

Final Technical Report

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Holocene Faulting of the Cerro Goden Fault, Western Puerto Rico

Collaborative Research with Judith Zachariassen
and University of Puerto Rico at Mayagüez

Principal Investigator: Christa G. von Hillebrandt-Andrade
Puerto Rico Seismic Network
University of Puerto Rico
PO BOX 9017
Mayagüez, PR 00681-9017
Tel. 787-608-2577; Fax: 787-265-1684
Email: christa@midas.uprm.edu
<http://redsismica.uprm.edu>

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Introduction

The objective of this research is to determine the presence through trenching of active faults in the Añasco Valley in Western Puerto Rico. Puerto Rico lies within the complex plate boundary zone between the North American and Caribbean plates. It is bounded by numerous large offshore structures that accommodate most of the plate boundary motion, have been the site of several M7 or greater historical earthquakes, and thus pose a significant seismic hazard to the island. Within Puerto Rico, the southwestern region represents the area of greatest seismic activity which is characterized by shallow depths (Huérffano et al, 2005). Several large bedrock faults occur on the island of Puerto Rico, but their Quaternary history has been largely undetermined. However, recent paleoseismic work, in the Lajas Valley revealed the presence of Holocene Faults (Prentice and Mann, 2005). Recent geological and onshore and offshore geophysical studies also have suggested Late Quaternary faulting along the Cerro Goden fault in western Puerto Rico (Mann et al, 2005; Grindlay et al, 2005).

The Cerro Goden fault, which runs along the base of the Cadena de San Francisco range north of Añasco in western Puerto Rico and joins with the Great Puerto Rican Southern Fault Zone, disrupts Eocene and older rocks but its Quaternary history is unclear. It bounds the northern part of the Añasco valley. More than 600 shallow earthquakes have been recorded in this region since 1987. A reconnaissance study by Mann and others (2005) found geomorphic evidence of Quaternary displacement. A high-resolution seismic and paleoseismic trenching study in spring 2004 by Michael Rymer, Rufus Catchings, Judith Zachariassen, Carol Prentice and other researchers from the USGS and the University of Puerto Rico, revealed evidence of several near surface fault strands along the strike of the fault and trench evidence of Holocene faulting at one location. The Cerro Goden fault lies within 10 km of Mayagüez, the largest urban center in western Puerto Rico and the third largest in the whole island. Characterizing the Holocene history of the fault is crucial to developing accurate seismic hazard estimations for the city and

the region. Puerto Rico is densely populated and has been occupied for hundreds of years. Much of its infrastructure is old and/or not built to rigorous standards adequate to withstand shaking from large local earthquakes. Improving infrastructure, zoning regulations, and increasing human safety depend on accurate knowledge of onshore seismic sources.

As part of this project Judith Zachariassen and Christa Hillebrandt of the University of Puerto Rico, Mayagüez proposed to undertake a paleoseismic investigation of the Cerro Goden fault. The paleoseismic study was undertaken by Judith Zachariassen with the support of Christa G. von Hillebrandt-Andrade and the student Rafael Abreu. Carol Prentice and Eugene Schweig from the USGS, Western and Central region, respectively, also participated in some of the trenching.

