

# The Evolution of Seismic Risk Characterization in Panama and its Consequences

Luis Alfaro

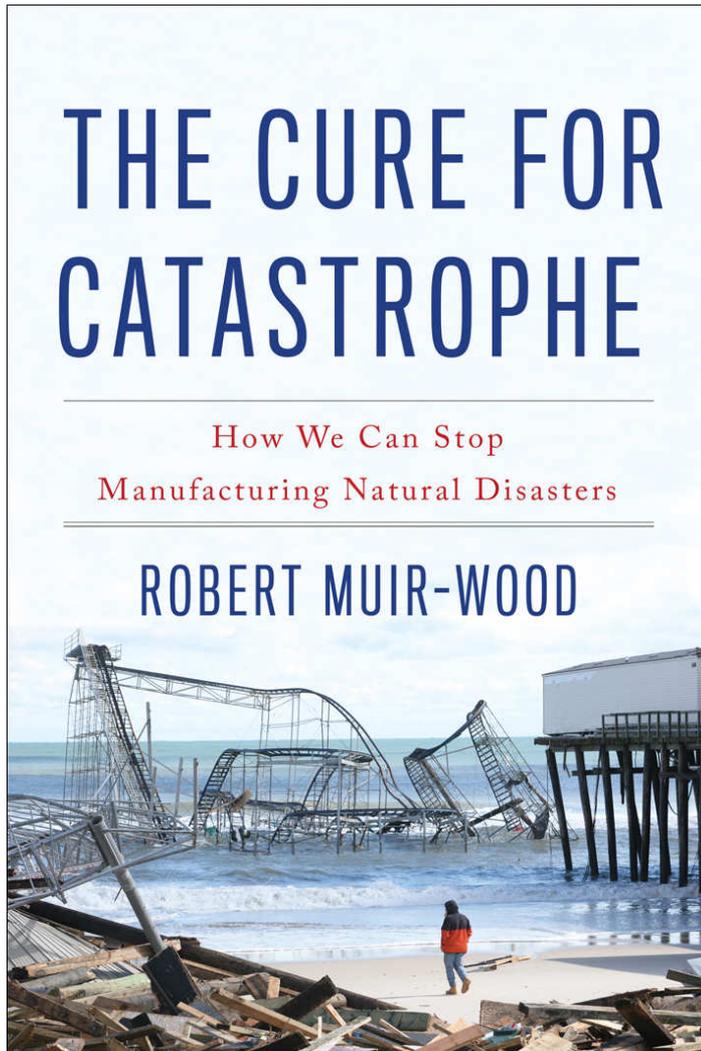
Member of the Panama Structural Code Committee  
Retired VP of Engineering Panama Canal Authority

**PGS Workshop on “Geotechnics of Natural Hazards”**

*April 26, 2019*

# Introduction

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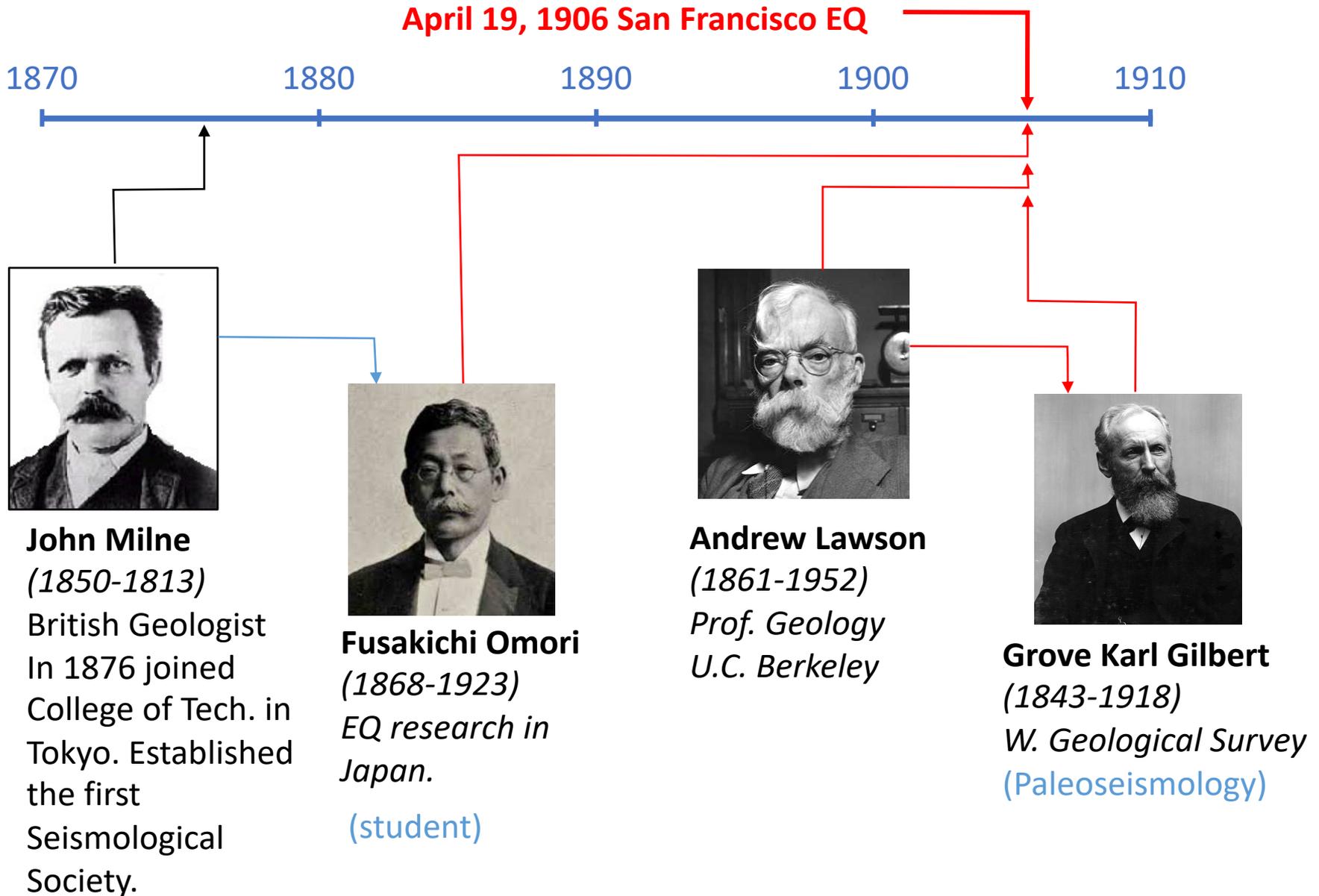
**Robert Muir-Wood, Ph.D.**  
*Chief Research Officer, RMS*

## ***Fundamental Thesis***

With current scientific knowledge, cities could become immune to catastrophes within a generation.

