

Cambios Sismológicos en Puerto Rico y su Impacto en las Edificaciones

Expo – Foro 2023: ¡Alerta!

¿Colapsan Condominios y Edificios?

- Cámara de Comercio de Puerto Rico
- Bonnet Insurance Brokerage Corporation

por: Prof. *José A. Martínez Cruzado, PhD*

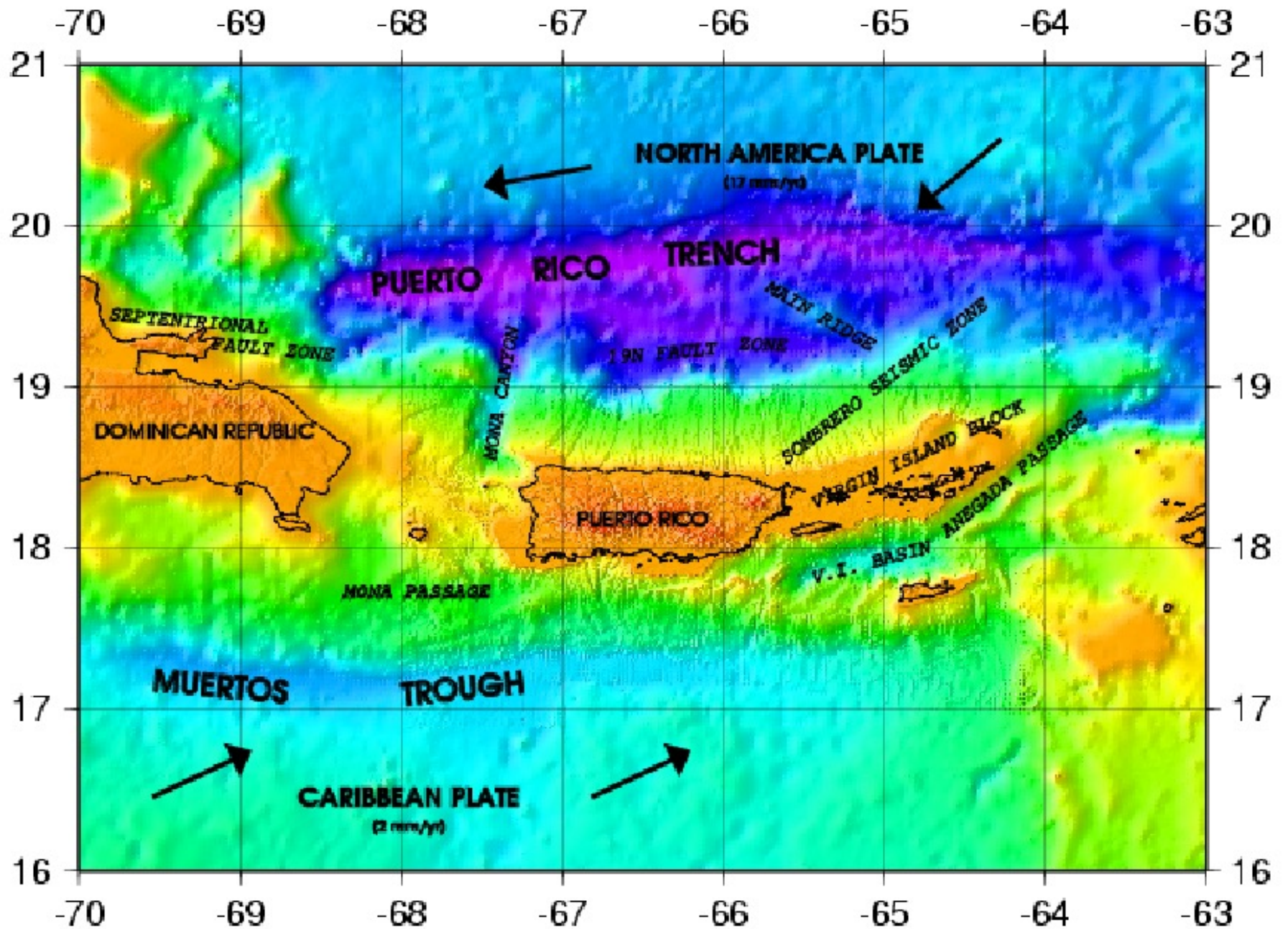
Programa de Movimiento Fuerte de Puerto Rico

Departamento de Ingeniería Civil y Agrimensura

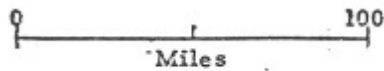
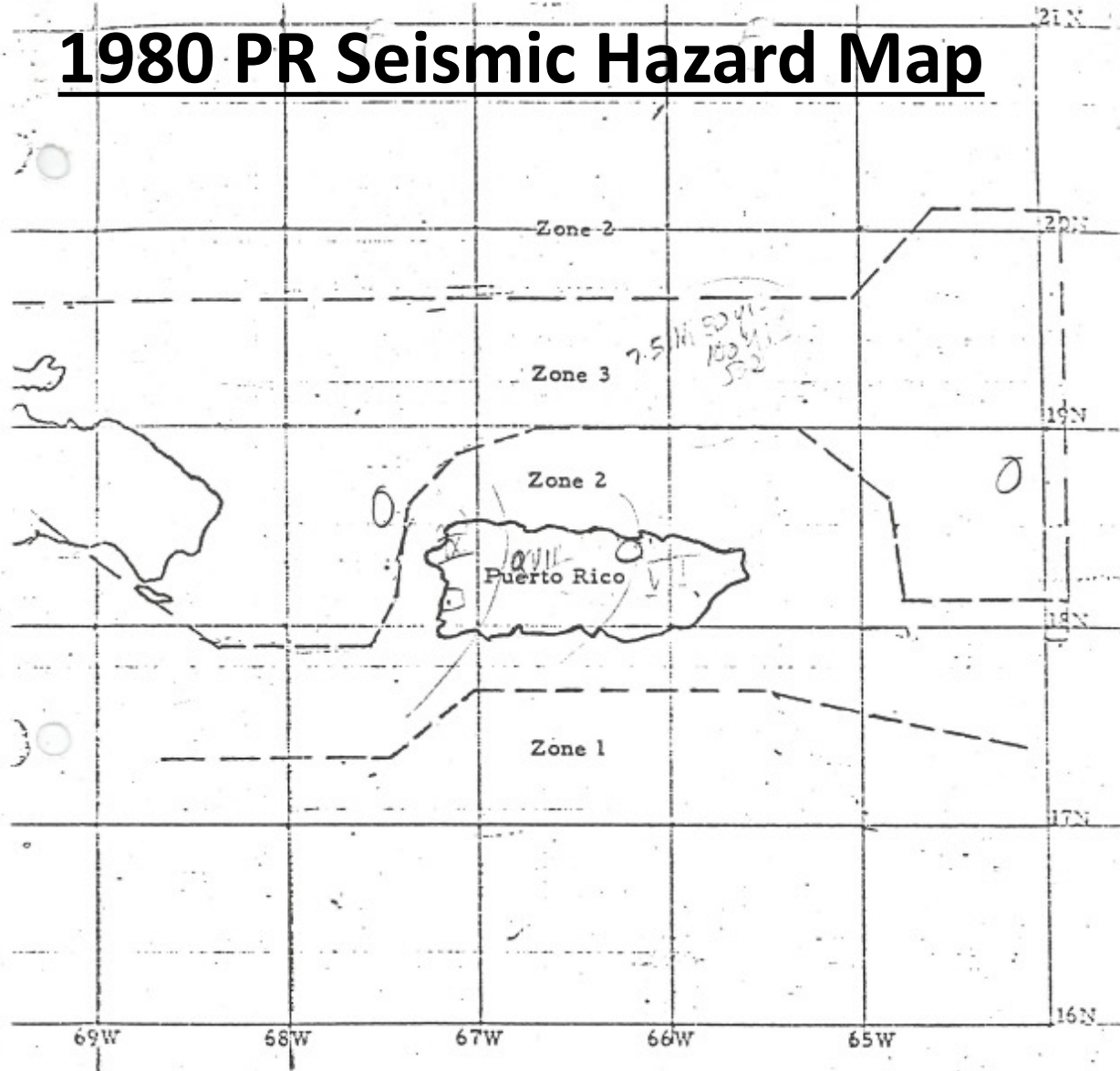
Universidad de Puerto Rico en Mayagüez