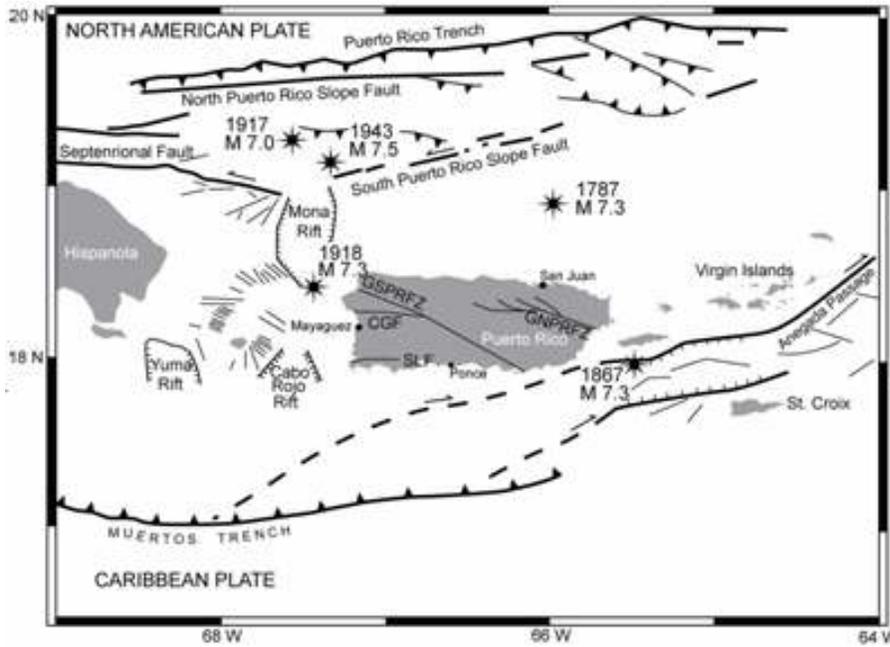


Figure 1. Tectonic setting of Puerto Rico showing major tectonic structures (Prentice and Mann, 2005). Stars represent approximate locations of epicenters of large-magnitude historical earthquakes. GNPRZ great Northern Puerto Rico Fault Zone; GSPRFZ great southern Puerto Rico fault zone; CGF, Cerro Goden Fault; SLF South Lajas Valley Fault.

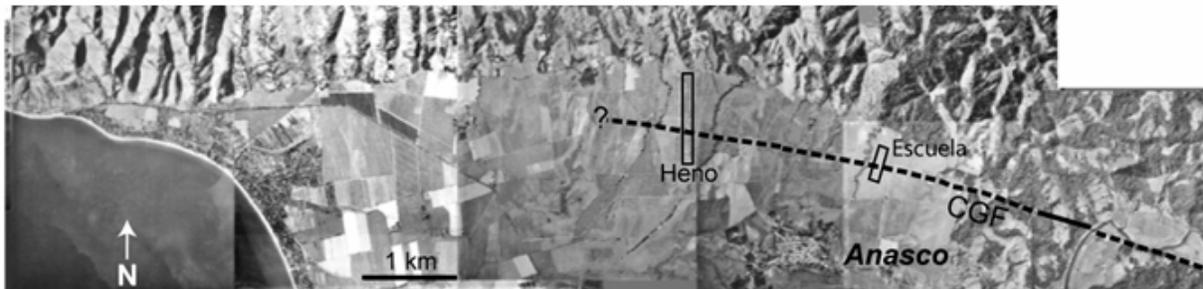


Figure 2. Composite of 1936 air photos of the northern Añasco Valley. Dashed line depicts the inferred trace of the Cerro Goden fault. Heno and Escuela are the sites of the 2004 high resolution geophysical surveys and 2004-2005 paleoseismic trench excavations.

Investigations Undertaken

Prior to this project high-resolution seismic and paleoseismic trenching studies were carried out in the region. In March 2004, two high-resolution seismic surveys were carried out in Añasco under the direction of Michael Rymer and Rufus Catchings of the USGS with the support of the Puerto Rico Seismic Network (PRSN) in March of 2004 (Rymer et al, 2005). According to the interpretations of Rymer et al, there were several disruptions that were consistent with the proposed faulting of Mann and other (2005) and photo and satellite images. These traces extended from depth up to the surface.

In March and April, 2004, Carol Prentice and Judith Zachariassen, with the support of the Puerto Rico Seismic Network excavated two trenches in the Escuela site. No fault was exposed in the first trench where a sequence of debris flows and quiet water sediments were observed. The second trench revealed a sequence of fine Holocene sediments juxtaposed across a sub-vertical boundary against Pleistocene weathered red clay and gravel. It was concluded by Prentice and Zachariassen that this juxtaposition could represent Holocene activity of the Cerro Goden fault.

The current project was designed to examine the Cerro Goden fault further. Additional trenches were to be excavated across the features identified in the seismic lines at the Heno site. In March and April, 2005 we excavated 5 trenches located above three such features. In addition, we returned to the Escuela site and re-excavated and deepened the 2004 trench that had the sub-vertical contact.



Figure 3. Example of one of the trenches at the Heno site, Añasco.

For this project, it was the responsibility of Christa G. von Hillebrandt-Andrade to:

1. Procure permissions for the trenching at the Heno and Escuela sites.
2. Make the arrangements for the rental of the equipment (backhoe, shores and pumps) needed for the trenching.
3. Provide Zachariasen with administrative and internet facilities for office work.
4. Provide personnel for the trenching. The student Rafael Abreu helped at all the trench sites and also provided very helpful translation services between the back hoe operator and Zachariasen.
5. Dissemination of the results.

Results

Trenches

No faults were exposed in the trenches excavated at the Heno site in 2005. All of the trenches revealed a sequence of unfaulted, horizontally-bedded fluvial deposits. Most of the sediment was grey-brown with some orange mottling. Dark grey to black organic-rich horizons were also identified and sampled.

The re-excavation of the Escuela 2 site revealed that the sub-vertical contact exposed in 2004 was not a fault scarp, but a fluvial contact, buttress unconformity.

Radiocarbon

According to Zachariasen (pers. com.), the radiocarbon samples at the Escuela sites were younger than 1210 AD. At the Heno sites, the deposits were even younger, all less than 600 years.