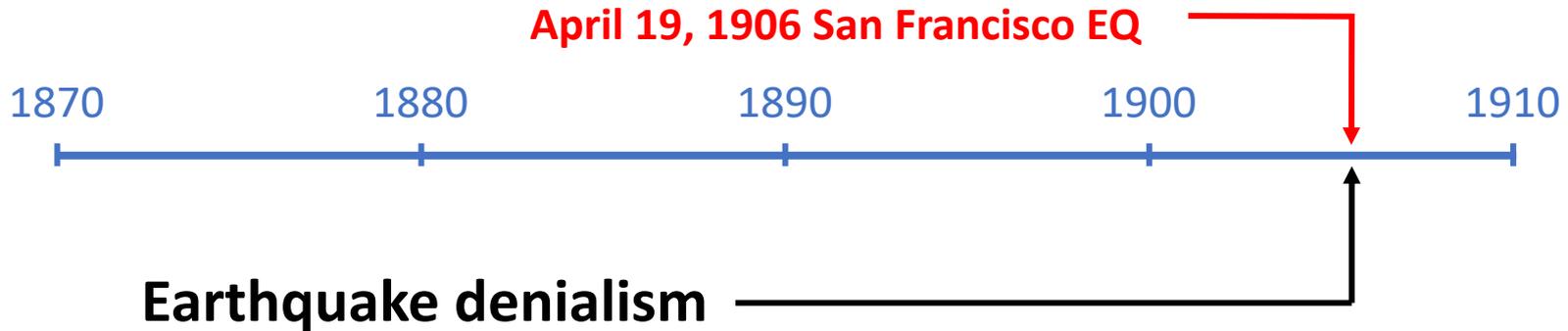
# An early “inconvenient truth”

Reference: “The Cure for Catastrophe” (Robert Muir-Wood)



# An early “inconvenient truth”

Reference: “The Cure for Catastrophe” (Robert Muir-Wood)



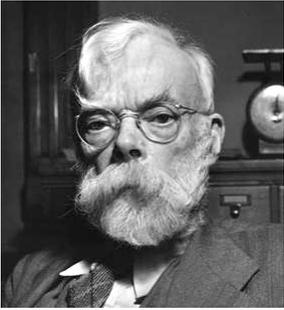
**Purpose:** to suppress research or publicity that might threaten Californian prosperity.

Within a week of the EQ, the San Francisco Real Estate Board passed a resolution to rebrand:

“**San Francisco Earthquake**” as the “**San Francisco Fire**”

# Response

Reference: *"The Cure for Catastrophe"* (Robert Muir-Wood)



**Andrew Lawson**  
(1861-1952)  
*Prof. Geology*  
*U.C. Berkeley*



**Carnegie Institution**  
(Washington, D.C.)



Lawson Earthquake  
Commission Report  
(1908) - *no forecasts*



**Harry Fielding Reid**  
(1859-1944)  
*Geophysicist Johns*  
*Hopkins University*



Geodetic Data  
(*mapped the San*  
*Andreas Fault*)  
after the 1906 EQ



Elastic Rebound  
Theory

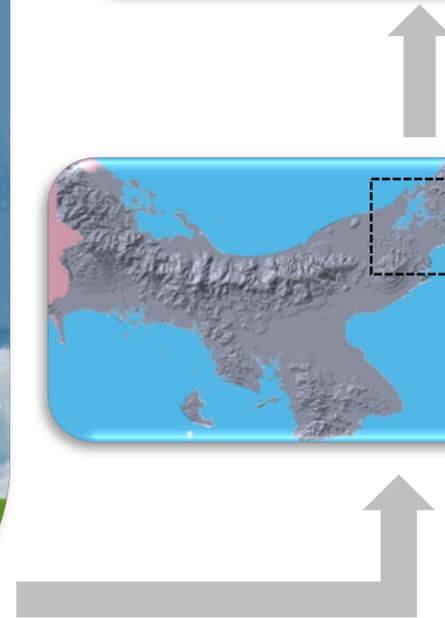


**Charles Derleth Jr.**  
(1874-1956)  
*Prof. Civil Eng.*  
*U.C. Berkeley*

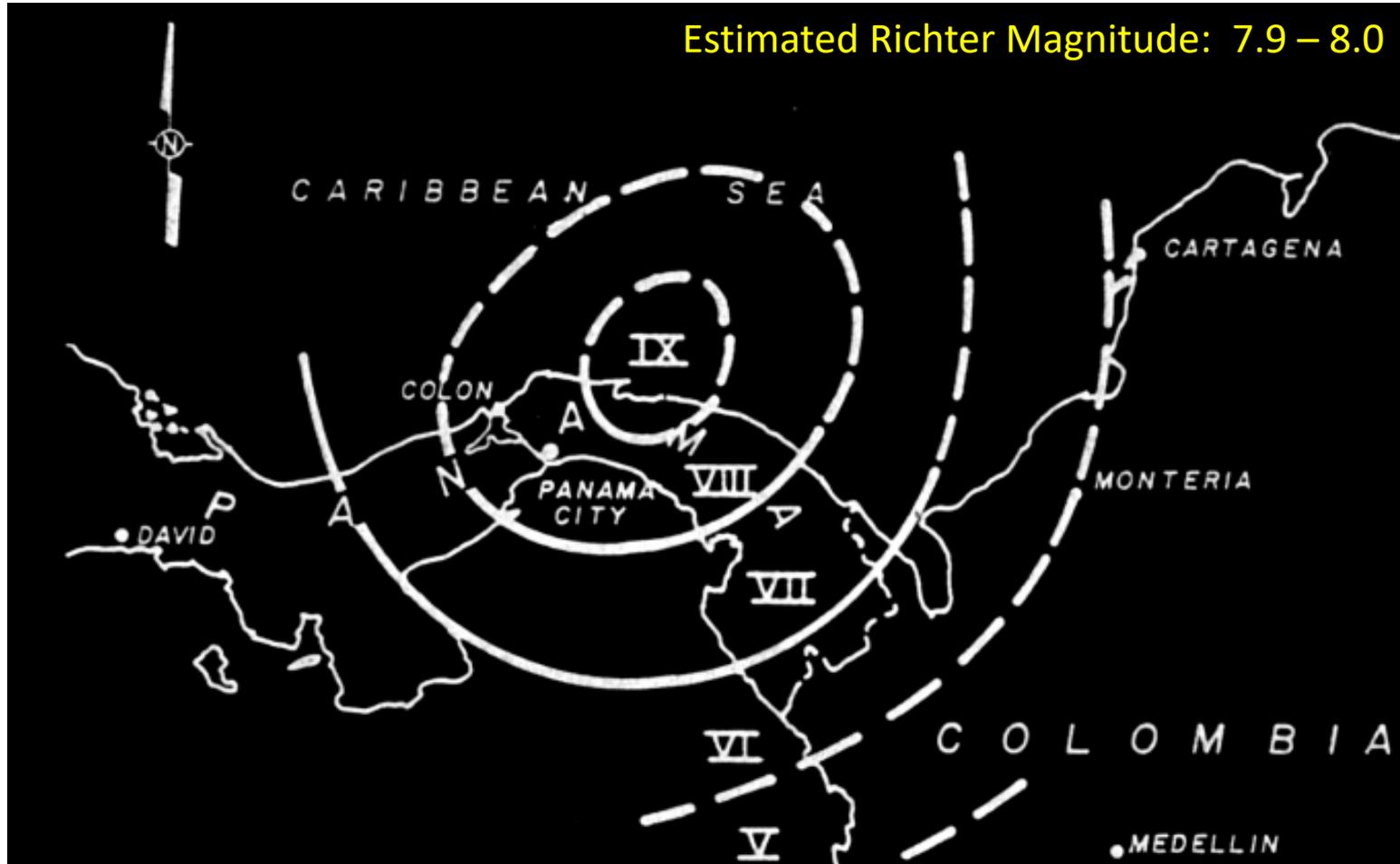
*"...it will do San Francisco and California in general, more lasting good to admit that there was an earthquake, and that with honest and intelligent construction and the avoidance of geologically weak locations, our losses would not have been so great."*

