2012 SCEC Annual Report

Collaborative research: Documentation of Tsunami Deposits in the Carpinteria Estuary: A signal of Great Earthquakes on the Pitas Point Thrust

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Summary of Science Outcomes

1) Seven cores were collected from the Carpinteria Salt Marsh in 2012, with the longest complete core to 3.7 m depth.
2) Radiocarbon analysis from two cores indicates subsidence and a sedimentation rate of about 2 m per millennium, which is likely tectonic in origin.
3) Faunal analysis of the shallow (< 1 m) cores indicates the absence of offshore foraminifera and diatoms for the past few hundred years. Thus, the microfaunal results do not support the interpretation that a distinctive sand layer is the result of a tsunami from the 1812 earthquake, although these results are not definitive. Deeper cores were drilled after the faunal analyses were complete, so analyses of the deeper strata remain for the future.
4) In the deeper cores, there is not an obvious tsunami sand that corresponds with the approximate time frame of the most recent Pitas Point terrace uplift event (700-800 years BP), although there is a sand with an abrupt lower contact that falls within the correct timeframe and may be of tsunami origin. Further microfauna analysis will determine if offshore species are present, and whether this sand could be the result of tsunami.

Summary of Outreach Outcomes

One graduate student from SDSU (Erik Gordon) is currently involved in the field and lab work. Rockwell participated in the SCEC annual meeting and pre-meeting SoSAFE workshop on field interpretation of offset geomorphic features along the San Andreas fault. Rockwell has also made several presentations on the Pitas Point fault / Ventura Avenue Anticline uplift history to various geologic groups (cf. San Diego Association of Geologists). Peters is incorporating results from this study into the USGS Multi-Hazard Demonstration project (MHDP) Science Application for Risk Reduction (SAFRR) Tsunami Scenario. Results from this study will be part of a USGS Open-File Report to be published by September 2013

Introduction - Large earthquakes and their associated tsunamis in Sumatra (2004) and Japan (2011) have brought into sharp focus the hazards associated with convergent margins. The Transverse Ranges is southern California's version of a convergent margin and recent work between Ventura and Carpinteria has demonstrated that the Ventura Avenue Anticline (VAA) and associated Pitas Point – Ventura thrust (Figures 1 and 2) have produced large uplift events. The amount of inferred uplift, on the order of 6-9 m per event, likely results in the production of a sizable tsunami along the Santa Barbara – Ventura County coastline, although until recently no one has looked for tsunami deposits in this region. This past year, we were funded to begin detailed analysis of existing cores, to recover additional cores, to develop the chronology of sediments and search for direct evidence of tsunami deposits at the Carpinteria Salt Marsh. Towards that end, we conducted preliminary diatom and foraminifera analysis of four shallow gouge cores from the western margins of the marsh, which based on new radiocarbon analyses indicates that this part of the section is less than 500 years in age. In the east-central part of the marsh, we collected five moderately long cores using three different techniques to experiment which method yields the longest and most complete cores (best recovery). These cores, which range from 1.5 to 4.5 m in depth, all contained abundant organic material (charcoal, shells, buried peat or marsh surfaces), and we selected 20 samples for dating to test 1) whether active late Holocene subsidence is occurring, and 2) which materials would afford the best chronologic results to guide all future dating of the marsh sediments.

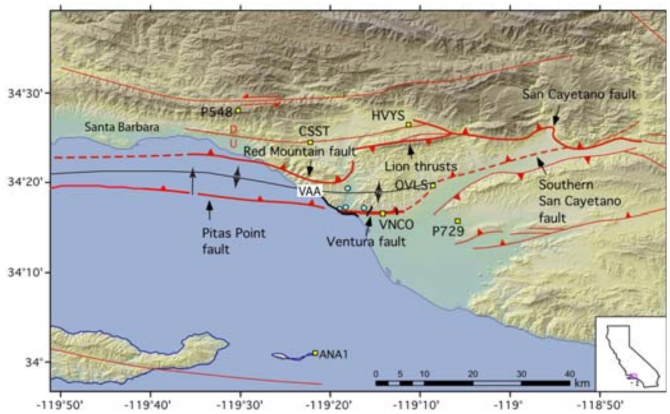

Figure 1. *Map showing the Pitas Point-Ventura thrust and associated Ventura Avenue Anticline in the hanging wall in the western Transverse Ranges. The fold, which extends from Ventura to as far west as Point Conception, traverses offshore into 500-600 m deep water.*

Figure 2. *Map of the coast between Carpinteria and Ventura. Note that the VAA and locus of uplift is a mere 5 km from the Carpinteria coast. A large tsunami will cover this distance in minutes.*

Results – From the four new cores collected this past February to about 80 cm depth, four radiocarbon dates on peat layers indicate that the upper 80 cm of the western portion of the marsh was deposited after AD 1450 (Figure 3). Extensive analyses for exotic foraminifera and diatoms (Mary McGann at the USGS and Eileen Hemphill-Haley at Humboldt State) did not find evidence for offshore species, which either indicates that the historically reported 1812 tsunami did not penetrate a half kilometer inland at Carpinteria, or that it did not deposit offshore fauna this far into the marsh. Nevertheless, the sandy layer does meet other criteria (sharp basal contact, normal grading) for possibly being of tsunami origin and we will do further analyses on future cores to be collected.

