Tree-rings + Earthquakes = Paleoseismology

Why study paleoseismology?

The study of past earthquakes, paleoseismology, is important because the historical record is too short to indicate how often disastrous earthquakes occur. The paleoseismic record can add important information about prehistoric earthquakes events and thus aid in estimating future earthquake hazards. Old trees that have been damaged by earthquakes can record evidence of prehistoric earthquake disturbance in their annual growth rings.

How trees record earthquake history.

The effects of earthquakes can influence the growth or even cause the death of trees. By carefully looking at the specific growth environment of trees and their geologic setting we can estimate how trees might respond and be affected by seismic events. The table below summarizes possible links between earthquake related events and what might be found in the tree-ring record.

Change in Trees*	Physical Change	Possible Cause
PHYSICAL DAMAGE (unusually narrow or missing rings, abnormal cells)	top, major limb, trunk, or root system broken off	violent shaking and/or local earth movement
	corrasion, scarring	seismically activated material impacting tree (e.g., landslide, seiche, tsunami)
GROWTH RATE CHANGE		
Increase (wider rings)	improved growth environment, nutrient supply, or site hydrology	change of site into more favorable conditions, loss of competitors
Decrease (narrower rings)	poorer growth environment, nutrient supply or hydrology	change of site into less favorable conditions
Variation increase (rings widths change inconsistantly)	some damage, some competitors felled, surface disturbed	disturbance overrides normal growth
	ground surface tilted or tree pushed over	surface rupture, landslide, tilting
REACTION WOOD†		
	partial flooding	minor subsidence
TRAUMATIC RESIN CANALS#		
	barren surface stabilized or newly available	uplift, change in base level, landslide, or other catastrophic event
TREE GROWTH INITIATED (date of first ring)		
	surface covered, burying trees	rapid sedimentation, landslide, or other catastrophic event
TREE GROWTH TERMINATED (date of terminal ring)	surface inundated	subsidence, drainage blocking

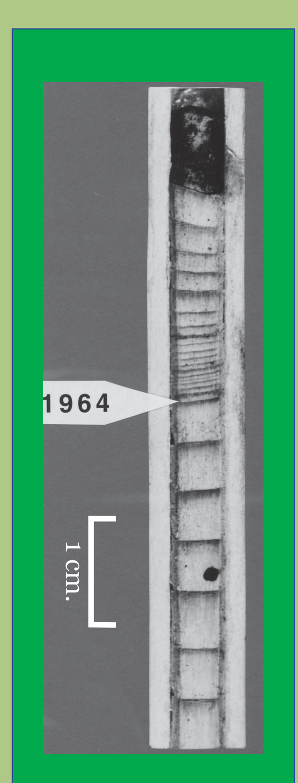
* Some of these changes can be caused by biological, climatic, or other factors that must be considered when making interpretations. Accurate dating and sampling from a number of appropriate locations are the means to confirm interpretations. Changes should be compared to undisturbed growth in the same region.

† Reaction wood is defined here to mean the geotropic (gravity-influenced growth) response by an inclined tree to regain its vertical stance and strengthen its lower trunk (Low, 1964; Scurfield, 1973; Shroder, 1980, Timmell, 1986). In conifers the darker, thicker-walled cells are called compression wood. Similar appearing cells can also be caused by partial flooding.

\# Traumatic resin canals are open vertical pores surrounded by abnormal cells The canals are caused by various

Analog studies: Known earthquakes in action.

To understand the tree-ring record we must study the effects of known earthquakes on tree rings. These are termed analog studies. We can then look at the record of annual rings from older trees for the same type of evidence of seismic disturbance. Below are two examples that show effects of known earthquakes on the annual rings of trees. One is the effect of the 1964 Alaska earthquake on a coastal Sitka spruce in Alaska and the other is a white fir sample showing the effects of the 1857 earthquake on the San Andreas fault in California.