**In the end, reason prevailed**

# Panama



# Earthquake of 7 September 1882

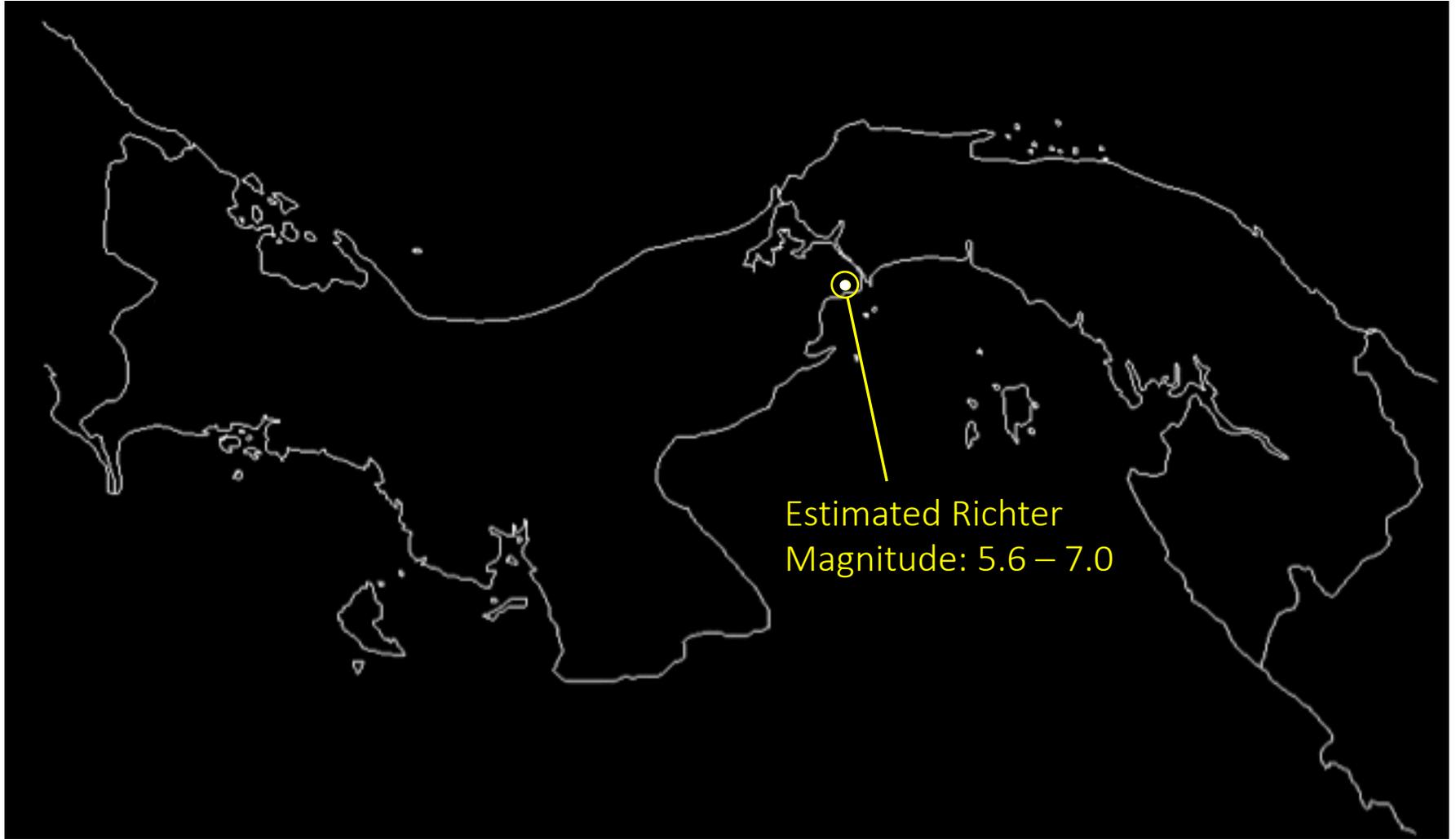


Reference: "Seismicity Evaluation Report on the Tabasará Hydroelectric Project in Western Panama", Acres International Ltd., Niagara Falls Ontario, Canada (1981).

