nice to live in California . We have nice weather, a relaxed lifestyle, unmatched scenery, superb recreation, few tornados and mostly a good economic climate. But, we've got earthquakes.

Seismologists predict that a major temblor will strike the area sometime in the next tens of years. The magnitude of this event may be as large as the one which occurred in San

Francisco in 1906, but this one will be accompanied by a loss of life estimated to be in the tens of thousands and property damage in the tens of billions of dollars.

Consider then, what would happen immediately after "the big one." During the first few days and weeks, there will be numerous aftershocks, each one larger than any earthquake ever felt by local people before. Even months later, there will be magnitude 5 earthquake aftershocks. All the normal fears of an earthquake, something we can neither predict nor control, will be reinforced and cause many to pull up stakes, quit their job and leave the state. Many homes and some businesses will be put up for sale immediately afterwards. There will be many sellers and practically no buyers while the memory of this catastrophically disturbing event is constantly reinforced.

While the attributes of living in Northern California make the price of real estate the highest in the country, the effects of the earthquake and its aftershocks will cause the price of real estate to drop at a rate faster than we have ever seen, perhaps by as much as 20 to 30, maybe 40 percent in a month or two. There will be minimal price support level as some will be willing to sell their homes at any price to finance the purchase of another place somewhere else in the country.

Soon after the subsidence of the principal aftershocks, some keen observers of the California scene will have an epiphany: seismologists, sociologists, and even a few residents will realize that this area will probably not experience another great earthquake for as long as 50 to 100 years. Some reporters, camped out to dig up local stories, will then write about this observation as a story in itself.

This realization that the most disturbing drawback of living in the state will not happen for many generations combined with the *then relatively* low price of real estate will, rather suddenly, increase the demand for homes and some businesses. Starting from an earthquake-depressed price to this sudden market-driven higher price will cause a rise for a short time exceeding possibly the pre-earthquake level. Companies and individuals with sufficient cash and credit will be in an extraordinary position to buy and later resell by taking advantage of this one time fire sale-- and subsequent land rush as it were – like buying an Internet stock in the 'bubble' at the offering price and then selling it quickly. But, *Caveat Realtor*!

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Stopping the Earthquake at the Front Door

Simple things to do in your house to help save life and limb
(or what Martha would have suggested if she were a seismologist)

Next month will mark the 105th anniversary of the great San Francisco earthquake. It could well have been called the Daly City or Marin County or Portola Valley earthquake, for it occurred along 200 miles of the San Andreas fault, abruptly shearing Alpine Road 6 feet near Willowbrook. That temblor was a magnitude 7.8. Another one, somewhere on this or a nearby segment of the fault, is inevitable. It's just a matter of time.

So what can we do about it? We can at least be prepared. So, be forewarned and at least anticipate an earthquake. Learn what we can do to minimize injury and be able to handle the emergencies on our own.

First of all, we can do the normal things all Californians know about such as having an emergency first aid kit, water, food, flashlight(s), spare batteries, radio (remember, your car radio might suffice, but have the keys accessible in the rubble) and other items listed in your emergency preparedness instructions.

Because local phone lines will be jammed, try using your cell phone to call a friend or family in another time zone to report your status even for the benefit of local family and friends and have them do likewise. Have a family communications plan.

Because Portola Valley is a more-or-less a modern community with reasonably up-to-date building codes, our homes are as well designed as practicality allows. Make sure the water heater is strapped and a turn-off tool is attached to the outdoor gas meter.

An overlooked consideration- one which could save life or injury - is to safeguard your immediate environment in a room where you normally spend about eight hours a day: your bedroom. You are more likely to be in bed than any other single place at the time of an earthquake. Make sure you have no glass-framed (or heavy) pictures on the wall near your bed or heavy vases within 10 feet of your bed. Large bookcases have to be fastened firmly to the studs in the wall. The seismic waves can abruptly move the walls of the room, leaving an unattached bookcase or other heavy object momentarily stationary in space. The abrupt return of the walls will then slam the bookcase more than ten feet across the room and inflict serious injury to anyone in the room.

Lastly, keep your wits about you afterwards, especially in the dark, while wading through debris, broken glass, and across wet, slippery floors, while you're looking for your copy of this PV Forum edition with the helpful hints. Have several small LED flashlights on handy shelves in the bedrooms. Above all, have a *default* plan where you and your family know what to do instinctively when all hell breaks loose on the fault -- that's why it's called "da fault" plan, Dummy