21 de Septiembre de 2023

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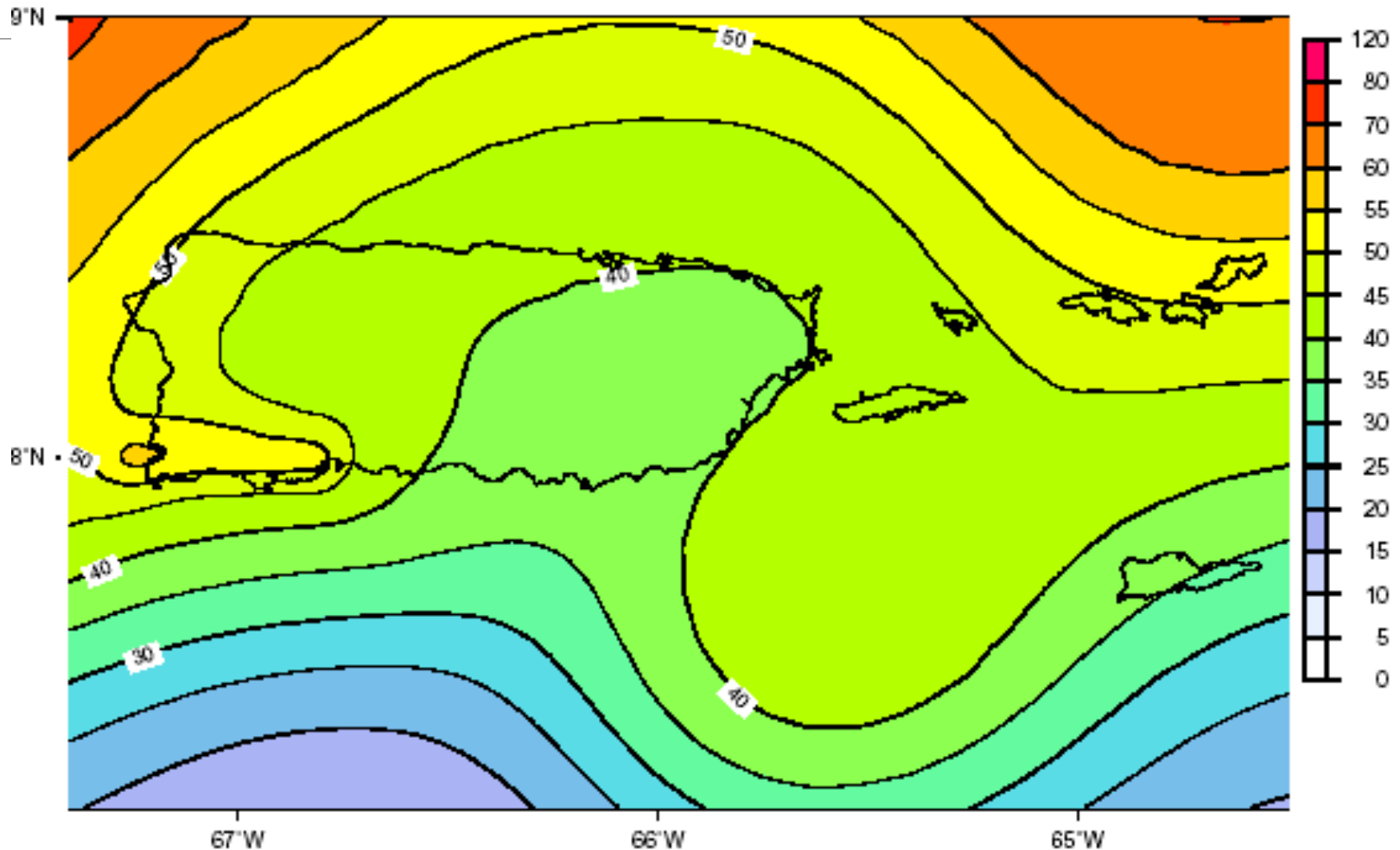
1980 PR Seismic Hazard Map



SEISMIC ZONING OF PUERTO RICO REGION. The zones correspond to Uniform Building Code zones.

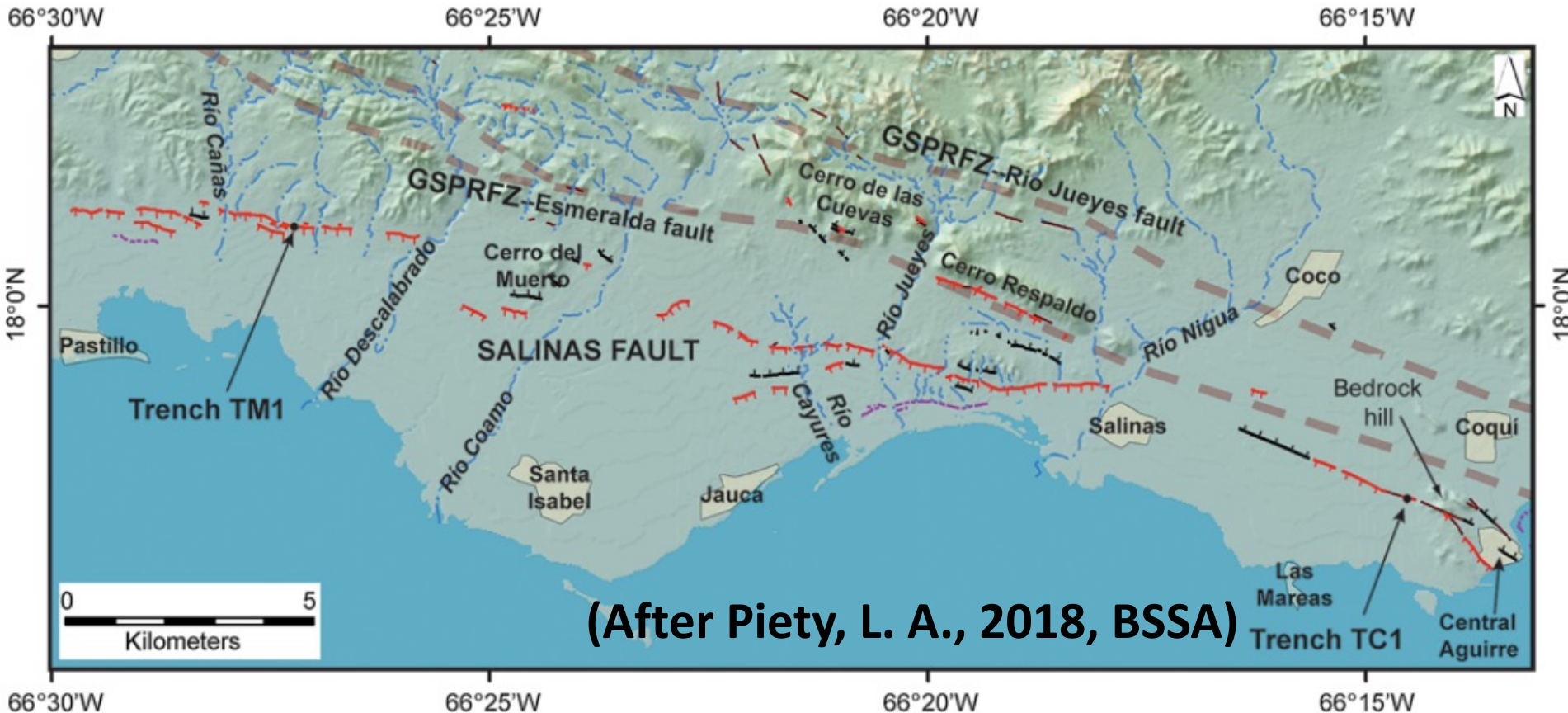
PR SEISMIC HAZARD MAP (2003)

PGA with 2% probability of exceedance in 50 years
 from all modeled sources (2,475 y).



Background - Motivation

- Since 2003, some studies have been carried out that demonstrate the existence of, at least, one more onshore fault with Holocene surface rupture... Salinas' fault... ..and maybe GSPRFZ.

