Recording Prehistoric Tsunami Events on the Pacific Coast, Guerrero State, Mexico

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Abstract

The study of prehistoric earthquakes and tsunamis using geomorphic features and deposits has provided valuable information in the assessment of earthquake and tsunami hazards. These studies have been complemented with the analysis of the sediment recorded, where sudden changes on marine to terrestrial environments and vice versa can be record, and where tsunami deposits have been preserved. The Pacific coast of Mexico is a tectonically active coast that has experienced numerous large magnitude earthquakes (M>7.5) in historical time, and more than 50 documented tsunamis since 1732. Geomorphic and stratigraphic studies on the Guerrero coast reveal the feasibility of using the stratigraphic record of lagoonal sediments to document past earthquake and tsunami events on this coast. Core samples from nine study sites show distinct stratigraphic changes with depth, indicating clear rapid change in depositional environments over time. At least three tsunami events and possibly seven marine inwash events have been identified in the past 4600 years BP on the Guerrero coast. This information is significant to assess tsunami hazard and complements tsunami hazard mapping of this coast where the tsunami historical record is not well constrained.

Introduction

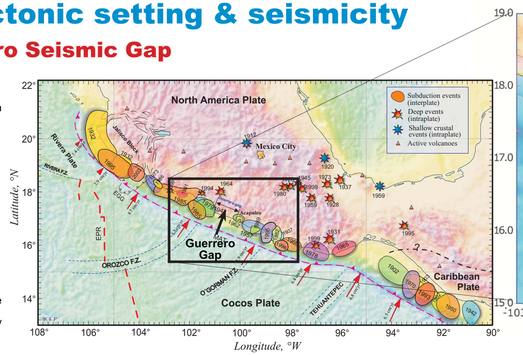
The specific objectives of this study are (1) to derive rates of tectonic deformation from geomorphic and stratigraphic studies of the Guerrero coastal area, and (2) to examine the feasibility of this stratigraphic approach to identify prehistoric earthquakes and tsunamis in the coastal lagoons of Guerrero, Mexican Pacific coast. The Guerrero gap coastal area, where a major earthquake is expected to occur, parallels the Cocos plate subduction zone. Convergence rates vary from 5.2 cm/yr to 5.8 cm/yr (Figure 1). The Guerrero gap has experienced several historical earthquakes, notably the 1911 (7.8 Ms) event. However, no large magnitude events since the 1911 earthquake and only a few M~6 events have occurred near the Guerrero gap edges. A major interplate earthquake of estimated magnitude Mw=8.1 to 8.4 has a high probability to occur. The probability for a tsunami occurrence is also high. Historical records indicate that at least 10 tsunamis have reached this coast since 1732 (Sanchez and Farreras, 1993).

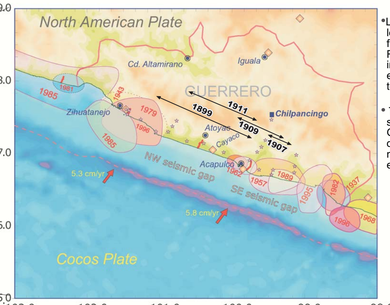
Typically, tsunami records in Mexico come from tide-gauge registers. Tide-gauge measurements in Mexico initiated in 1952. This is a relatively short record to fully understand the hazard that tsunamis pose to the highly populated Mexican coast. Historical and register data indicate that at least 50 tsunamis reached the Pacific coast of Mexico since 1732; 34 of these tsunamis originated from local sources and all of them were produced by earthquakes (Sanchez and Farreras, 1993; Farreras, 1997). The maximum wave height recorded with tide-gauge instruments for the most recent tsunamis is 3.0 m. However, historical data for the last three centuries, based on visual observations, suggest that the tsunami wave heights on the Mexican Pacific coast can be larger. For instance, the November 16, 1925 tsunami that hit the Zihuatanejo coast, Guerrero state, produced an 11-m-high wave, and on June 22, 1932, the tsunami that arrived to Cuyutlan, Colima state, produced a 10-m-high wave. Both tsunamis produced considerable damage and human loss. Considering the short record of instrumentally registered tsunamis, tsunami hazard assessment based on these data might be underestimated. It is extremely important to integrate a record of prehistoric tsunamis based on geologic evidence of tsunami deposits on the Pacific coast of Mexico to fully understand tsunami hazard on this region. Deposits of prehistoric tsunamis