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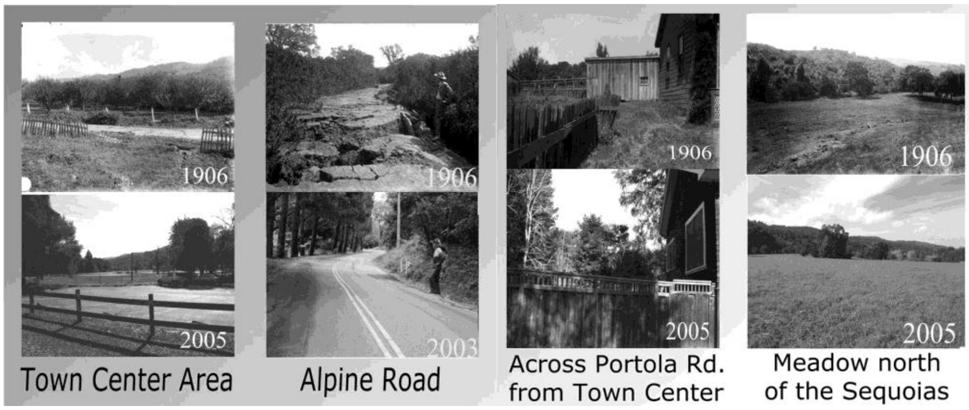
Finding Fault in the Town

Portola Valley is bisected by the San Andreas Fault. It’s location determines where we can or cannot build our homes. Even when all is quiet, this fault, its location and implications of violent motion and potential damage, still affect our lives. And, since it brings together rocks from far away places, the fault also influences our topography, where we can build our homes and how we build them. Uppermost on our minds, though, is when the San Andreas fault will next make its move and cause an earthquake that will affect us all, in one way or another.

The last time our local segment of the San Andreas fault experienced noticeable shear was during the earthquake in 1906 when it created a rupture up and down 250 miles of its length. In Portola Valley it sheared Alpine Road about 6 feet near Willowbrook; it created a ruptured furrow across the meadow north of the Sequoias; it wrinkled the road across Portola Road near the Town Center; and it shifted a fence adjacent to a house across Portola Road from the Town Center. Photographs of these ground shear displacements were obtained for the famous 1908 *Andrew Lawson Report*, commissioned to study the sometimes-then-called, “Santa Cruz fault.” See the attached composite copies of these 1906 photos acquired from the UC Berkeley library archives with their modern-day settings.

The location of this shear zone places the active ‘Woodside trace’ of the San Andreas fault a few hundred feet west of the previously mapped location of the main trace (the Trancos trace). Most likely, these sites and others with established infrastructure will again exhibit right-lateral shear displacement at about the same locations and some new ones, as well.



Now that we got the “where” down pat, we’re working on the “when.”

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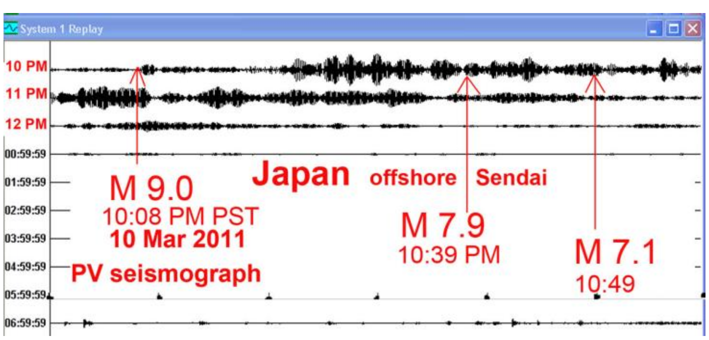
Japan Earthquake – interesting topics

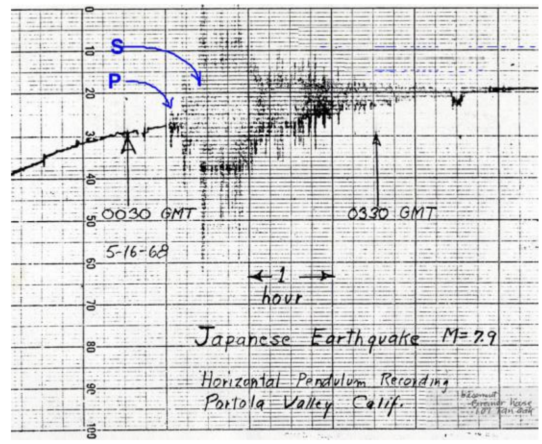
The earthquake in Japan and its associated effects has dominated the news. The many questions I have been asked since that time suggests that I should summarize those topics, but stick to those not already covered in the press or online.