**(Private consulting company report to the state's power company)**

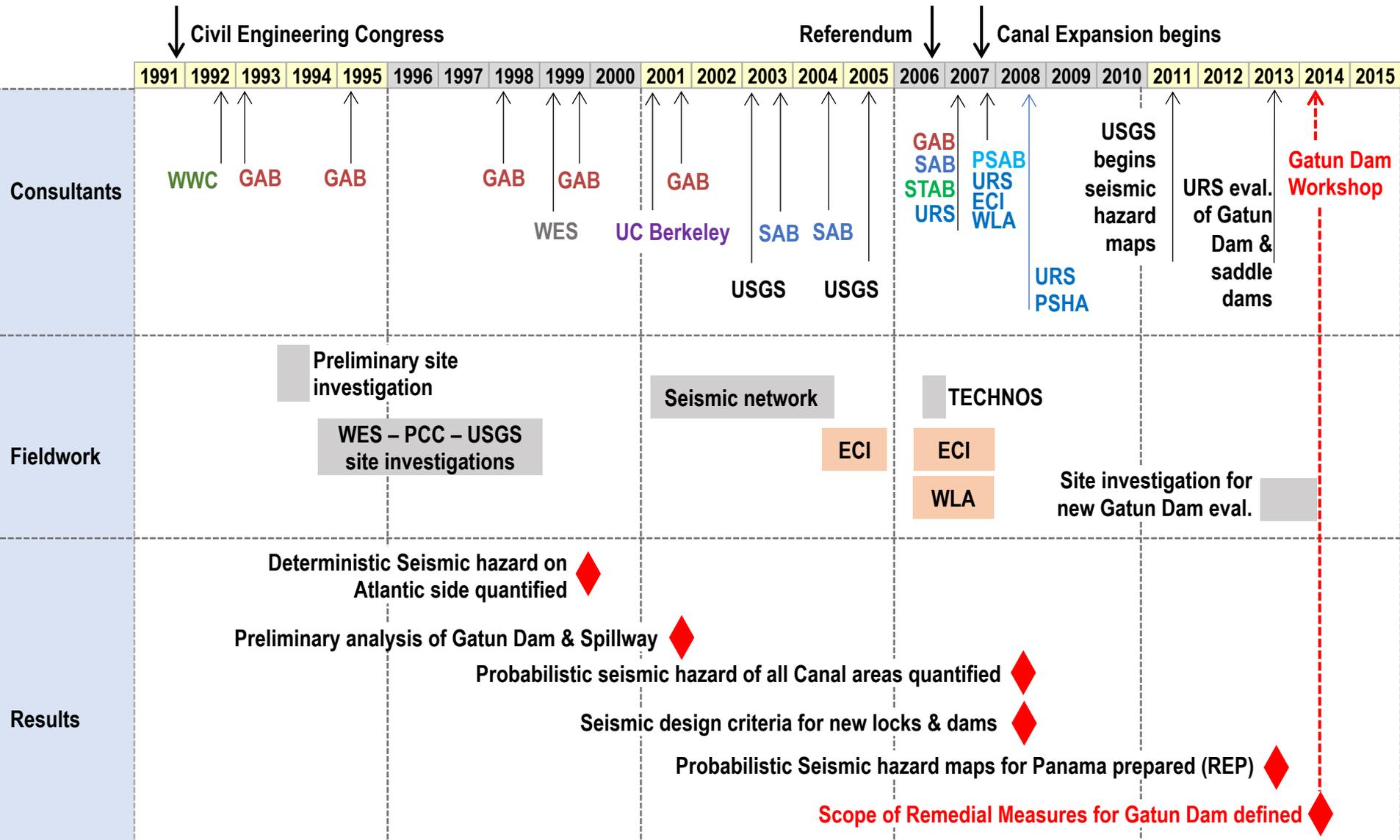
# Earthquake of 2 May, 1621

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Reference: Víquez, V. and Camacho, E. (1994), "El Terremoto de Panama La Vieja del 2 de mayo de 1621: Un sismo intraplaca", Boletín de Vulcanología, OVSICORI-UNA

# Chronology of investigations on seismic risk in the Canal area



GAB: Geotechnical Advisory Board  
 SAB: Seismic Advisory Board  
 STAB: Structural Advisory Board

PSAB: Paleoseismic Advisory Board  
 WES: Waterways Experiment Station  
 USGS: US Geological Survey

URS: URS Corp  
 WWC: Woodward Clyde Consultants  
 REP: Panamanian Structural Code

ECI: Earth Consultants International  
 WLA: William Lettis & Associates  
 UC: University of California