In October 2012, we returned to Carpinteria and used a 60 mm diameter gouge corer for two additional cores, and found that the maximum depth that we could recover core was limited to about 2.7 m. We also tried a vibracore system that recovered cores of 1.5 and 3.7 m. Finally, we used a modified portable soil coring system (hydraulic push core) that was partially successful in recovering a 1.5 inch diameter core to a depth of 4.5 m, although recovery in the lower 1.8 m was questionable. We attempted to use the 3-inch diameter core barrel, but found that recovery was very poor. In all, we have reasonably good to excellent recovery in five cores, and taken together, complete recovery up to or exceeding 3 m depth from the northcentral portion of the marsh among the several holes. From the two gouge cores, we extracted over 40 charcoal and peat samples for radiocarbon analysis. We submitted twenty of these samples from core 2010-g03 (Figure 4) for dating (Table 1) to test which materials would give the most reliable results, and to test for reservoir effects because some or all of the marsh vegetation may have a marine component of carbon.

We collected 1-2 cm-thick slices from the organic-rich parts of the core, or where there was obvious charcoal. Each sample was dispersed in deionized water and passed through a 125u sieve. The fines that passed the sieve were allowed to settle in a plastic bucket, and the organic humus complexed with fine clay formed a thin, dark brown skin on the surface of the sediment. This organic clay was collected and labeled by depth with an "H" designation. The screened material was dried and picked under a binocular microscope for charcoal, seeds, foraminifera, and plant lignans/roots.

The rationale for this separation is that charcoal always records when the plant material grew, not when it was burned or deposited. For trees and other woody vegetation that grow annual rings in a subaerial environment, each growth ring dies at the end of the season, so the heartwood of an old tree can be centuries older than the outer wood. Upon burning, samples derived from the heartwood may have substantial inheritance. Consequently, radiocarbon dates on detrital charcoal are always older than the sediment in which they are hosted, if only by a few years, so the charcoal dates were expected to provide upper limits to the age of the stratum from which it was derived.

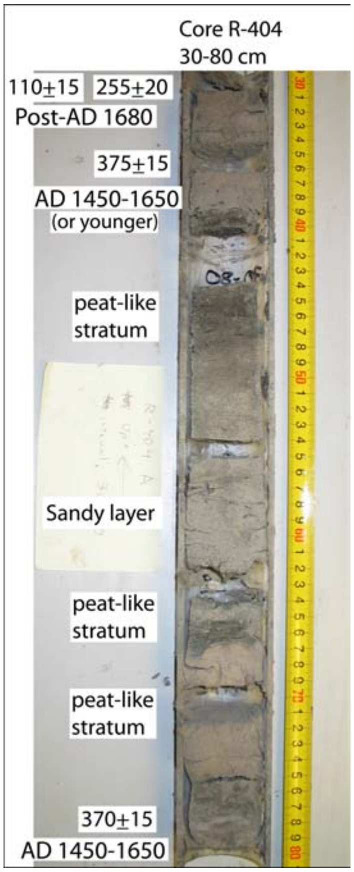

Figure 3. *Radiocarbon dates on charcoal and seeds recovered from the peat-like layers in core R-404, indicating that the upper 80 cm of marsh deposits are no older than about 500 years.*

Table 1. Carpinteria radiocarbon dates from cores R404 and C12.