Receiving notification via email from the USGS a couple of hours after the earthquake caused me to look at our local seismogram online, which I later distributed to PVForum. It took about 23 minutes after the main earthquake for the first noticeable seismic event to register on our Portola Valley seismograph. But, hours later there were still seismic waves coming in, something I had never seen before from a single earthquake. Well, turns out, it was not the only one. Following the principal M 9.0 event, a M 7.9 aftershock (larger than the SF 1906 earthquake!) occurred 30 minutes later and a M 7.1, 10 minutes after that. While the latter was probably was not recorded. the principal contributor to the



The original earthquake sent out several kinds of earthquake waves, some compressional and very fast and others, transverse and slower. The fastest path from each is deep into the earth where the rocks are more dense, the slower ones through shallower rocks so that an almost continuous stream of waves from one earthquake is received at our PV seismograph from this point 5,000 miles away. The majority of the observed earthquake waves, after the first hour or so of P and S waves, were probably Rayleigh waves, surface waves that for a M 9.0 may actually travel all the way around the earth, sometimes more than once. See seismogram attached for these multiple earthquakes.

See another M 7.9 earthquake *in 1968* at right which I recorded from my basement here in PV using a similar homemade seismograph.



An interesting observation not mentioned in the press coverage was that there was a M 7.2 earthquake—itself a very large earthquake—two days before the big event at about the same location, same depth. It could be said that this was the principal earthquake triggering the M 9.0 as an aftershock, albeit a very large one. Remember that all aftershocks are merely local mechanical re-adjustments to a new stress/strain picture caused by the displacements from the original earthquake. In fact, *none* of the aftershocks of any earthquake occurs at the location of the original epicenter but rather all around it until the whole area is once again in equilibrium, sometimes taking a year or more, for an earthquake of this magnitude.

It might interest you to know that for an earthquake of this size the whole earth will also vibrate like a bell in various natural modes, for a month or so. It is probably still ringing now, as you read this. So, you see, it isn't that drink you had last night. Do you suppose that if an earthquake of the right frequency hits the earth like the proverbial singer's voice breaking the glass, and occurs on December 21, 2012 Mayan prediction for . . .?

Speaking of magnitude, references to earthquakes in this country no longer refer to the "Richter magnitude" but use Moment Magnitude (M_W), more or less the amount of movement times the area being moved. In other countries, such earthquakes are reported for their 'intensity' at a given location. i.e., how much damage is observed. It uses the Modified Mercalli scale, expressed in Roman numerals from I to XII, where the latter is complete destruction.

You have also noted talk about the earth slowing down as an indirect effect of the movement of the plates which caused the earthquake. One plate was pushed (as a thrust fault) under another in what is called subduction, thus raising the latter. That very large mass of rocks being raised up means that the earth now has more mass further from the center of the axis of the spinning earth. A principal in physics describes the *conservation of angular momentum*, which, simply stated, means that if the mass times the distance (from the axis of rotation) of a spinning object increases, the speed of rotation has to decrease. Less complicated examples are: a spinning skater slows down her rotation by extending her hands and arms, as does a tumbling high-diver in a fetal position who must straighten out to enter the water. Before you change your watch, be aware it is now 1.8 millionths of a second later than you think and time to stop reading this nonsense.

Hope this was of interest to you quake junkies.

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So near – yet so far

Did *fear of shear* trump *shirking from shaking* in our new Town Center?

During the run-up to the decision to construct the new Town Center, many in the Town couldn't believe that it was worth $20 million to effectively move the old one a mere 100 yards away! Well, that's almost what we did—I say, almost. The important operative words here would be: *to be* *built* and *not* *on*, the San Andreas fault.

Earthquakes originating from motion along faults can damage buildings in several ways: shaking due to seismic waves; shear if the fault is under a structure; landslides on alluvial slopes; distortion from liquefaction if the structure is underlain by water-saturated unconsolidated sediments; or demolition from the impact of water in a tsunami. Any of these would have been enough to cause serious damage and possibly injure those inside.

Geologic studies had shown no evidence of liquefaction nor landslide at the then proposed level site and the coastal areas of the Town were not expected to experience a tsunami. For the Town Center site, therefore, we had to focus on shear and shaking.

Shear damage means breaking or tearing apart of a structure. The old Town Center was built smack-dab over the now-known active trace of the San Andreas fault. In a major quake when --not if -- the ground surface ruptures, so too, will the building. Contrary to some local rumors, no man-made structure or plants will hold the earth together. The nature of the historic faulting under the old Town Center was even more complicated as it tended to shear across a wide zone in what is called, *en echelon* faulting. However, it is possible to design and construct a building to withstand, to some extent, underlying shear, but this can only be done from scratch and such structures are exceedingly expensive to build. Following considerable geologic studies, we determined exactly where on Town-owned property the active faults were located and where they were not located, so it was indeed possible to relocate the structure(s) nearby and know that it will not fail—at least not due to shear damage.