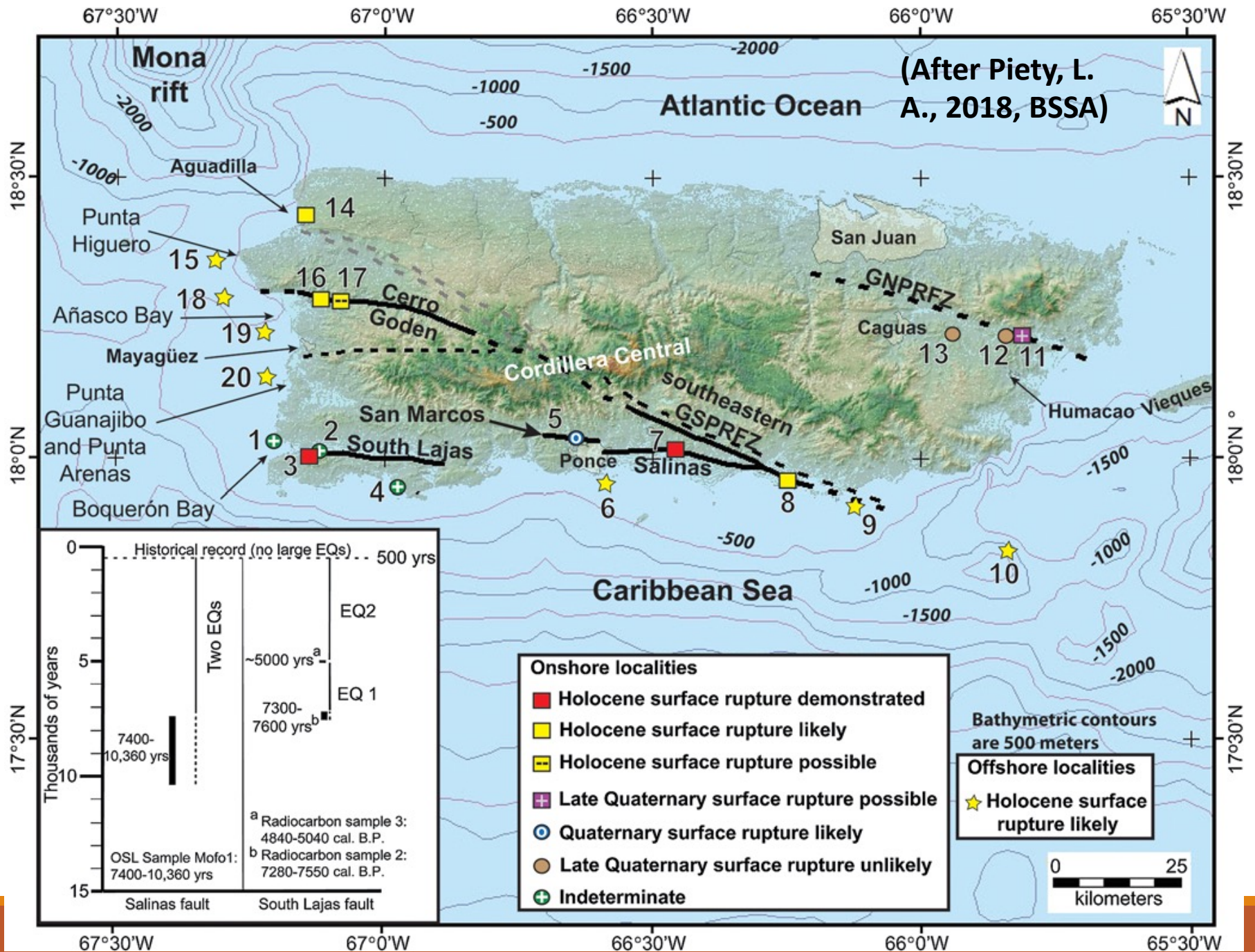




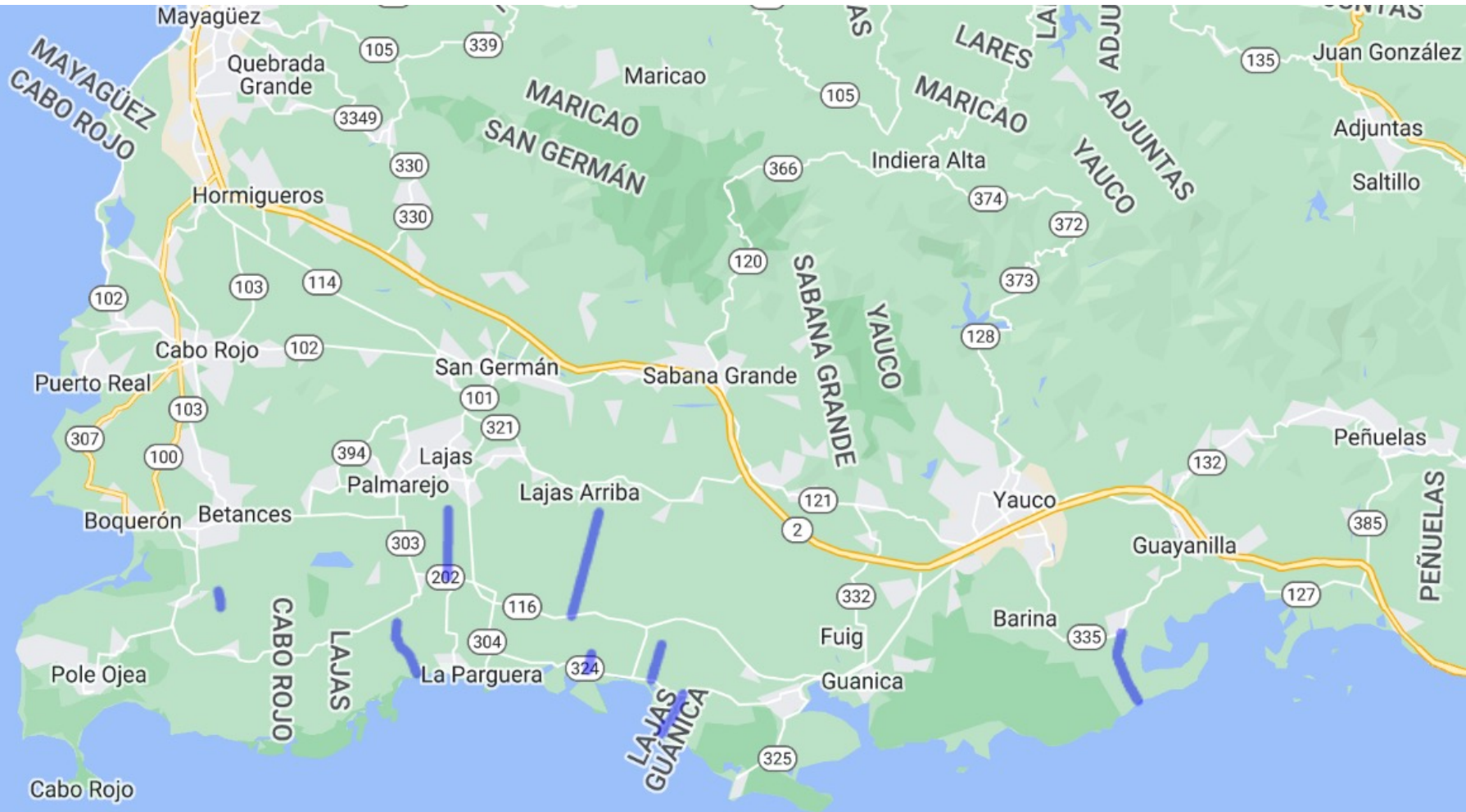
- 60 m long trench



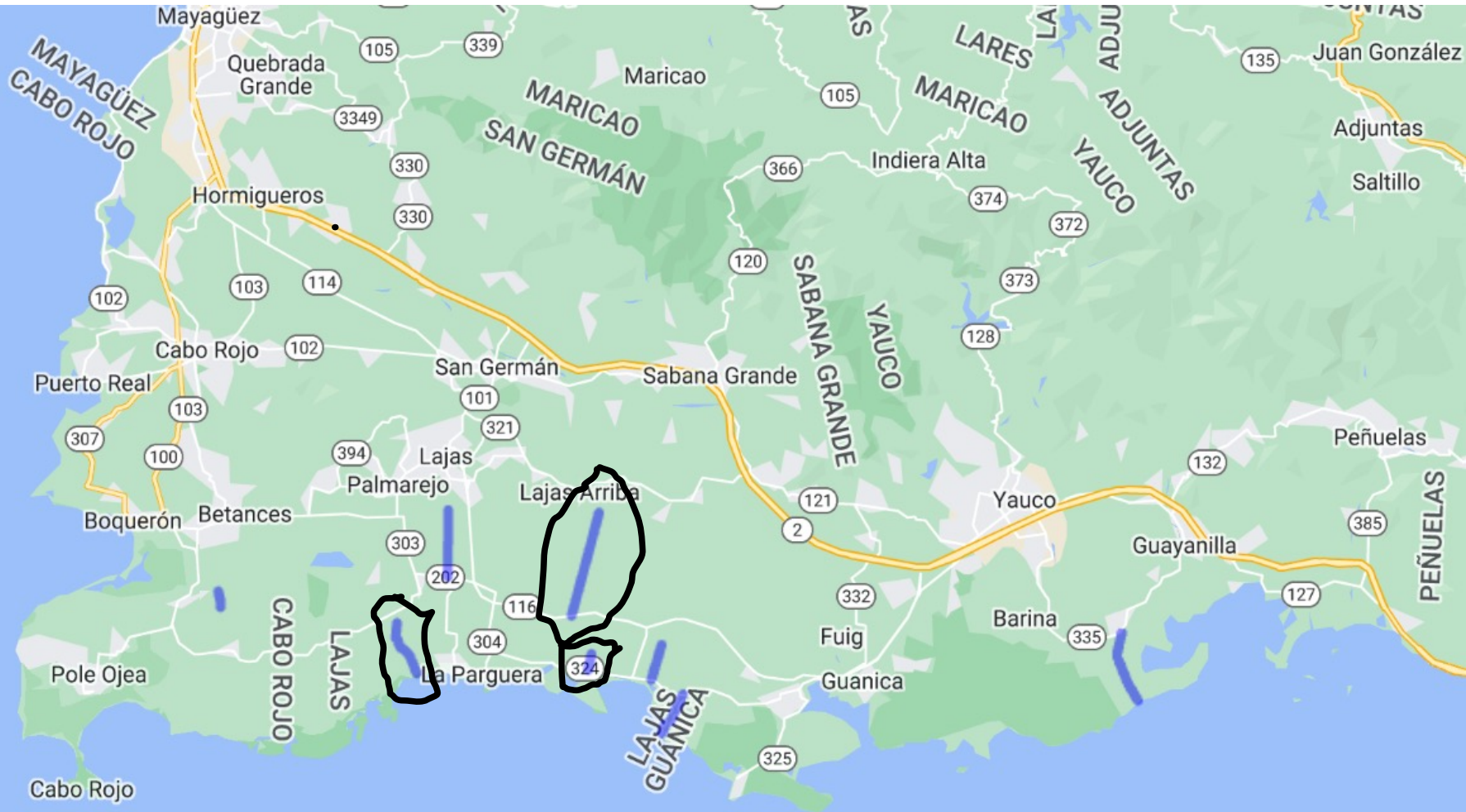