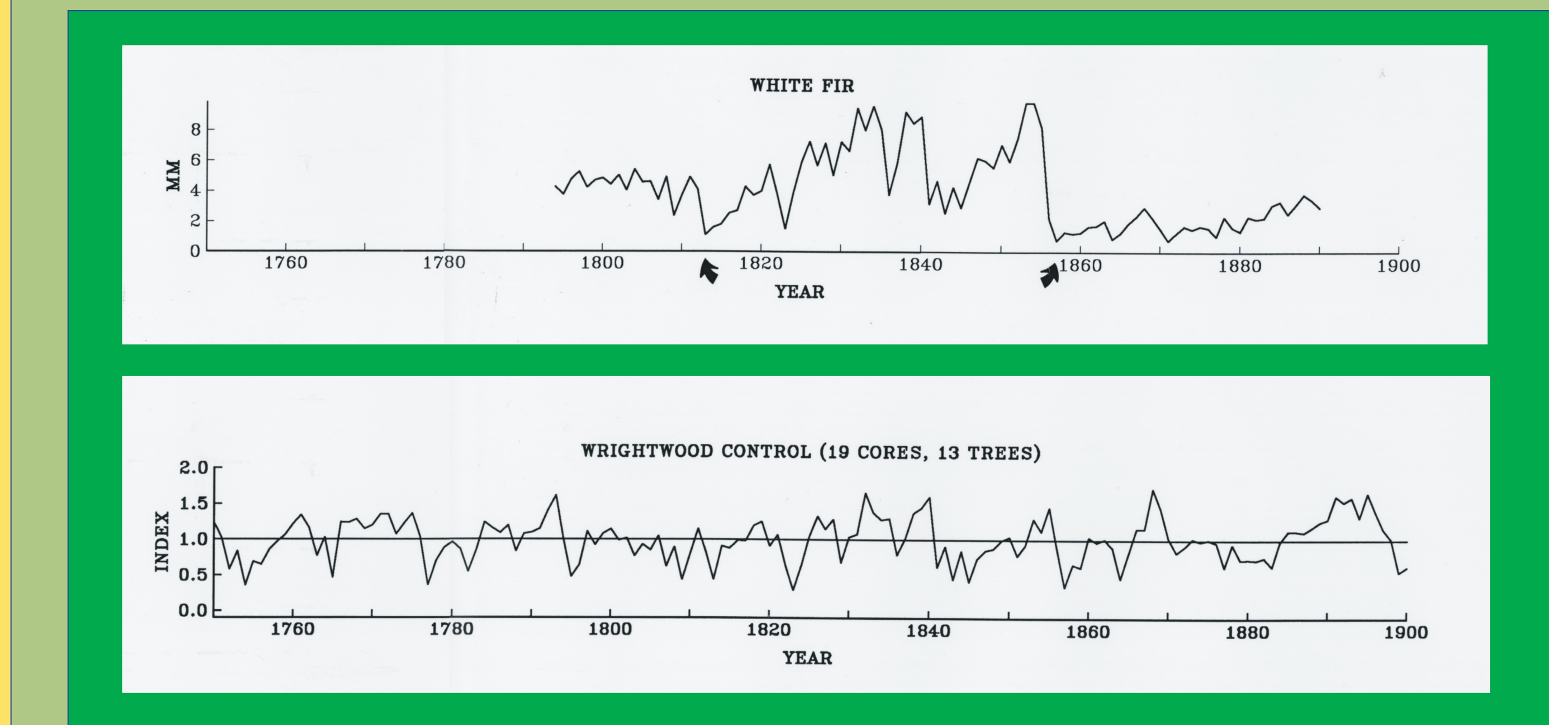


ALASKA

Photo of a core sample from a Sitka spruce (Picea sitchensis) growing just above the former high tide level on the coast: It is from a location about 240 km east of the epicenter of the 1964 Alaska earthquake, the largest historical earthquake in America. The tree, growing in unconsolidated sand, was shaken violently and the root system damaged. The annual rings show normal growth in 1963 and abrupt decrease in 1964. Several trees sampled at this location show a similar response to the event and there are trees at other coastal locations that show growth ring changes due to the earthquake. If the earthquake had been unknown, analysis of all the trees would have shown disturbance along a great distance of coastline and a probable great earthquake.