Seismic data

To site the trenches, the results of the two USGS seismic reflection surveys were used in the absence of surface features. According to their interpretations, there were disruptions of sediments at several locations which extended from ca 1000 m depth all the way to the surface. Nevertheless, no faults were found in any of the trenches. Due to this disparity, the PRSN requested the raw seismic data from the USGS.

Earthquake data

In a complementary study, HYPODD relocations were performed on the western Puerto Rico seismic database of the Puerto Rico Seismic Network (Abreu, 2005). For this study a total of 626 events which were located digitally in the region for the 1991-2002 time period were used. An initial CCHAR run was done and preliminary HYPODD relocations were also performed. The initial results confirm the East-West trend of seismicity through the Añasco valley but did not constrain much further the locations (Figure 4).

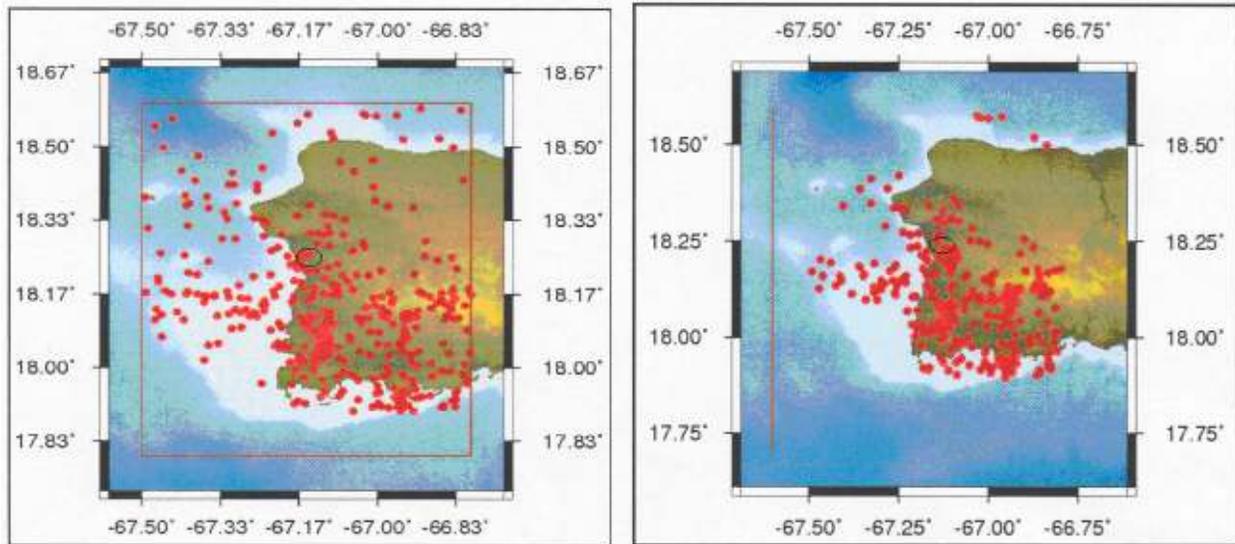


Figure 4. Standard PRSN locations (left) and HYPODD relocations (right) for microseismicity of Western Puerto Rico. Note, no significant constraint of epicenters in the Añasco Valley.

Dissemination

On March 3, 2005 a seminar was organized in the geology department. Judith Zachariassen gave the lecture “The Paleoseismology of the Sumatra Subduction Zone”. She also discussed the trenching work that was to be performed. The results of the trenching have been presented in dozens of lectures given by Christa G. von Hillebrandt-Andrade. Significant opportunities for disseminating the results in Puerto Rico were: Puerto Rico Senate Safety Commission (March, 2005), Triple S Insurance Corporation (May, 2005), State Emergency Management Annual Conference (May, 2005), ACE Insurance Corporation (June, 2005), Puerto Rico Society of Research Administrators (September, 2005) and FM Global (November, 2005).

Non-Technical Summary

The Añasco Valley is a seismically active region in western Puerto Rico. Evidence for Quaternary faulting along the Cerro Goden fault has been found, but the current seismic hazard map does not consider any fault in this region. Five trenches were excavated across possible traces of the Cerro Goden fault to investigate its Holocene earthquake history. No faults were found. The sediments are very young, less than 600-900 years old. If the trenches were accurately located over fault traces, these have not experienced surface faulting in the past 600 years. Traces further east in older sediments need to be investigated.

Reports published

None to date

Data availability

Trench logs are available from Judith Zachariassen, 488 Kenilworth Ave, San Leandro, CA 94577
Tel: 510-633-9744, email: judyzach@comcast.net.

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