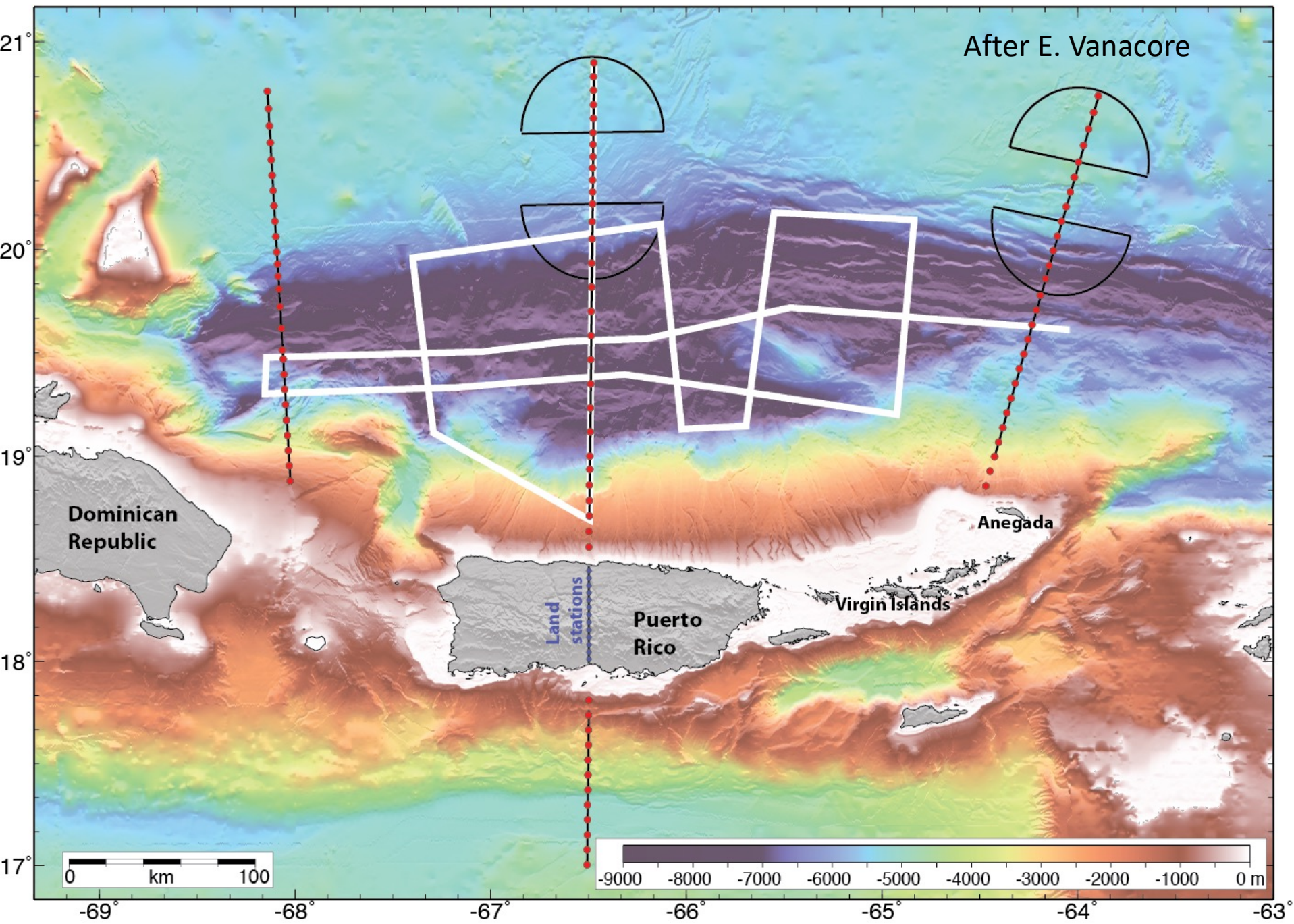


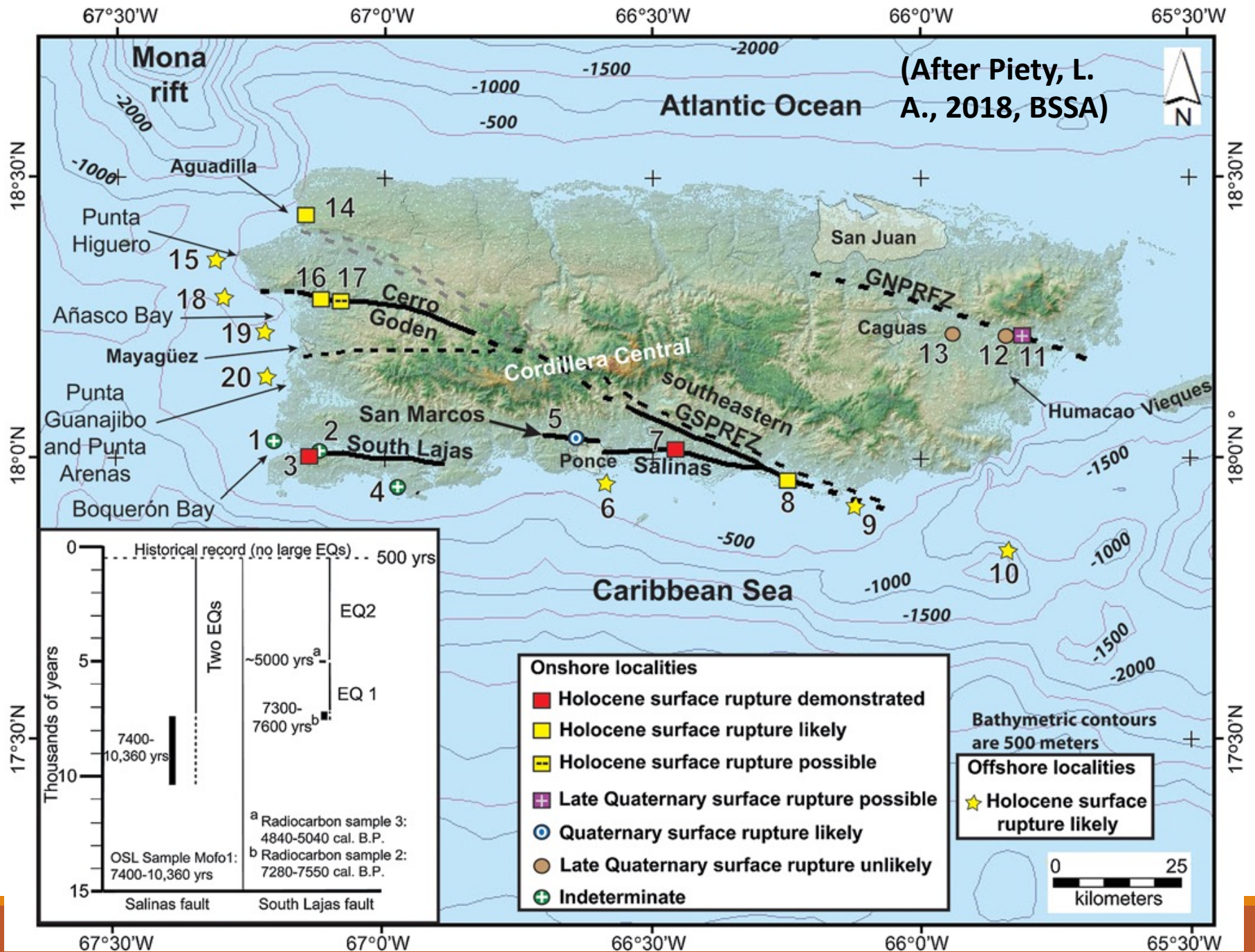
Geophysical studies performed on April, 2023