SAN ANDREAS FAULT

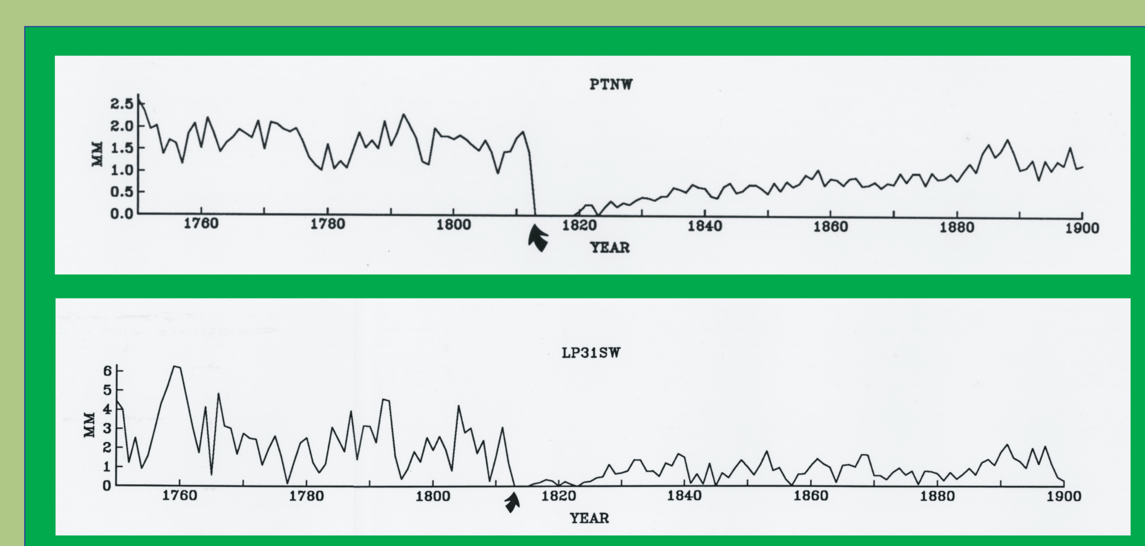
An earthquake with an epicenter at a known location along the San Andreas fault occured in 1857. The graph of ring widths below from a white fir tree shows an abrupt and long lasting decrease in growth at 1857. This is linked to damage from the 1857 quake. The lower plot shows the Wrightwood control chronology developed from trees in the same region but growing away from the fault zone. These control trees are not likely to be damaged in an earthquake. The rings-widths reflected in this control chronology reflect climatic variation. The comparison of these two graphs strenthens the theory that the decrease in growth in the white pine was due to the 1857 earthquake- only it shows an abrupt and long lasting decrease in growth. More can be learned from these trees, however..........



Tree-rings moonlighting as paleoseismologists.

The same white fir mentioned above shows a decrease in growth at 1813 that is not seen in the Wrightwood control chronology. A study of other old trees along this fault segment revealed that they had been greatly disturbed and rings were very narrow or even missing for several or more years starting in 1813. The anatomy of the rings indicated a normal ring for 1812 but suppressed growth starting in 1813, thus limiting the disturbance to the non-growing season of 1812-13. Only trees close to the fault were disturbed. Other trees in the area showed no unusual growth at this time. A search of old coastal mission records revealed information about an earthquake in December of 1812 but there was uncertainty about the location. Evidence of disturbance was present in nine trees along this 12 kilometer segment of the San Andreas fault. The conclusion was that the trees were disturbed by the 1812 earthquake. This segment of the fault had experienced two earthquakes only 45 years apart; the 1812 event and the documented 1857 event. Thus the trees provided an important addition to the record of seismicity in the area. Photos and graphs from two (named Pool Tree and Lone Pine Canyon Tree) of these nine trees are shown to the right.

Pool Tree, left; Lone Pine Canyon Tree, right.