Sample	w/	depth (cm)	Material type	Lab No.	14C Age (BP)	Calibrated Age (calendar year)	Calibrated Age Years B.P. (ka)
Core R404 dates							
R404-A		31-32	sd	114055	255±20	AD 1529-1797	
R404-A		36-37	ch	114056	375±15	AD 1451-1618	
R404-A		31-32	ch	114057	110±15	AD 1689-1926	
R404-A		79-80	ch+sd	114058	370±15	AD 1452-1621	
Core C2010 dates							
C1210-03		72.5-75.5	ch	120438	155±15	AD 1668-1946	0-0.35
C1210-03		72.5-75.5	rt	120439	665±15	AD 1282-1386	
C1210-03		72.5-75.5	H	120453	1010±15	AD 993-1030	
C1210-03		98-99	sd	120440	245±15	AD 1648-1661	0.36±0.01
C1210-03		108-109	ch	120441	240±20	AD 1642-1797	0.37±0.02
C1210-03		108-109	rt	120442	490±15	AD 1415-1441	
C1210-03		108-109	H	120454	1500±20	AD 537-615	
C1210-03		186-187	ch	120443	4725±20	BC 3631-3379	---
C1210-03		186-187	rt	120444	1810±15	AD 135-243	
C1210-03		186-187	H	120455	1920±15	AD 53-126	
C1210-03		202-203	ch	120445	7345±20	BC 6249-6093	---
C1210-03		206-207	ch	120446	1000±15	AD 993-1110	0.96±0.06
C1210-03		225-226	ch	120447	1130±20	AD 880-981	1.08±0.05
C1210-03		225-226	rt	120448	1125±15	AD 889-972	
C1210-03		225-226	H	120456	2445±25	BC 751-409	
C1210-03		252-253	ch	120449	1270±15	AD 684-773	1.29±0.05
C1210-03		252-253	rt	120450	1515±20	AD 442-604	
C1210-03		252-253	H	120457	2295±15	BC 400-265	
C1210-03		259	ch	120451	1500±30	AD 442-638	1.47±0.1
C1210-03		259	rt	120452	1605±15	AD 412-534	

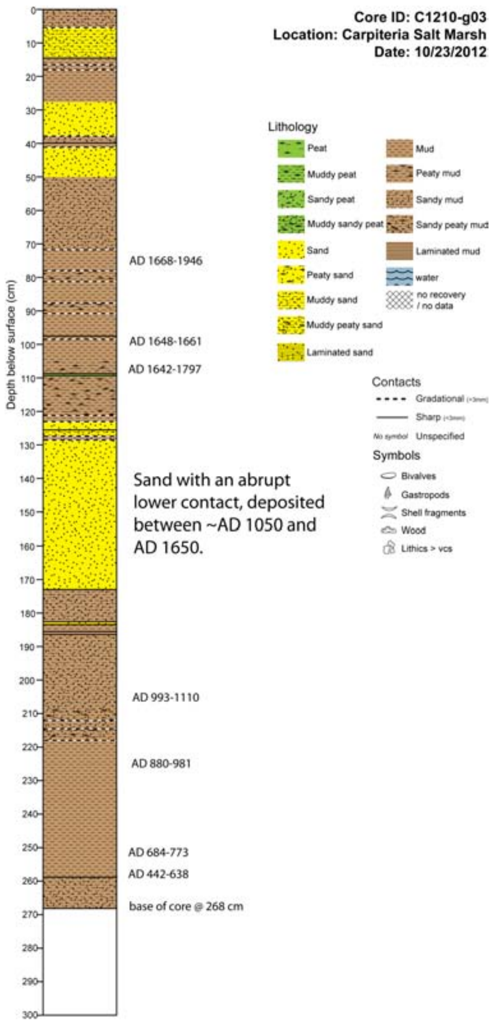

Figure 4. *Log of core 2010-g03, with the reliable age dates shown at their collected depths. Note the sand layer at 125 to 172 cm depth: this layer has a sharp lower contact and falls within the age range for the most recent uplift event at Pitas Point, although other characteristics such as cyclic, graded bedding are not evident.*

In contrast, the samples containing plant lignans mixed with roots were anticipated to be younger than the charcoal because the roots can penetrate from higher in the section. Similarly, in situ decomposition of organic remains produces humus which complexes with the fine clay, so these samples have the potential to be younger than detrital charcoal. The caveat for the humus samples is that if the organic component is derived from stripping of hill-slopes in the Santa Ynez Mountains, then dates derived from these samples could potential be older than charcoal.

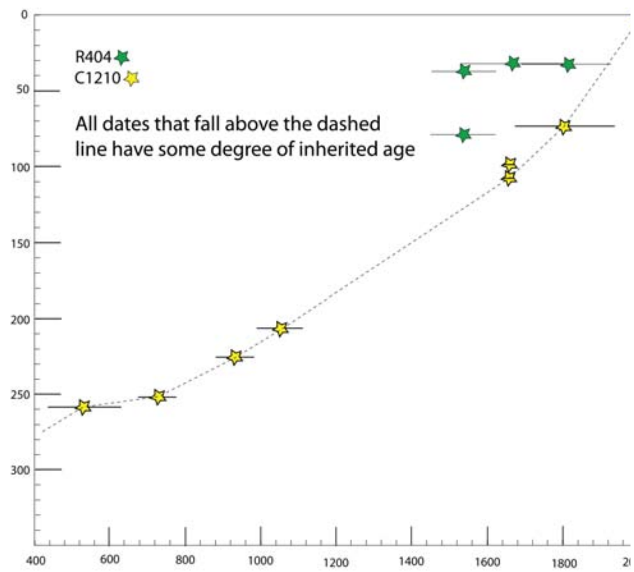

Figure 5. *Plot of radiocarbon ages versus depth for dated samples from cores R404 and C1210-g03. The samples from core 404 either have some inheritance, or the northwestern area of the salt marsh has received more recent sedimentation. The dates from core 1210 indicate an average sedimentation rate of about 2 m per millennium, with a possible acceleration in the past several hundred years. Buried root mats and peat-like layers suggest subsidence.*