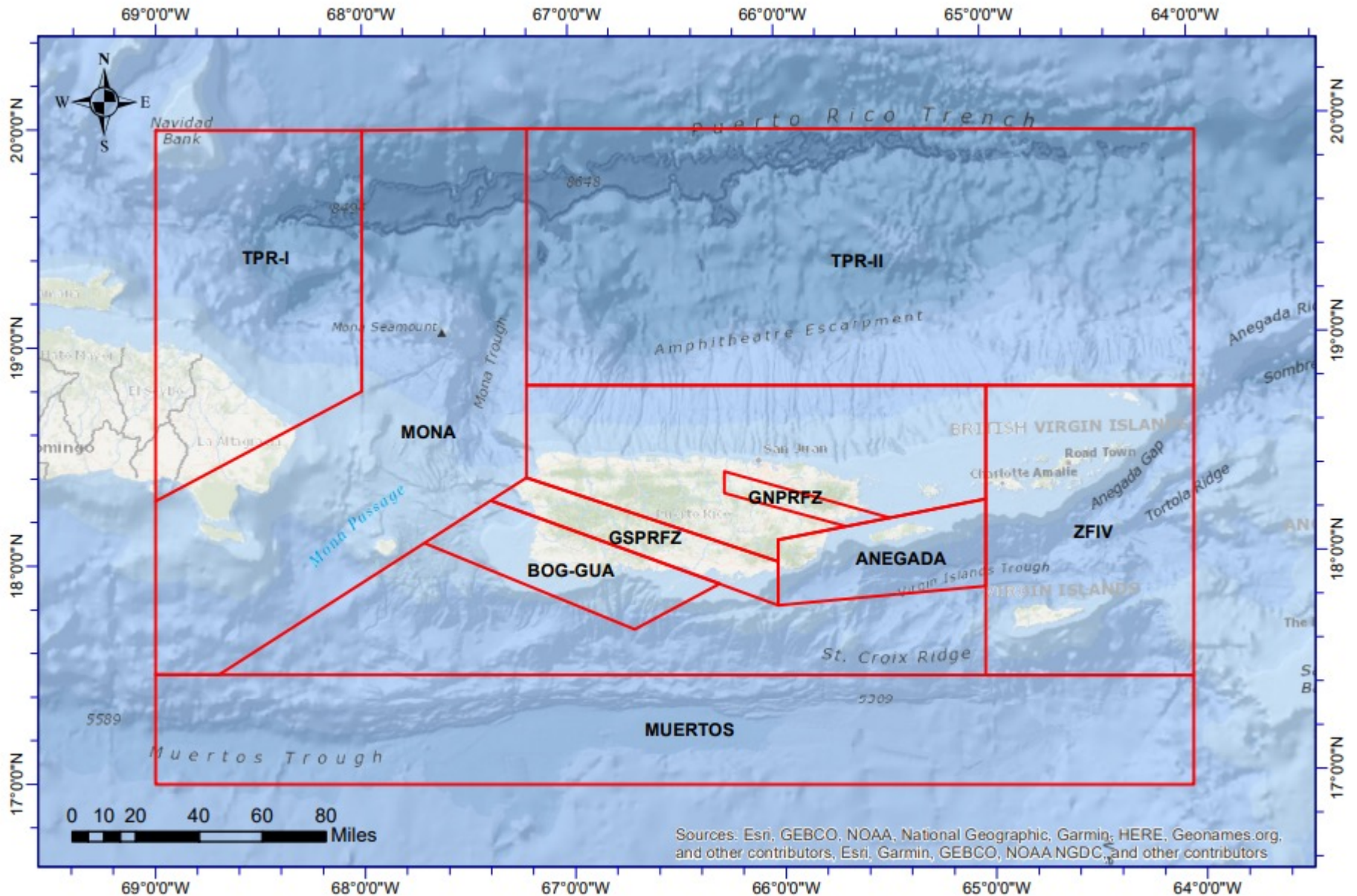
Geophysical studies performed on April, 2023