# Members of the Advisory Boards during these studies

## Geotechnical



Norbert  
Morgenstern



J. Michael  
Duncan



Robert  
Schuster



William  
Marcuson



Rob  
Wesson



Antonio  
Bobet



Robin  
Fell

## Seismic



Rob  
Wesson



Julian  
Bommer



Lloyd  
Cluff



Paul  
Sommerville



Farrok  
Nadim

## Structural



Robert  
Hall



Anil  
Chopra



Sam Yao



Enrique  
Matheu

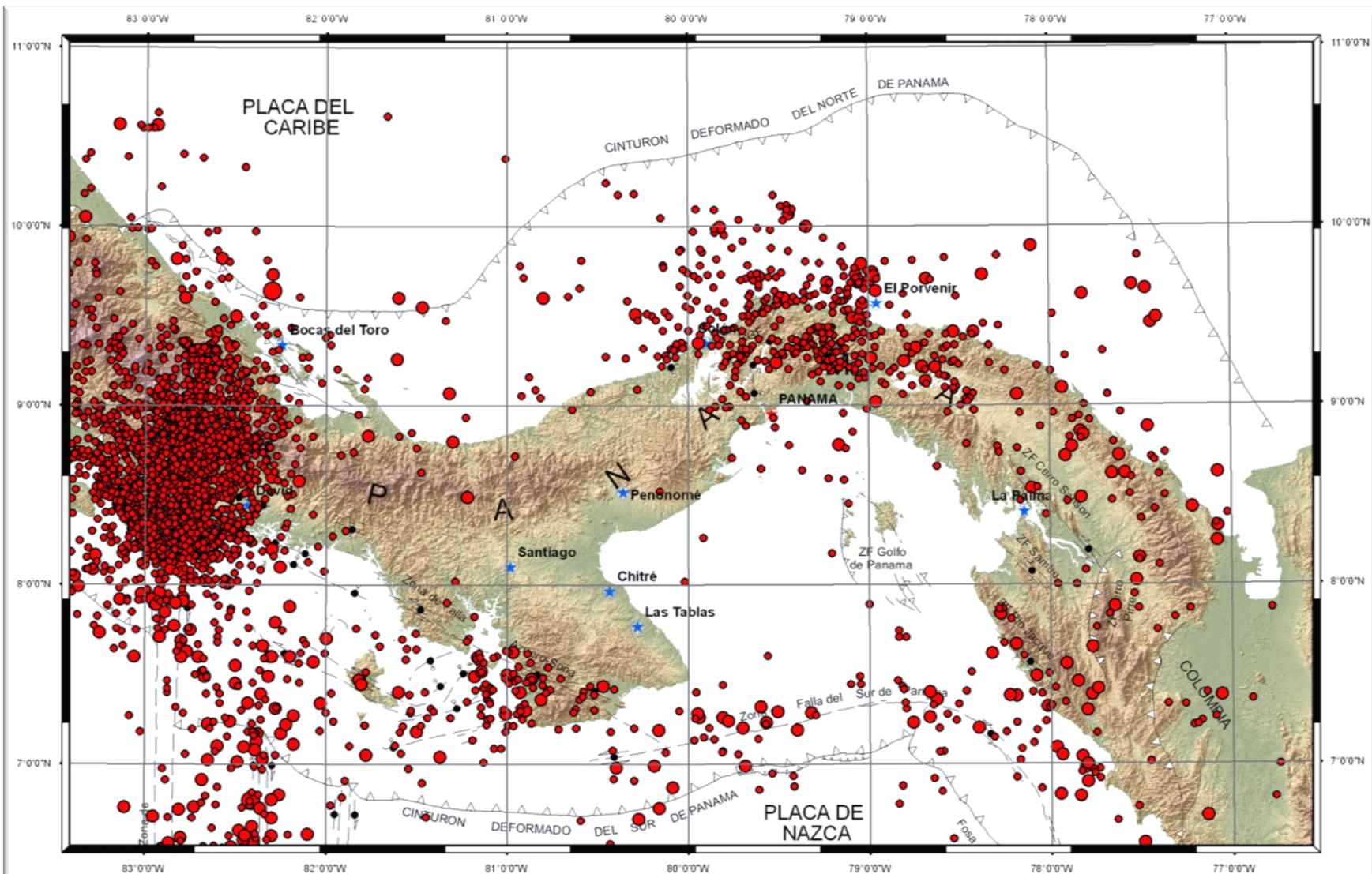


José  
Roesset



Martin  
Weiland

# Panama Canal's seismic instrumentation network



Magnitud\_Mw

- 1.5 - 4.0
- 4.1 - 6.5
- 6.6 - 8.0

## Sismicidad en Panama 2000-2012

0 25 50 100 150 200

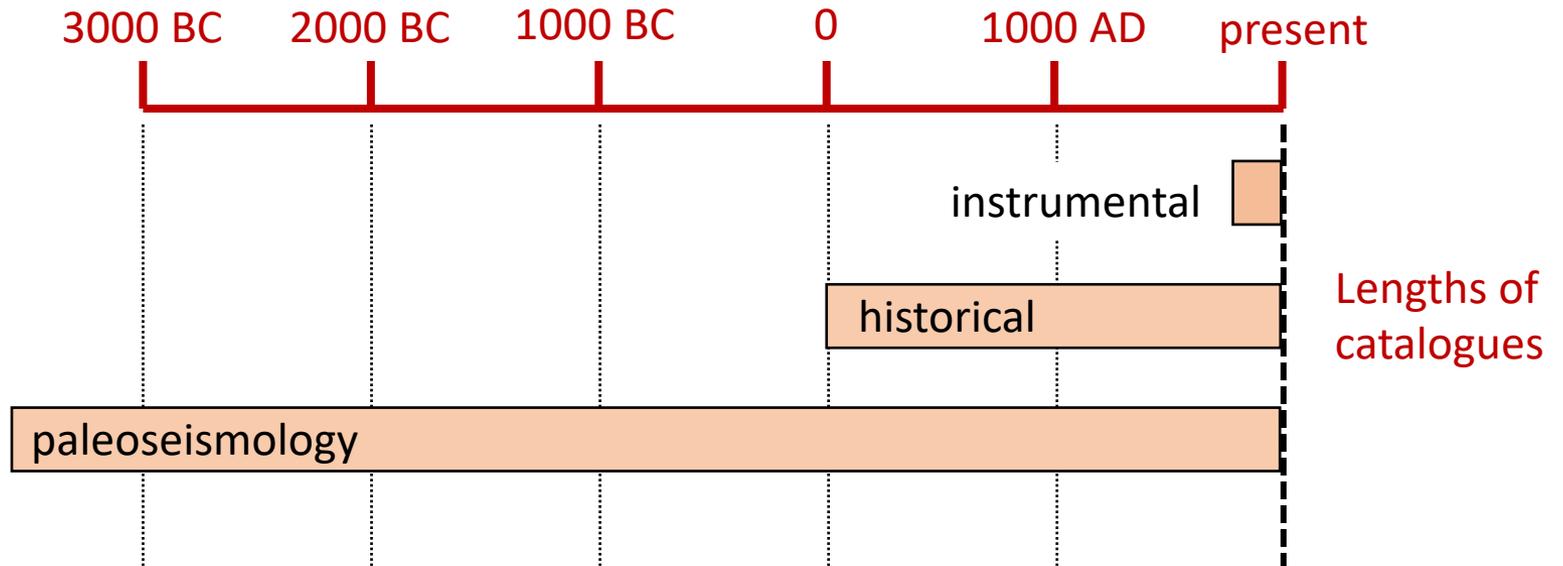
1:3,000,000 Kilometros

Proyección: Transverse Mercator  
 Mapa por: Antonio A. Abrego Maloff  
 División de Ingeniería  
 Autoridad del Canal de Panamá



# Paleoseismology

Reference: McCalpin, J. "Paleoseismology, methods and examples" (2009)



- Paleoseismology extends record of earthquakes into the geological past (Holocene).
- Instrumental catalogues are too short.

# Paleoseismic Contractors in Panama

**Earth Consultants  
International**

**William Lettis &  
Associates**



# The Central American Arc as a Soft Indenter, and the Internal Deformation of Panama

T. Rockwell, E. Gath,  
and R. Bennett

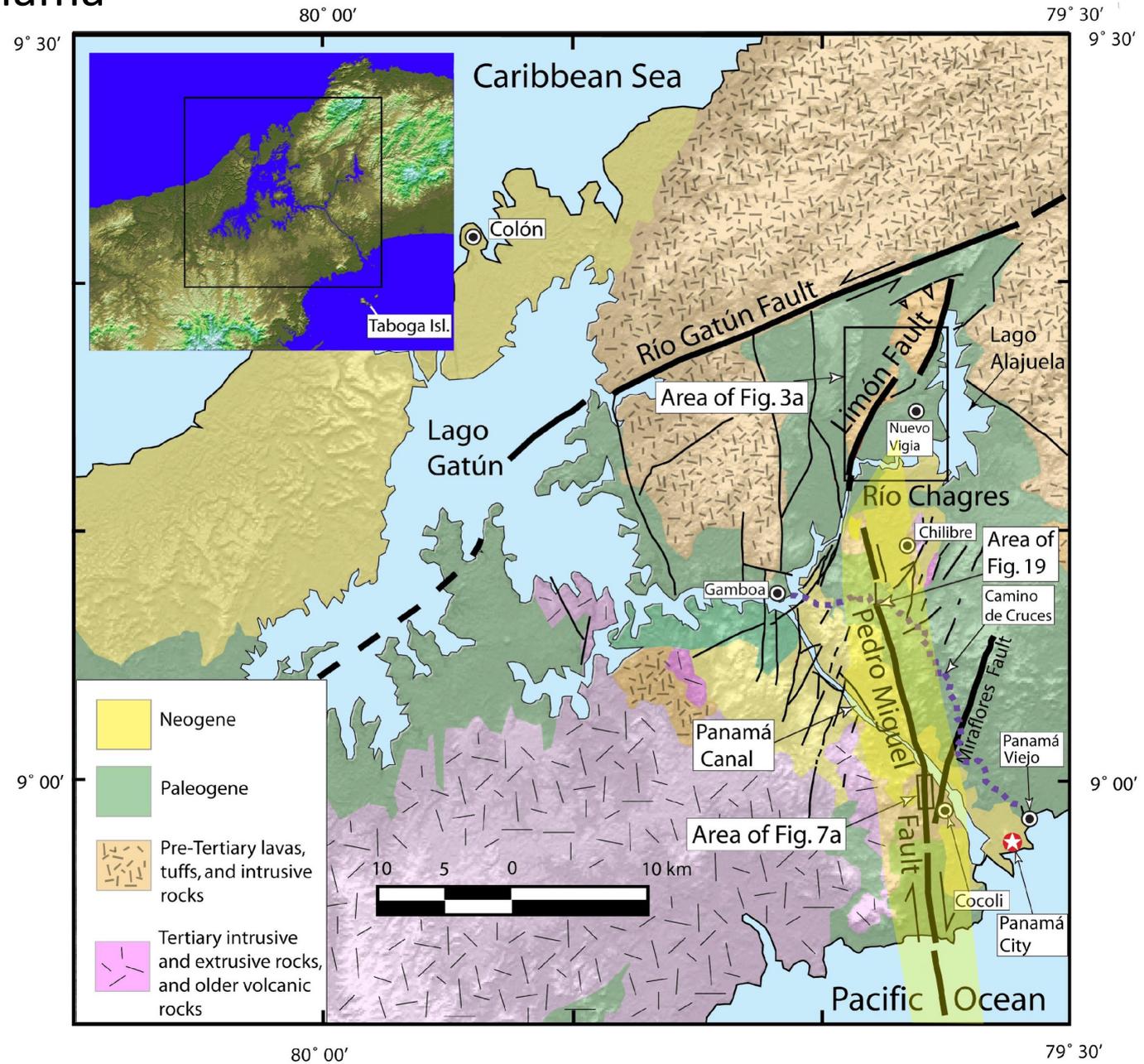
GSA Penrose  
Conference,  
**Neotectonics of Arc-  
Continent Collision**  
Manizales,  
Colombia, January  
17-21, 2010