1. Tectonic setting & seismicity

Guerrero Seismic Gap

Location of the Guerrero coast within the Guerrero gap. Subduction of the Cocos plate here occurs at convergence rates varying from 5.3 cm/yr to 5.8 cm/yr. The northwest Guerrero segment has experienced no large magnitude events since the 1911 earthquake, only a few Ms~6 events have occurred near its edges. A major interplate earthquake (~ Mw=8.1 to 8.4) has a high probability to occur.





- Locked zone located 55 km from the trench. Recurrence interval is estimated at 60 to 70 years.
- The northern section of the Guerrero Gap is due for a large magnitude earthquake

2. Methods

Assessing Land-level Changes During Earthquake Deformation Cycles on the Guerrero Coast

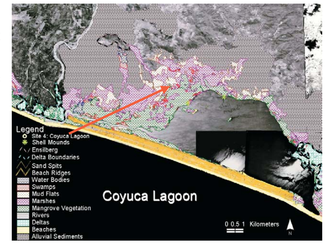
Combined Approach :

- Geomorphic mapping and landform characterization
- Sediment-Stratigraphic studies
- Geochemical analysis
- Microfossil analysis (diatom, foraminifer, ostracod)
- ^{14}C, ^{137}Cs, ^{210}Pb dating
- GPS measurements

3. Results - geomorphology

Geomorphology

Typical landscape of the Guerrero coast consists of a series of lagoons and bars. In general, the coastal landscape supports a model for long-term tectonic coastal subsidence of the Guerrero gap. A series of key geomorphic indicators such as elongated islands reminiscent of ancient barrier islands, submerged barrier islands, extensive marshy environments, increased depths in the lagoons close to the mid and southern areas of the gap, and submerged anthropologic features (shell mounds), among others, suggest active tectonic subsidence of the coast. Landscape variations within the gap from northwest to southeast indicate possible variations in the rates of deformation or perhaps tilting of the coast towards the southeast. Figure above shows example of landscape features at the Coyuca lagoon.



4. Results - coring

Mud Flats – coring locations

Suitable (i.e. low elevation, relatively undisturbed) coastal sites in Guerrero state for coring.

Vibrocores taken (2m to 5m length) using an Atlas Cobra corer, to determine an outline coastal/lagoonal stratigraphy.

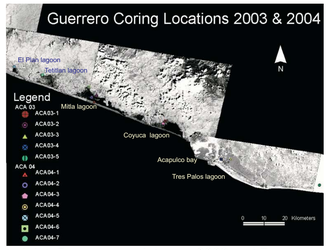
Cored sediment description was made in the field with preliminary identification of terrestrial or marine units.

Cores were either sealed intact or subsampled in the field prior to laboratory analyses (i.e. ^{210}Pb and ^{137}Cs for near-surface samples, and ^{14}C dating; sediment geochemistry, granulometric, magnetic properties and paleomagnetics; and microfossil).

GPS Measurements

Individual core sites were located by GPS, to determine their elevations relative to semi-permanent GPS stations set-up during the project by a team from UNAM, headed by V. Kostoglodov.