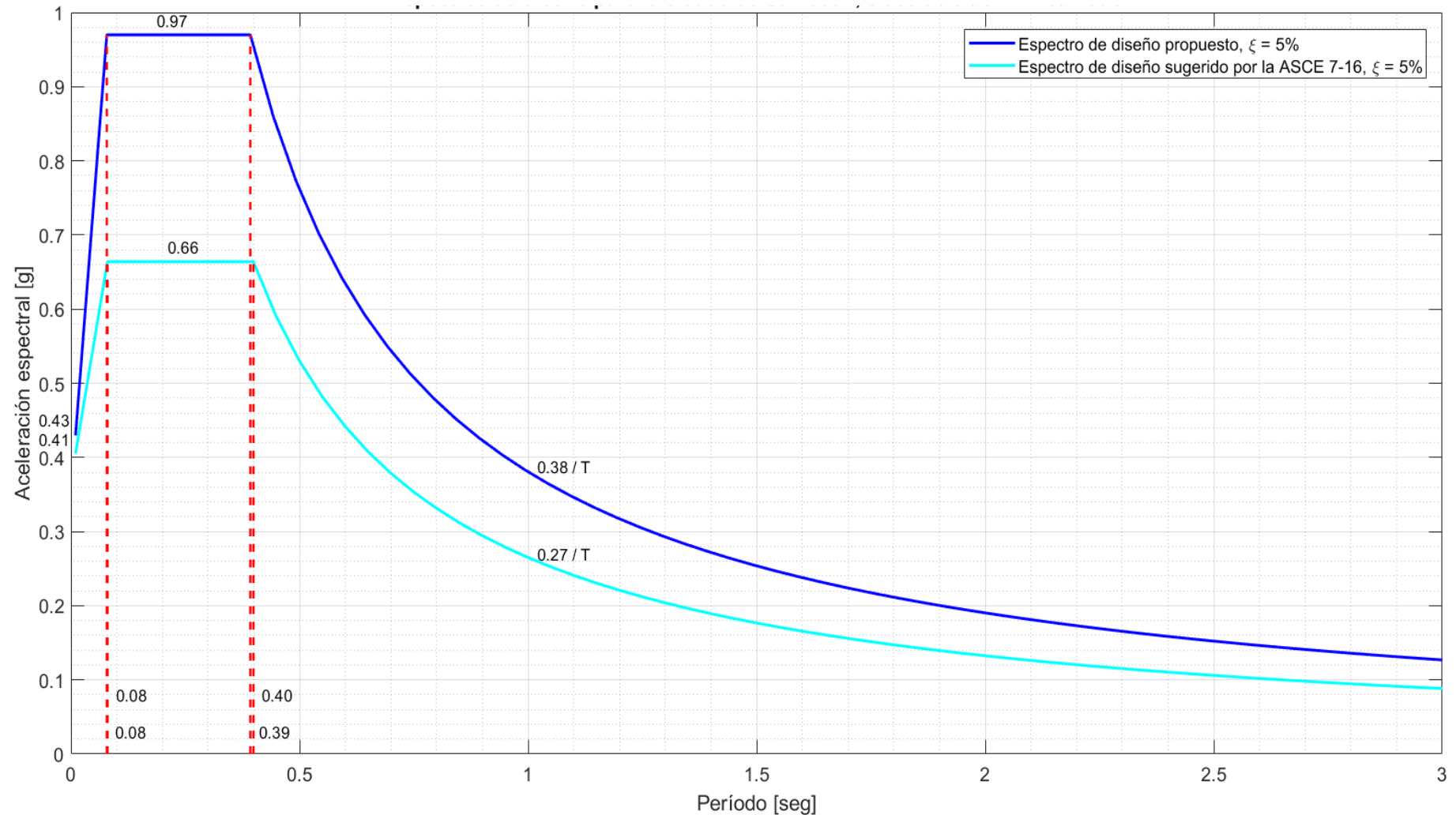




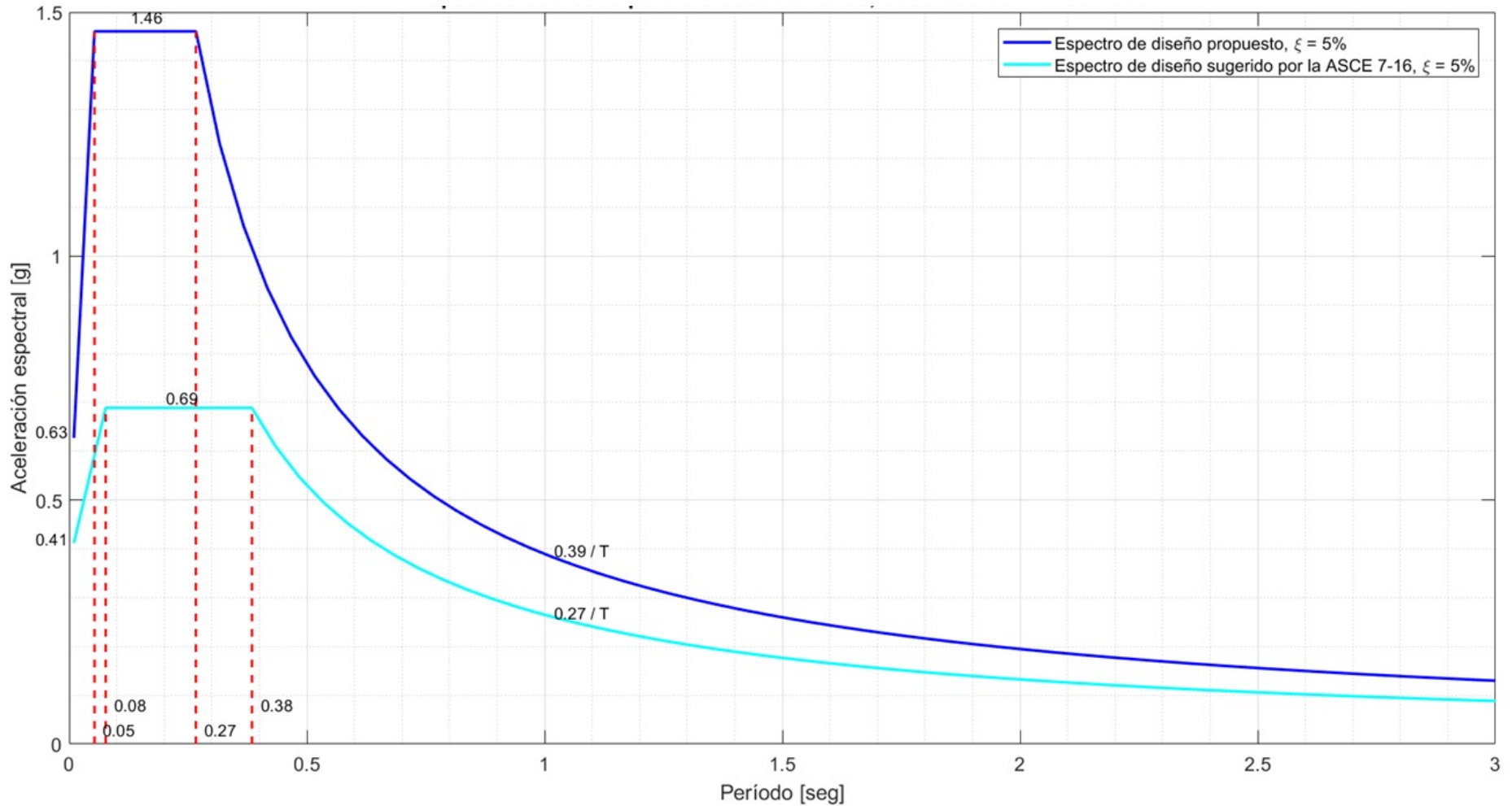
Distribution of Seismic Fault Zones for PR



Comparison of the Design Spectrum suggested for **San Juan**, and ASCE 7-16 for Site Class B - estimated



Comparison of the Design Spectrum suggested for **Ponce**, and ASCE 7-16 for Site Class B - estimated



Design philosophy of building codes

- Little damage is acceptable under frequent earthquakes.
- Repairable damage is acceptable under moderate earthquakes.
- ***Shall prevent collapse, but unrepairable damage is acceptable under infrequent earthquakes.***

**Building Codes
contains just**

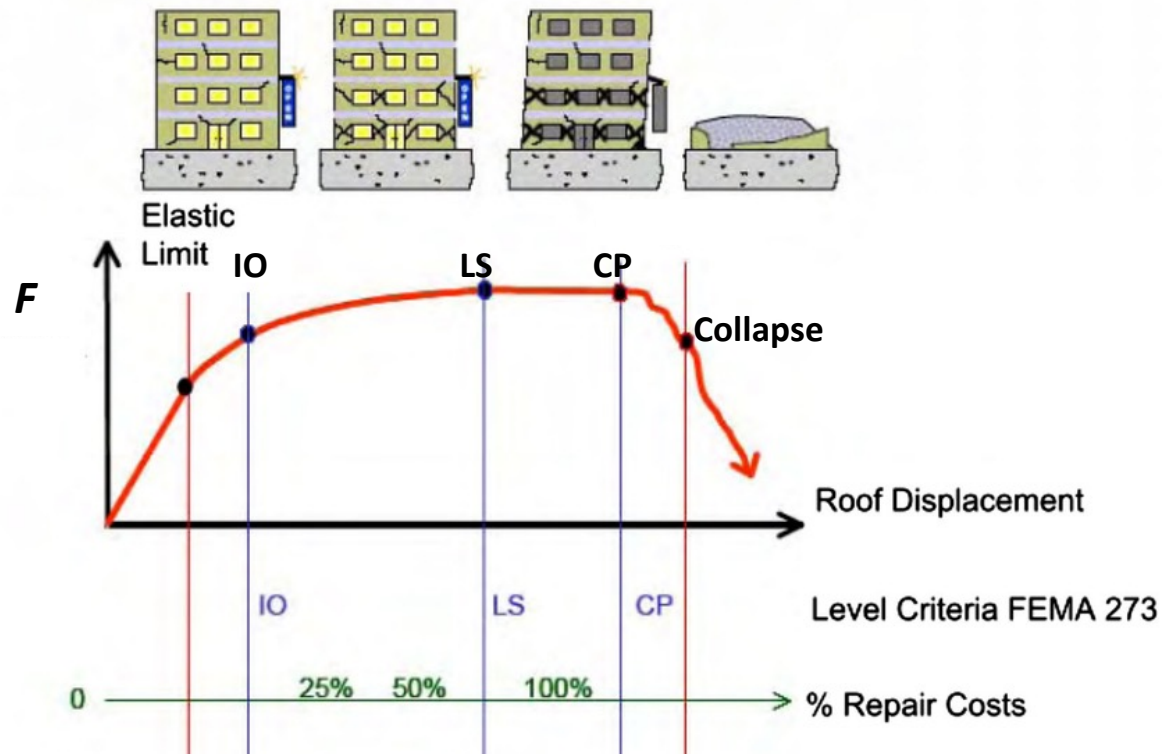
MINIMUM REQUIREMENTS



Performance Based Design

Three possible design targets:

- a) Collapse Prevention (CP)
- b) Life Safety (LS)
- c) Immediate Occupancy (IO)



If you design your house just meeting the minimum requirements of the building code then most probably:

YOUR HOUSE IS IN
COLLAPSE PREVENTION MODE

which means that you will need to demolish it what remains after the MC Earthquake, and then...