Pedro Miguel Fault

**AD 1621**

**AD 640**

**AD 455**



# 1. Transcription from document in “Archivo General de Indias”

Seville, Spain

## RELACION HISTORICA Y GEOGRAFICA DE LA PROVINCIA DE PANAMA (1640)

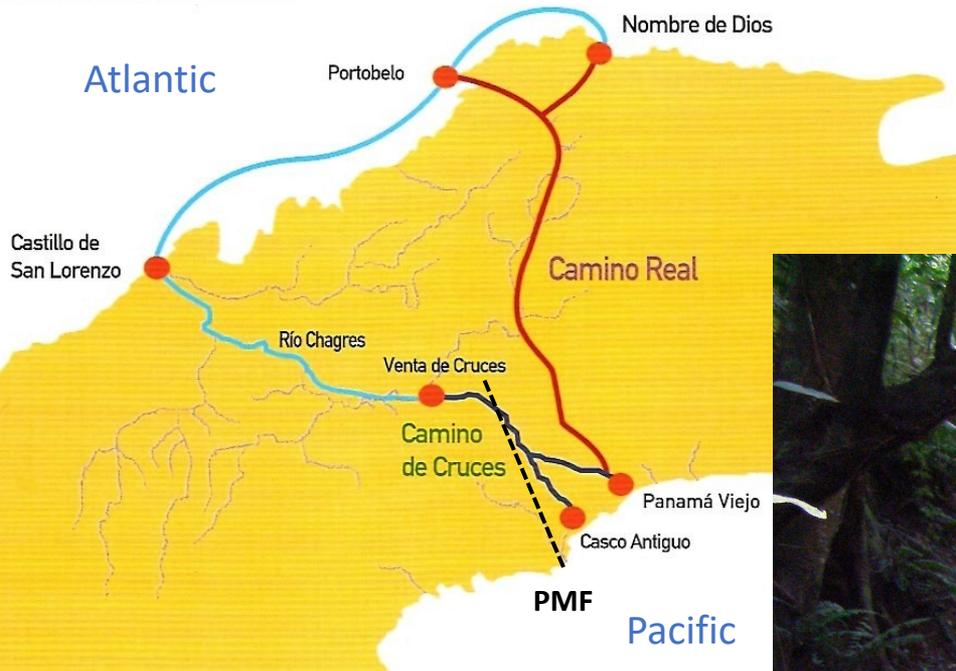
Por JUAN REQUEJO SALCEDO

Haviendo arriba tocado el estado en que yo hallé esta yglesia quando a ella vine por canónigo el año de 1619, tan trabajoso en lo espiritual y del culto divino como en lo material y temporal della, por estarse cayendo y hecho cienega, de que resultava mal olor de los cuerpos muertos, digo con la Historia general de Yndias y su descripción, tabla 8.a, capítulo 15, por Antonio de Herrera, coronista mayor de Su Magestad, que la Audiencia de Panamá, que primero se llamo Ciudad de Tierra Firme, es muy pequeño, porque por el despacho de las



- Detailed description of the 2 May 1621 EQ
- Damage to at least 12 identified structures
- Replicas for 3 ½ months

# 2. Evidence on XVI Century Colonial Roads



1<sup>st</sup> INQUA-IGCP-567 International Workshop on Earthquake Archaeology and Palaeoseismology, Baelo Claudia, Spain (2009)



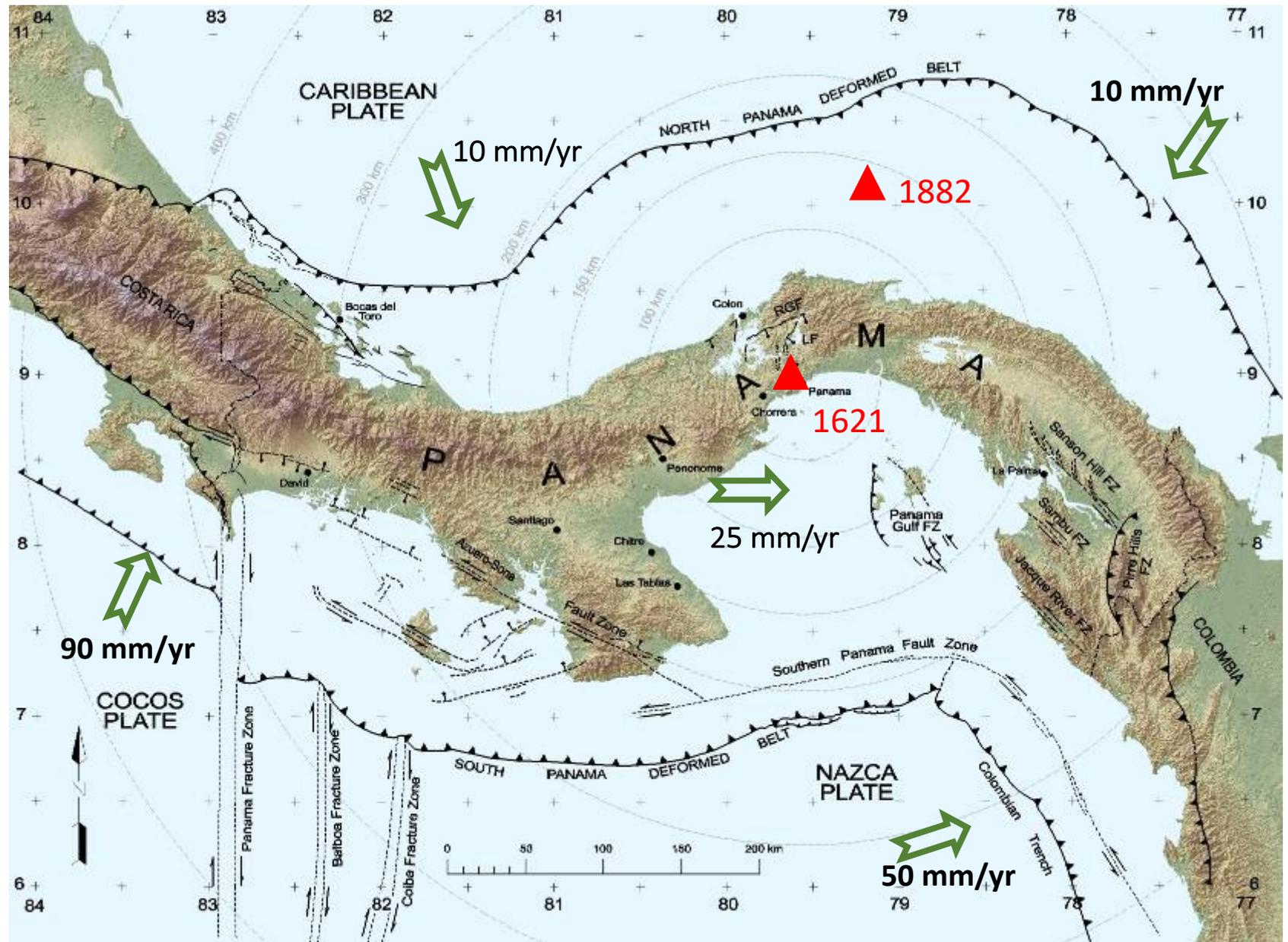
## COSEISMIC OFFSET OF THE CAMINO DE CRUCES CONFIRMS THE PEDRO MIGUEL FAULT AS THE CAUSE OF THE AD 1621 PANAMÁ VIEJO EARTHQUAKE