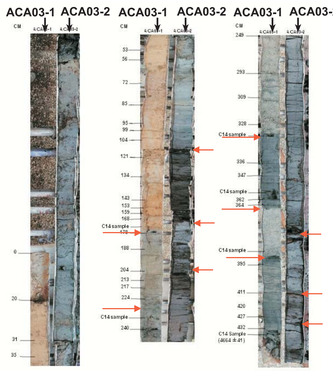
Coring sites



In total, 5 cores were taken in 2003 and 7 cores in 2004, from the Tres Palos, Coyuca, Mitla, Tetitlan and El Plan lagoon marshes (core ACA03-05 is not included in this study)

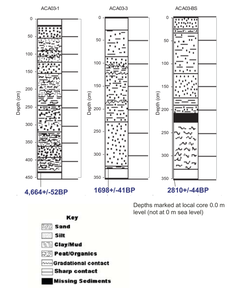
5. Results - core stratigraphy

Stratigraphy
Cores ACA03-01 and ACA03-02, at Coyuca and Mitla lagoons, Guerrero Coast



Pilot study-cores at Coyuca and Tres Palos lagoons. Cores show stratigraphic changes with abrupt contacts between sediments that clearly indicate significant changes in depositional environment over time. Red arrows show sharp contacts between sediment types. Depths are in cm.

Core Stratigraphy

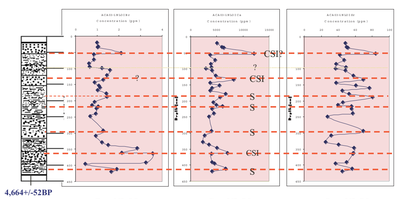


6. Results - sediment geochemistry

Interpretations of Elemental Distributions

- Distributions of 48 elements in core sediments predominantly reflect changes in stratigraphy/sediment composition. The geochemical and stratigraphic changes clearly indicate significant changes in depositional environment over time.
- There are significant downcore variations in Br, Ca, Sr, S, and Cl, .i.e. elements used in coastal settings as indicators of marine inwash events (e.g. tsunami), and the cores analyzed here show sedimentary horizons considerably enriched in Br, S, and/or Cl relative to underlying and overlying units.

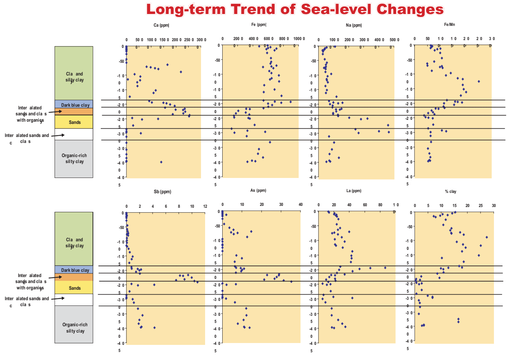
Interpretation of Marine Inwash Events In Core ACA03-01



S- saltwater inundation or marine inwash; CSI - catastrophic saltwater inundation (e.g. tsunami).

NLOI-Non loss on ignition

Long-term Trend of Sea-level Changes



The geochemestry of Las Salinas core sediments indicates four different events in time: 1) an initial stage of brackish/lagoonal setting indicated by the lowest/bottom (organic rich silty clay), at about 4630 +/- 37 yr BP; 2) a second event of a marine flooding inwash as shown by sands and intercalated sands and clay, at about 2836 +/- 34yr BP; 3) a marine setting indicated by the dark blue clay; and finally, 4) a terrestrial/lagoonal? environment indicated by the upper (0-190 cm) clay and silty clay. Diatom data confirm this interpretation.

Conclusion

- Stratigraphic and geochemical indicators of paleosalinity (Br > Sr > Ca >>Na > Cs >U) in the coastal marshes of Guerrero reflect abrupt contacts between sediments
- Stratigraphic and geochemical indicators of paleosalinity record sudden land and sea level changes
- 7 marine inwash events and possibly 3 tsunami events are recorded by stratigraphic/sediment and paleosalinity indicators
- Radiocarbon dates imply a sedimentation and long term subsidence rate of ~ 1 mm/yr
- Ongoing ^{14}C, ^{210}Pb and ^{137}Cs dating will estimate ages of paleoearthquakes and tsunami events