BUILD A NEW HOUSE

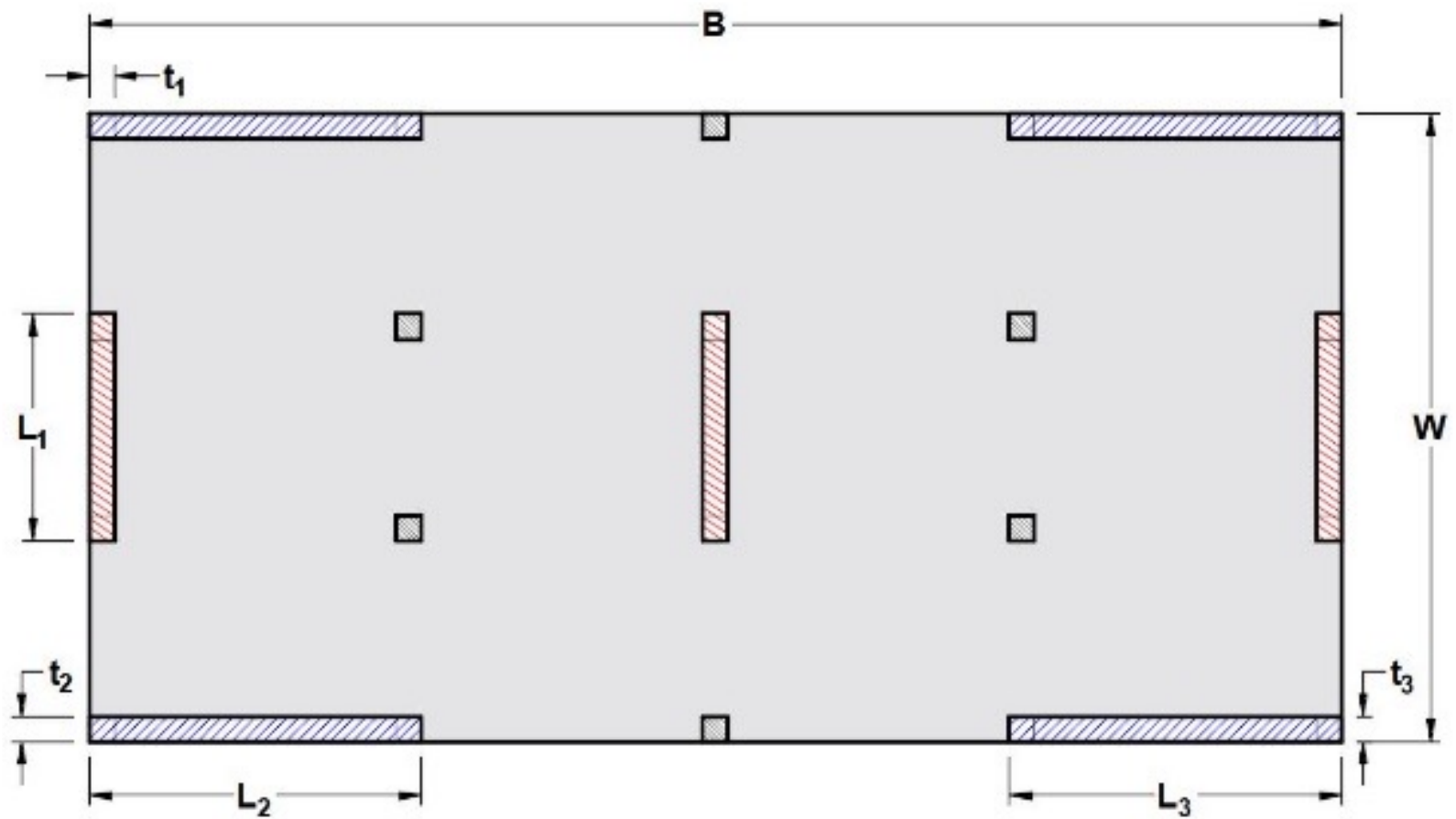
which represents a lot of **\$\$\$**

My suggestion is:

**Tell your designer to design your house with, at least,
the**

**Immediate Occupancy target in
mind**

[or keep it into the elastic range (Investing a little more money in the design stage will save you a lot of money after the MCE).]



% de paredes - Dirección N-S

$$\frac{3 L_1 t_1}{B W} \times 100 \geq 2.0$$

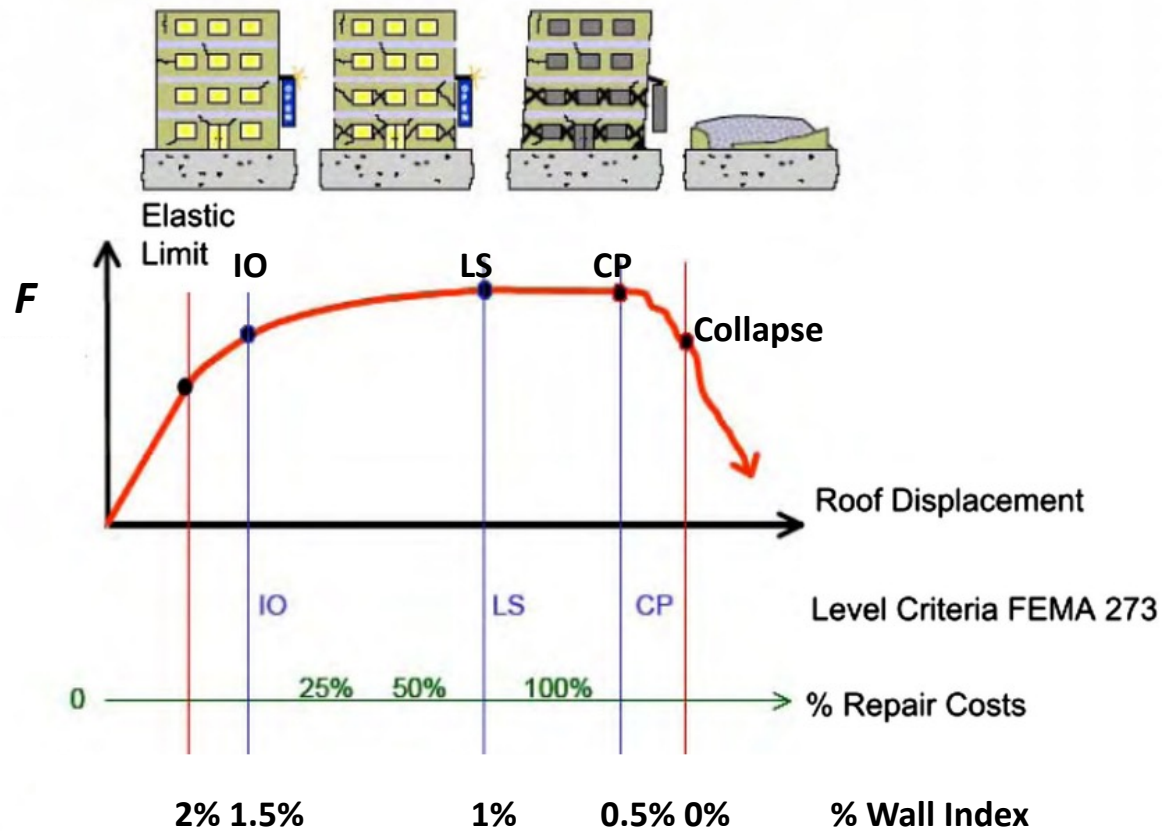
% de paredes - Dirección E-O

$$\frac{2 (L_2 t_2 + L_3 t_3)}{B W} \times 100 \geq 2.0$$

Performance Based Design

Three possible design targets:

- a) Collapse Prevention (CP)
- b) Life Safety (LS)
- c) Immediate Occupancy (IO)



Características de Pared Sismorresistente de Hormigón Armado

- 1. Tiene su propia fundación (cimientos).
- 2. Estar firmemente adherida al edificio.
- 3. $\sum A_{Wt} \geq 0.02 A_{planta}$ (en cada dirección ortogonal)
- 4. Tiene un mínimo de 8" de espesor (preferiblemente de 10").
- 5. Se le coloca doble cortina de varillas de acero.
- 6. Velar por colocar correctamente el confinamiento (acero transversal)
- 7. No introducir tuberías (pluviales, sanitarias ni eléctricas) en las paredes estructurales.

Edificio O'Higgins, Concepción, Chile



Some Buildings Seismically Instrumented by the PRSMP

PRSMP	E. D.	#	Altura	Largo	Ancho		Aspect Ratio	Wall Index, %	
Code	km	Stories	H	W1	W2	W1/W2	H/W2	Long	Tran
B03L	46.7	19/2	175'	151'	50'	3.0	3.47	0.97	3.49
B05L	96.4	21/0	184'	158'	43'	3.7	4.29	1.16	3.72
B02L	95.8	25/0	226'	181'	31'	5.9	7.37	2.40	4.75

after Celebi, Miranda, and Martínez–Cruzado, ASCE, 2021

Not dying during an earthquake is not enough, human beings should not be destined to misery after an earthquake.

Questions?