E.M. Gath (1) and T.K. Rockwell (1)

(1) 1642 E. Fourth Street, Santa Ana, CA 92701 USA. Email: [gath@earthconsultants.com](mailto:gath@earthconsultants.com)

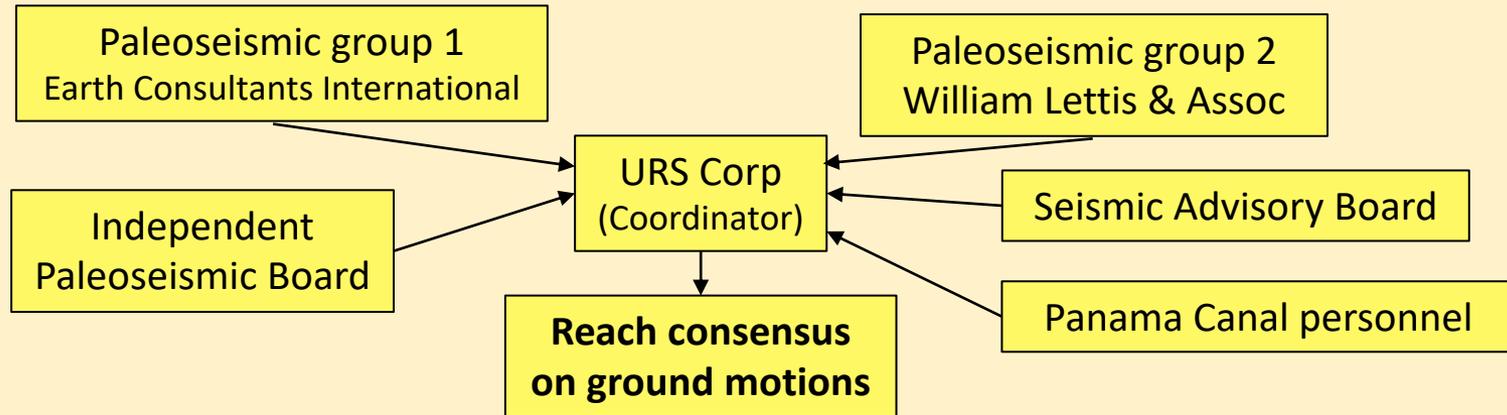
**ABSTRACT (Coseismic offset of the Camino de Cruces confirms the Pedro Miguel fault as the cause of the AD 1621 Panamá Viejo earthquake):** We completed a study of the Pedro Miguel fault where it crosses the ca 1520 Las Cruces Trail in Central Panama. Using tectonic geomorphic mapping, stream bank exposures, and hand-excavated trenches, we have demonstrated that the fault has generated a 2.8-3.0 meter displacement of the Trail, as well as of all fault-crossing geomorphic features in the local area. A unique cobblestone pavement used for the Trail, combined with the geomorphology, makes pre- and post-event reconstruction of fault slip highly accurate. Fault exposures demonstrate that the youngest alluvial deposits are offset, and the fault projects into the surface topsoil. We conclude that the Pedro Miguel fault last ruptured May 2, 1621 and caused the devastating Panamá Viejo earthquake.