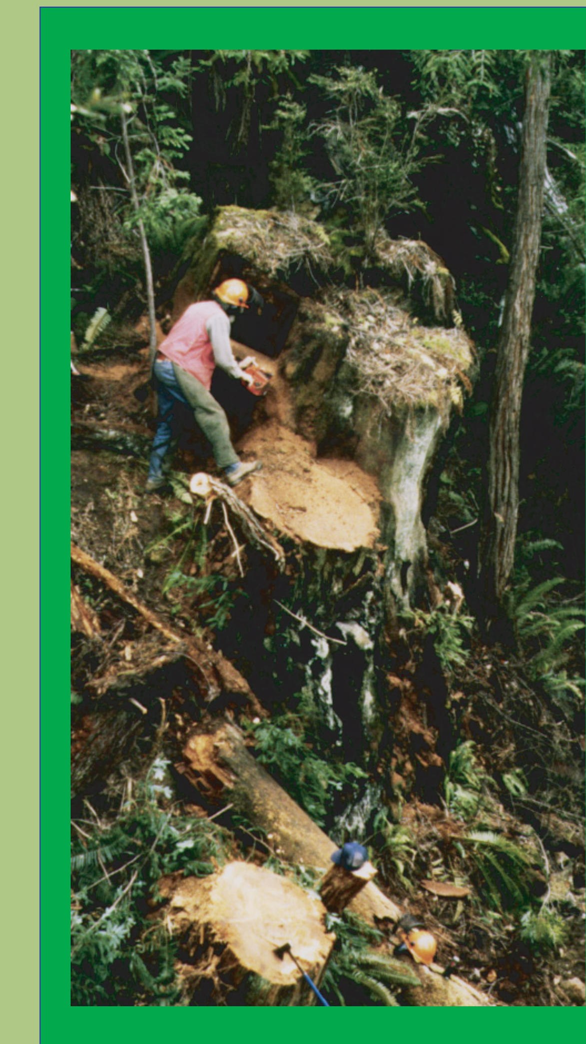


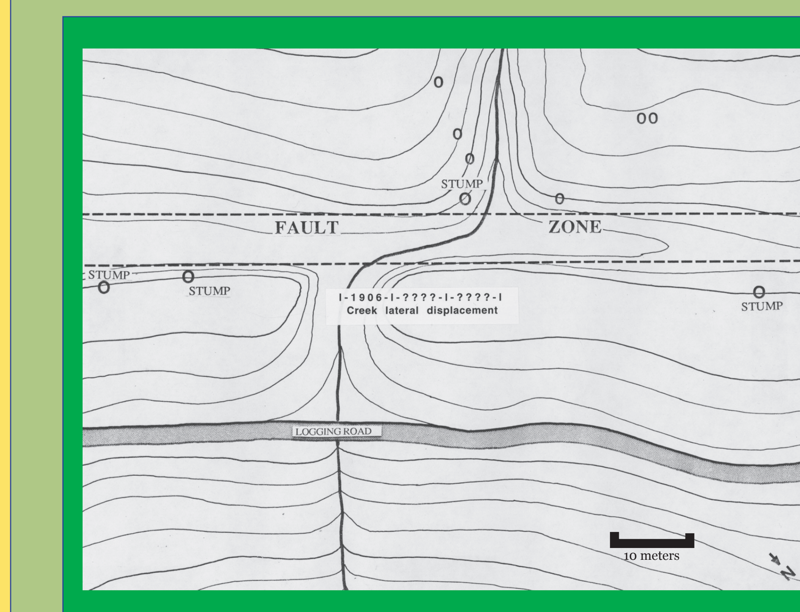
Ring-width measurements from the Pool Tree, top; and the Lone Pine Canyon Tree, bottom.

Photographs of cores from the Pool Tree, top; and the Lone Pine Canyon Tree, bottom. The cores are 5 mm. wide.

Ongoing studies

At the northern end of the San Andreas fault, the 1906 earthquake was a disaster to San Francisco. How often do these earthquakes occur? We are studying coastal redwood trees along the fault to try and find and date earlier events. One promising location is at a creek that probably has been offset by three earthquakes. The displacement is approximately equal to three times the 1906 movement. We are examining and dating the rings of samples cut from stumps that were logged around the turn of the 20th century, looking for evidence of simultaneous disturbance in the trees growing along the fault zone. This would indicate an earthquake damaged them. The map below shows an overview of the fault, tree stumps and creek.





We cut sections from the stumps of trees logged almost a century ago. Redwood is very decay resistant and the wood is preserved well enough for sanding, polishing and microscopic analysis.

The sections must be carried out of the woods to the road and then shipped back to the laboratory here at Lamont for surfacing and analysis. The actual years of growth are determined by matching the ring-width patterns with samples from living trees.

This photo shows trees killed in Cook Inlet, Alaska by the 1964 earthquake. Beneath them is a layer of subfossil trees killed by a previous earthquake. Radiocarbon dating places this earthquake at about 800 years before present. Samples of these subfossil logs were recently collected to see if tree-ring analysis can provide the exact calendar year of this earthquake.

For additional information, visit: http://www.ldeo.columbia.edu/trl/