In a seismically active area such as Portola Valley the greatest threat to structures not located directly over a fault is the shaking that accompanies large earthquakes. Major earthquakes generate damaging seismic waves that affect structures at distances up to 100 miles or more. To understand the effects of say, a magnitude 7 earthquake it may be helpful to consider such a quake to be many magnitude 5 earthquakes all occurring simultaneously along 20, 30, maybe 100 miles or more of the fault. Structural damage due to seismic shaking on a given structure is not caused solely by its proximity to the nearby fault, but rather the sum of all the shaking originating up and down the fault or nearby fault including across the Bay and by the nature of the subsurface geological conditions. A new building constructed under current building codes (not those of the 1950s) can be designed to better withstand the effects of seismically-induced shaking.

So, by re-establishing buildings away from the known fault and with good geological underpinnings and incorporating modern structural design, we have better insured the safety of the Town Center and its occupants, particularly those that are required, by employment, to be inside.

So, thanks to the chance location of the old PV School/Town Center, we also now have a Town facility much more useful to the current needs of the citizens of the modern Portola Valley.

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Earthquake insurance

peripatetic movie of plates sliding

access to Google Earth movie along SAF

1906 seismogram from Germany

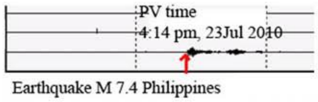
P and S waves

Worry about tsunami at Watsonville and the Bay in the event of an earthquake offshore the Pacific Northwest (Cascadia subduction Zone)

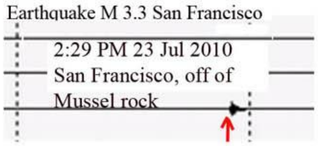
piezomagnetic topic, simplified?

compressive and shear around the world and how they tell us about the interior structure of the earth

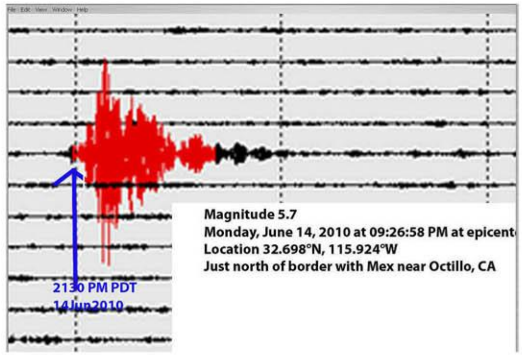
Major earthquakes
How tsunami wreaks havoc
Why we'll never have a M 9 earthquake

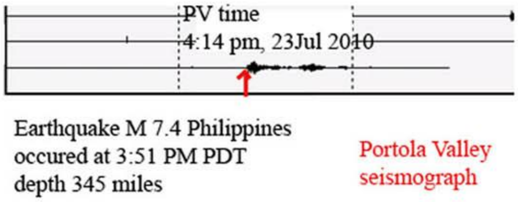


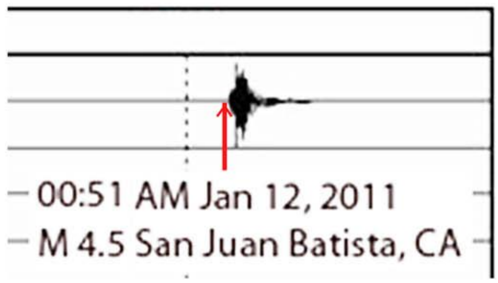
These look similar, but the upper one was 800,000 times as powerful as the lower one

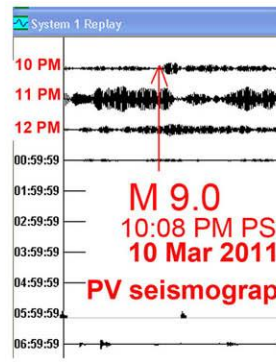


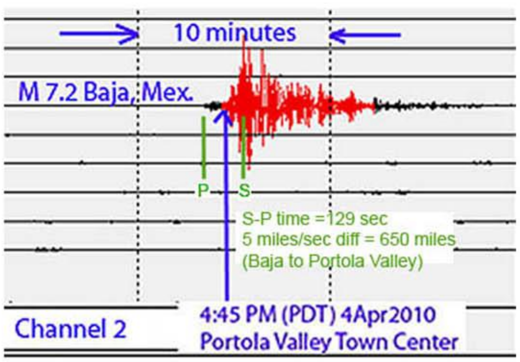
(both recorded two hours apart by the PV seismograph)

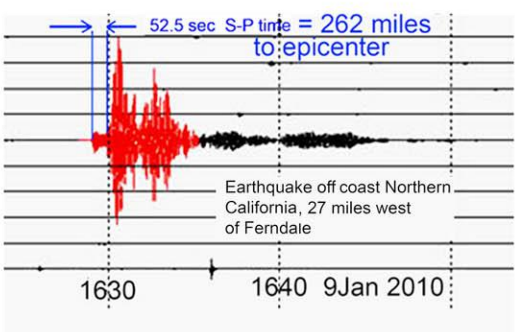












Earthquake off coast Northern California, 27 miles west of Ferndale