# Tectonic Map of Panama

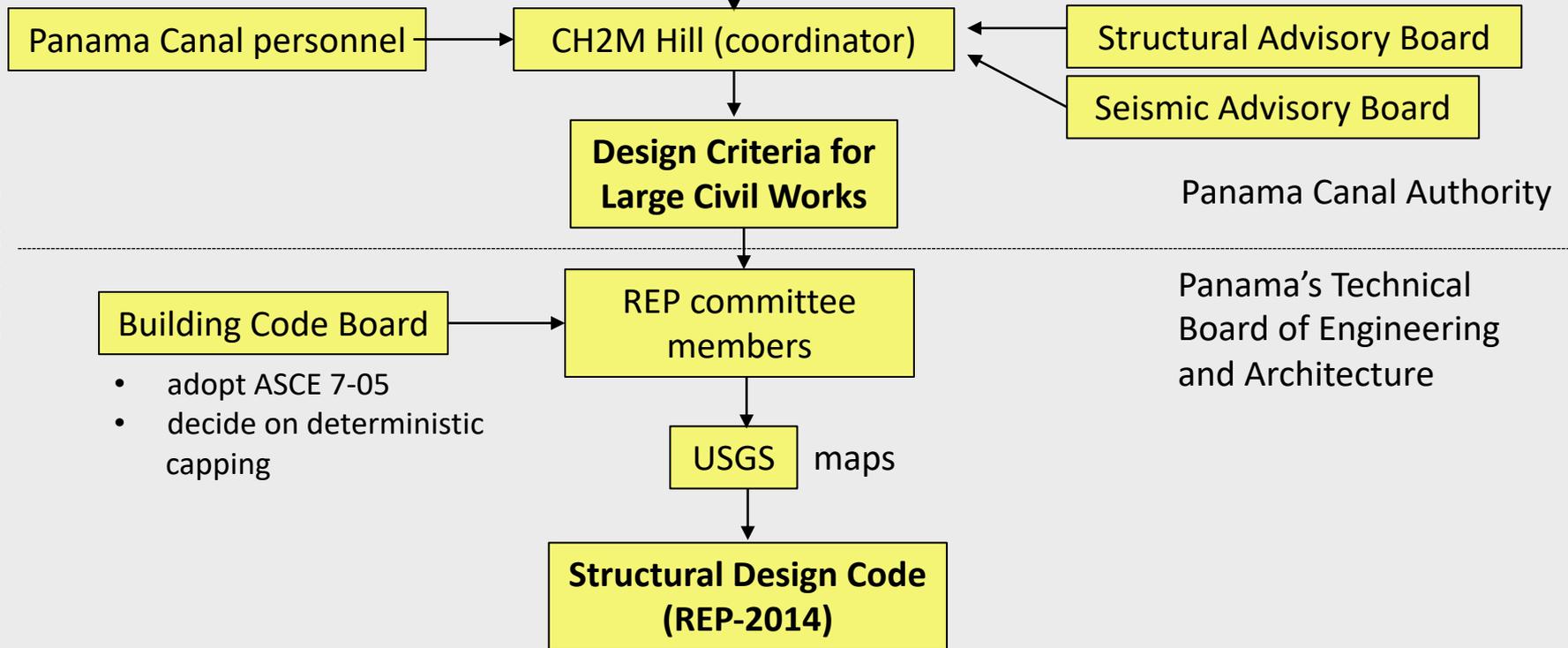


# Process leading to the definition of the Structural Design Code

Geotechnical



Structural



# Meetings with Independent Paleoseismic consultants

December 11-15, 2007

Dave Schwartz  
USGS

Bill Page  
Pacific Gas & Electric

Ray Weldon  
University of Oregon



# Meeting with members of the Building Code Board

June 29- July 1, 2010

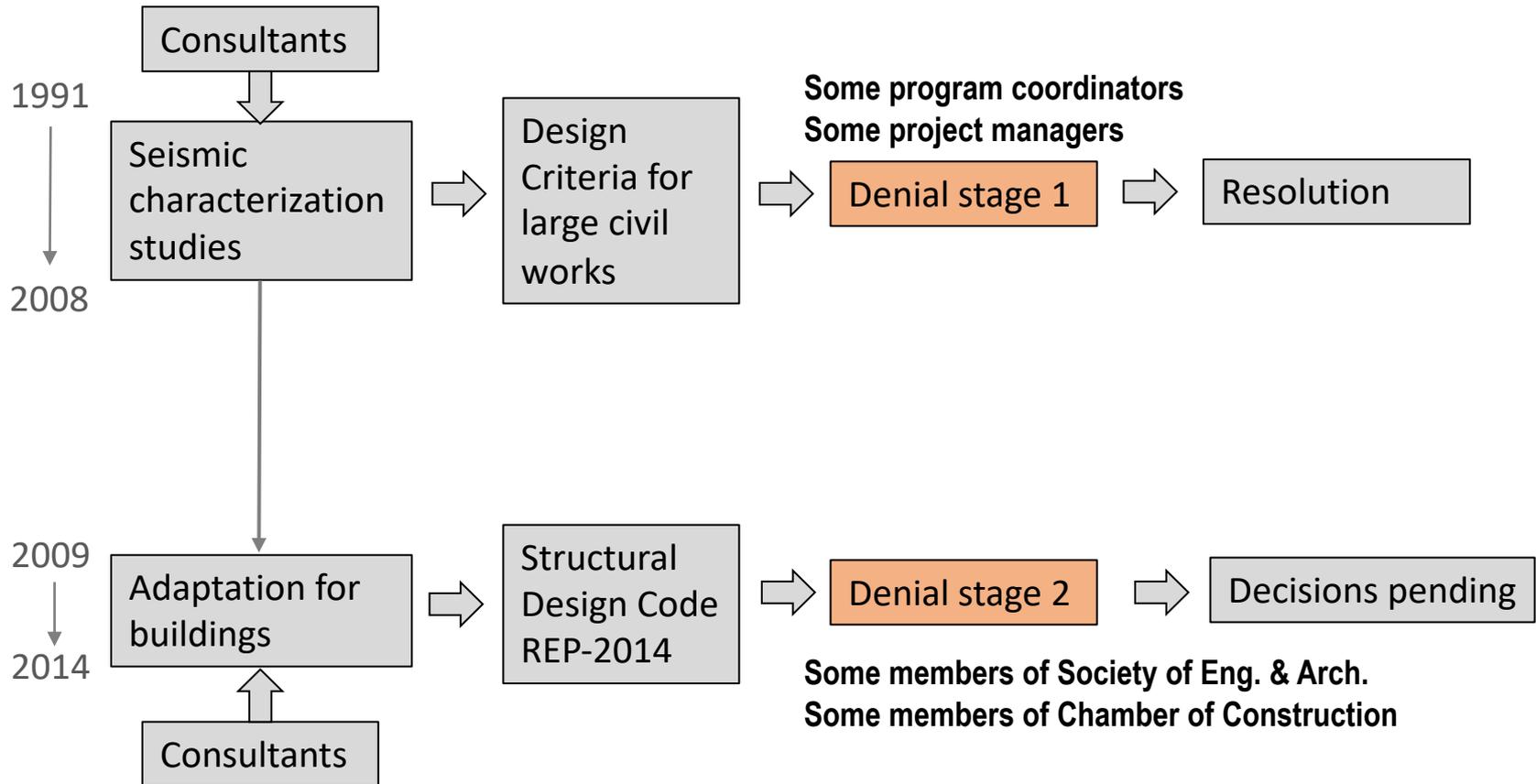


**Anil Chopra**  
UC Berkeley

**David Bonneville**  
Degenkolb

**Chris Polland**  
Degenkolb

# The 2 stages of denial



It doesn't much matter that Seismology is a much better developed science a century later.

# Various statements reflecting denial

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## Using erroneous historical facts to rationalize desired conclusion

- Ferdinand De Lesseps promised no more EQ like the 7 Sep 1882, 7.9M event, a few days after.
- Theodore Roosevelt chose Panama over Nicaragua because there are no EQs in Panama.

## Attempts to avoid the issue

- “There is no proof that those earthquakes occurred or that they can happen again.”
- “The burden of proof should be on the people proposing the code changes.”

## Ignorance

- “Those 2 EQ were long ago, they are no longer relevant.”
- “Those 2 EQ were not representative of the area.”
- “I have never felt anything like this in Panama before.”

## Attempts to create doubts

- “Seismicity is not a precise science.”
- “There are other consultants who think differently.”
- “If we were to accept this, what happens to the thousands of existing buildings. It is irresponsible to create panic.”

# Conclusions *(for now)*

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- Paleoseismology is a very useful tool in the hands of paleoseismologists.
- We have suggested further site investigation to add data, clarify matters and make the conclusions more robust.
- We are willing to make adjustments to the ground motion maps, **if** new and valid data supports it.
- We are not willing to make these adjustments based on unsupported opinions.

Thank you