Hospitals

***Hospital Benito Juárez
19 de Septiembre de 1985, after M8.2 EQ***



State Hospital at Hatay, Turkey

February 6, 2023, after M 7.8 Earthquake



Clínica Bío Bío, Concepción, Chile

27 de febrero de 2010, after M8.8 EQ



Hospital de la Universidad Católica, Santiago





Schools





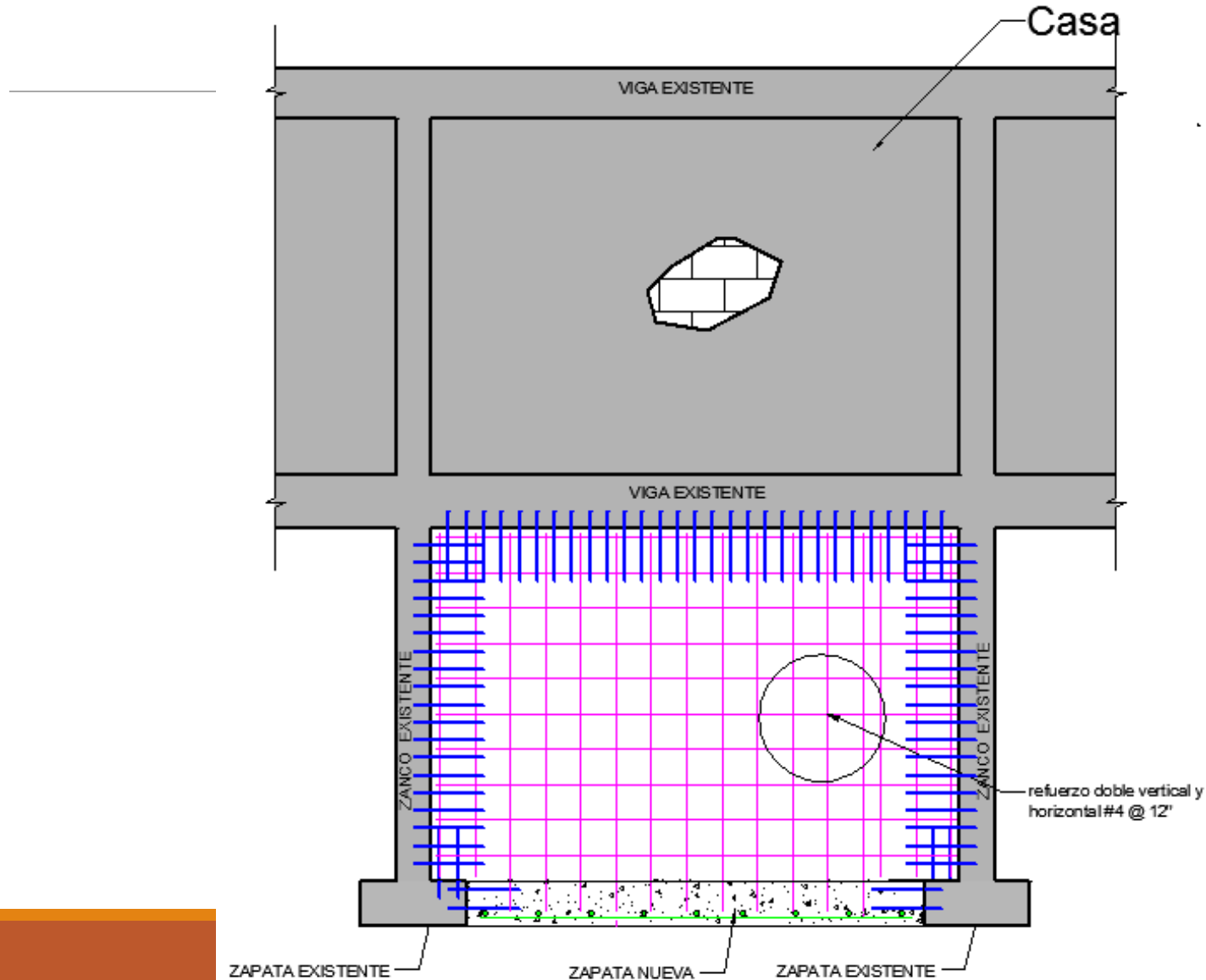


House on stilts on a hillside





Required reinforcement





**REHABILITACIÓN SÍSMICA
DE CASAS EN ZANCOS**



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“Seismic Rehabilitation of Houses on Stilts”

It can be downloaded from the webpage of the Cabo Rojo municipality at <https://www.caborojopr.net/>

or at: <https://ecoexploratorio.org>



Not dying during an earthquake is not enough, human beings should not be destined to misery after an earthquake.

Questions?



Hospital Militar de Santiago, Chile







Puerto Rico Strong Motion Stations Map - 2023

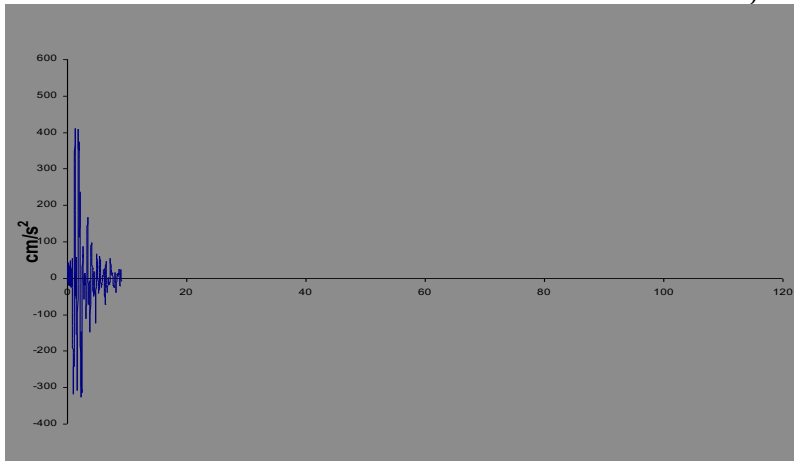


Legend:

▲ ETNA2 (31) ● Obsidians (70)

¿Para Cual Terremoto Diseñar ?

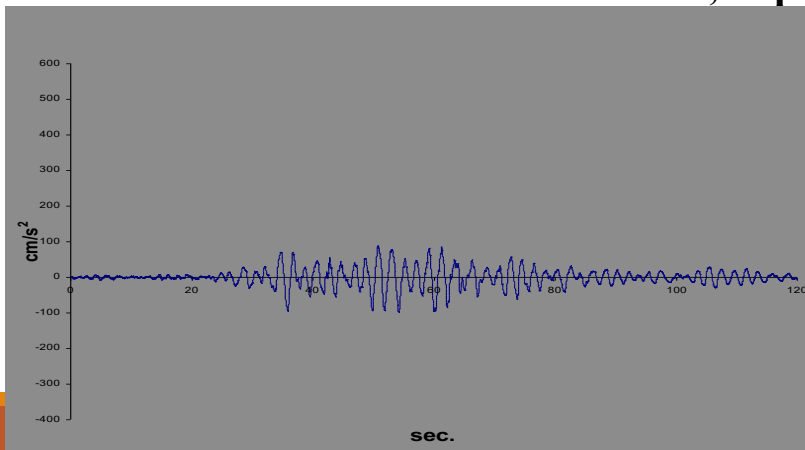
El Salvador; October 10, 1986



M = 5.4
ED = 5 km
PGA = 0.42 g
SMD = 6.6 sec.



Mexico; September 19, 1985



M = 8.2
ED = 400 km
PGA = 0.10 g
SMD = 41 sec.



Pasos sugeridos a seguir en caso de haber removido paredes estructurales

- Obtener los planos del edificio. Analizar el edificio a ver si el original resiste las cargas sísmicas esperadas considerando las “nuevas” fallas.
- Analizar el efecto de haber partido una (o las que sean) pared. De detectar potenciales problemas...
- Desalojar el edificio
- Apuntalar el edificio.
- Diseñar y construir reparación del edificio (de ser necesario).
- ¡CERO GARANTIAS!

Comparison of this study and ASCE 7-16

No	Town	PGA		Sds (g)		SD1 (g)	
		Study	ASCE 7 - 16	Study	ASCE 7 - 16	Study	ASCE 7 - 16
1	Ponce	0.63	0.41	<u>1.46</u>	<u>0.69</u>	0.39	0.27
2	Vieques	0.63	0.42	1.31	0.69	0.39	0.25
3	Maunabo	<u>0.63</u>	<u>0.39</u>	1.31	0.65	<u>0.39</u>	<u>0.23</u>
4	Mayagüez	0.63	0.47	1.31	0.82	0.38	0.32
5	Utua	0.63	0.42	1.31	0.71	0.38	0.28
6	Cabo Rojo	0.49	0.50	1.20	0.82	0.32	0.33
7	Culebras	0.47	0.44	1.16	0.73	0.30	0.27
8	Caguas	0.50	0.38	1.13	0.63	0.37	0.24
9	Aguadilla	0.38	0.49	0.98	0.87	0.30	0.33
10	San Juan	0.43	0.41	0.97	0.66	0.38	0.27
11	Fajardo	0.43	0.40	0.92	0.66	0.30	0.25
12	Arecibo	0.36	0.43	0.69	0.75	0.20	0.29

In few words...

- **We are using billions of US federal funds to design infrastructure with a BC that does not even include the minimum state-of-the-art knowledge regarding the Seismic Hazard Map.**