The 24 dates from cores R404 and C2012 are presented in Table 1. For most groups of paired samples, the charcoal samples yielded the youngest ages, with the humic samples the oldest. This implies that much of the organic carbon complexed with the fine clay fraction is derived from the hill-slopes of the surrounding mountains and exhibits substantial age inheritance. These types of samples are therefore not representative of the age of deposition, and are not used in the chronologic model.

Surprisingly, the samples with plant remains mixed with roots also dated older than the charcoal in most cases, with the two exceptions being samples collected from 187 and 203 cm depth, which yielded much older ages than the samples from above or below. These two detrital charcoal samples are inferred to have substantial inheritance. The plant / root samples, however, should have been no older than the detrital charcoal samples if both are from vegetation grown in a subaerial environment, and the simple explanation is that there is a significant reservoir effect associated with these samples owing to their in-situ growth in a semi-marine environment. The reservoir effect does not appear to be consistent, however, and ranges from zero to 500 years.

The remaining seven charcoal samples from C2012 are all in stratigraphic order and we use these dates as the best representation of the chronology of core C2012. All future dating will be conducted solely on detrital charcoal, unless we can resolve a common reservoir correction that would allow use of the plant lignans.

The dating results indicate a sedimentation rate of nearly 2 m per millennium. With the current marsh surface very close to mean sea level, root mass horizons and peat-like layers below sea level suggest subsidence. Plotting the ages of the most reliable radiocarbon dates against the depths from which the samples were collected yields a reasonably constant sedimentation rate for the upper 2.7 m of core, with possibly an accelerated rate in the past several hundred years.

A sandy stratum from about 125 to 168 cm depth is the only candidate for a tsunamigenic deposit. It does fall in the correct age range for the most recent uplift event at Pitas Point, but sedimentological aspects of the sand are not entirely consistent with a tsunami origin. This stratum has been sampled for future diatom and foraminifera analyses.

Bibliography of SCEC-funded Publications for 2012

Fletcher, John M., Orlando J. Teran, Thomas K. Rockwell, Mike Oskin, Ken W. Hudnut, Karl J. Mueller, Ronald M. Spelz, Sinan O. Akciz, Eulalia Masana, Geoff Faneros, Alex Morellan, Joann Stock, Austin Elliott, Peter Gold, Jing Liu-Zeng, Alejandro Gonzalez, David Lynch, Alejandro Hinojosa, Javier Gonzalez, 2013 in review, Assembly of a large earthquake from a complex fault system: surface rupture kinematics of the April 4, 2010 El Mayor-Cucapah Mw7.2 earthquake. Submitted to Geosphere, February, 2013. SCEC contribution 1697.

Marliyani, G.I., Rockwell, T.K., Onderdonk, N. and McGill, S., 2013 in press, Straightening of the northern San Jacinto fault, California as seen in the fault structure evolution of the San Jacinto Valley step-over. Bulletin of the Seismological Society of America, accepted February, 2013. SCEC contribution 1628

Onderdonk, N., Rockwell, T.K., McGill, S., and Marliyani, G., 2013, Evidence for seven surface ruptures in the past 1600 years on the Claremont fault at Mystic Lake, northern San Jacinto fault, California. Bulletin of the Seismological Society of America, v. 103, no. 1, p. . doi: 10.1785/0120120060 SCEC contribution 1503

Kimberly Blisniuk, Michael Oskin, Kathryn Fletcher, Thomas Rockwell, Warren Sharp, 2012, Assessing the Reliability of U-series and ^{10}Be dating techniques on Alluvial Fans in the Anza Borrego Desert, California, Quaternary Geochronology*,* SCEC contribution 1646. doi.org/10.1016/j.quageo.2012.08.004

Salisbury, J.B., Rockwell, T.K.**,** Middleton, T.J., and Hudnut, K.W., 2012, LiDAR and Field Observations of Slip Distribution for the Most Recent Surface Ruptures Along the Central San Jacinto Fault. Bulletin of the Seismological Society of America, v. 102, no. 2, p. 598-619. doi: 10.1785/0120110068. SCEC contribution 1470

Wechsler, N., Allen, E.E., Rockwell, T.K., Girty, G., Chester, J., and Ben-Zion, Y., 2011, Characterization of pulverized granitoids in a shallow core along the San Andreas fault, Little Rock, CA. Geophysical Journal International, v. 186, p. 401-417. Doi: 10.1111/j.1365-246X.2011.05059.x SCEC contribution 1458.