Felipe Andrés Bañados Schwerter
University of British Columbia
Undistinguished Lecture Series 2021

Earthquakes:

Because we don’t have enough to worry about.

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Because we don't have enough to worry about.

RING OF FIRE
Mt. Garibaldi
Mt. St. Helens
Aleutian trench
Kurile trench
Japan trench
Izu Ogasawara trench
Ryukyu trench
Philippine trench
Mt. Pinatubo
Mt. Mayon
Marianas trench
Challenger Deep
Equator
Bougainville trench
Krakatoa
Java (Sunda) trench
Tonga trench
Kermadec trench
Puerto Rico trench
Middle America trench
Peru-Chile trench
South Sandwich trench


Valdivia


Ruta 206
Los Ríos
Google
Street View
Ruta 206
Google
Image capture: Oct 2015
© 2020 Google
Canada
Terms
Report

Contemporary Google Maps, Valdivia, Chile


Pta La Mision
Pta Loncoyen
Cutipai
Estancilla
Jardin Botanico UACh
Parque Urbano El Bosque
Niebla
Faro
Isla del Rei
Mancera
Guacamayo
Angachilla
R. Angachilla
Llancahue
Piedra
Altos del
E. Minas
E. Teja
Chilean Govt Official Map - 1909

Chilean Govt Official Map - 1909

Pta La Mision
Pta Loncoyen
Cutipai
Estancilla
Jardin Botanico UACh
Parque Urbano El Bosque
Niebla
Faro
ORRAL
Isla del Rei
Mancera
Guacamayo
Angachilla
R. Angachilla
Piedra
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Chilean Govt Official Map - 1909

Contemporary Google Maps, Valdivia, Chile


Ruta 206
Los Ríos
Google
Street View
Ruta 206
Google
Image capture: Oct 2015
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Report

Chile has a different attitude towards earthquakes

Let’s see an earthquake on Live TV (2min)

Chile has a different attitude towards earthquakes

Let's see an earthquake on Live TV (2min)

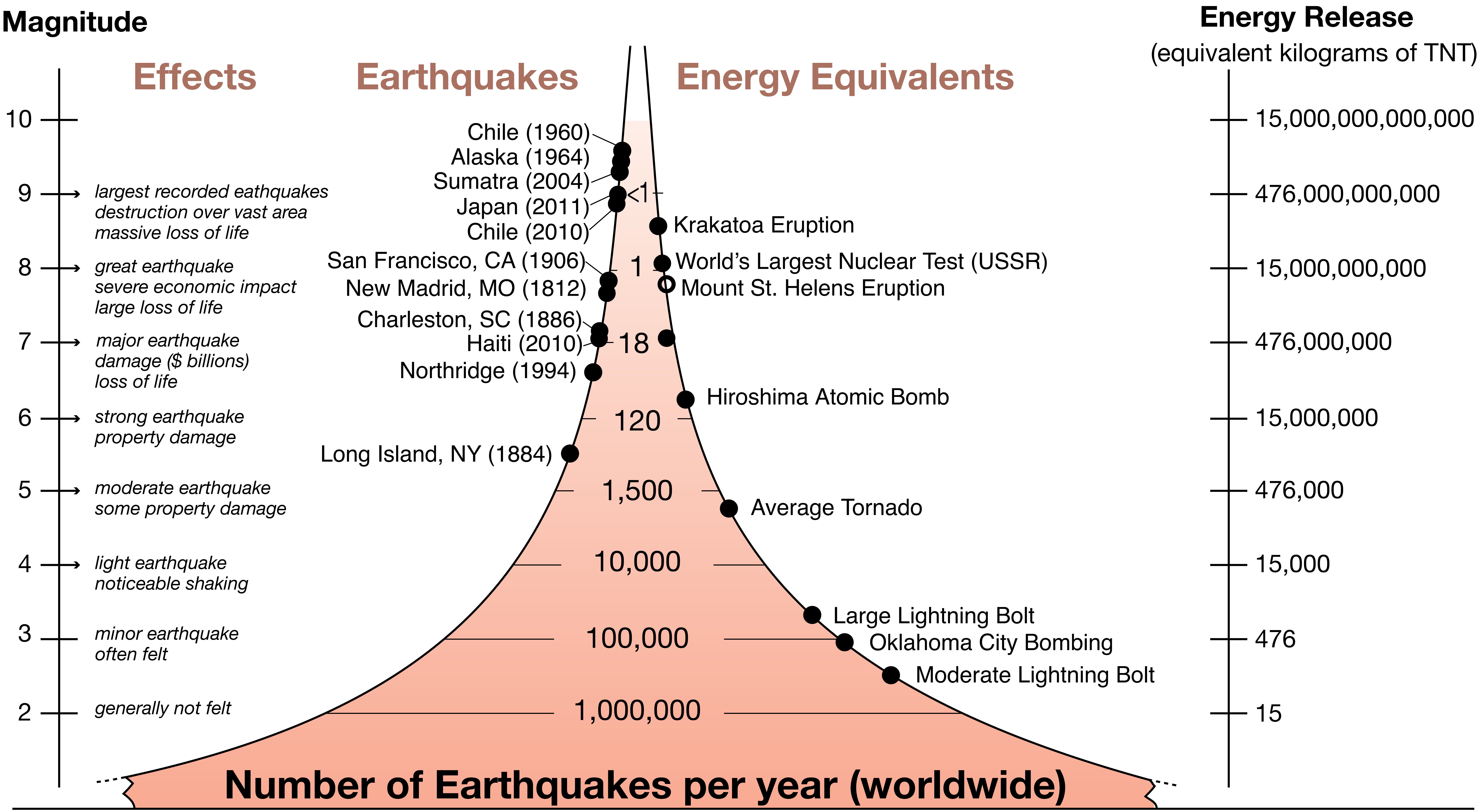

MANO A MANO
CPC CRITICÓ
It's 7:55 PM
Guest: It's while we're live!


MANO A MANO
It's 7:55 PM
Guest: It's while we're live!

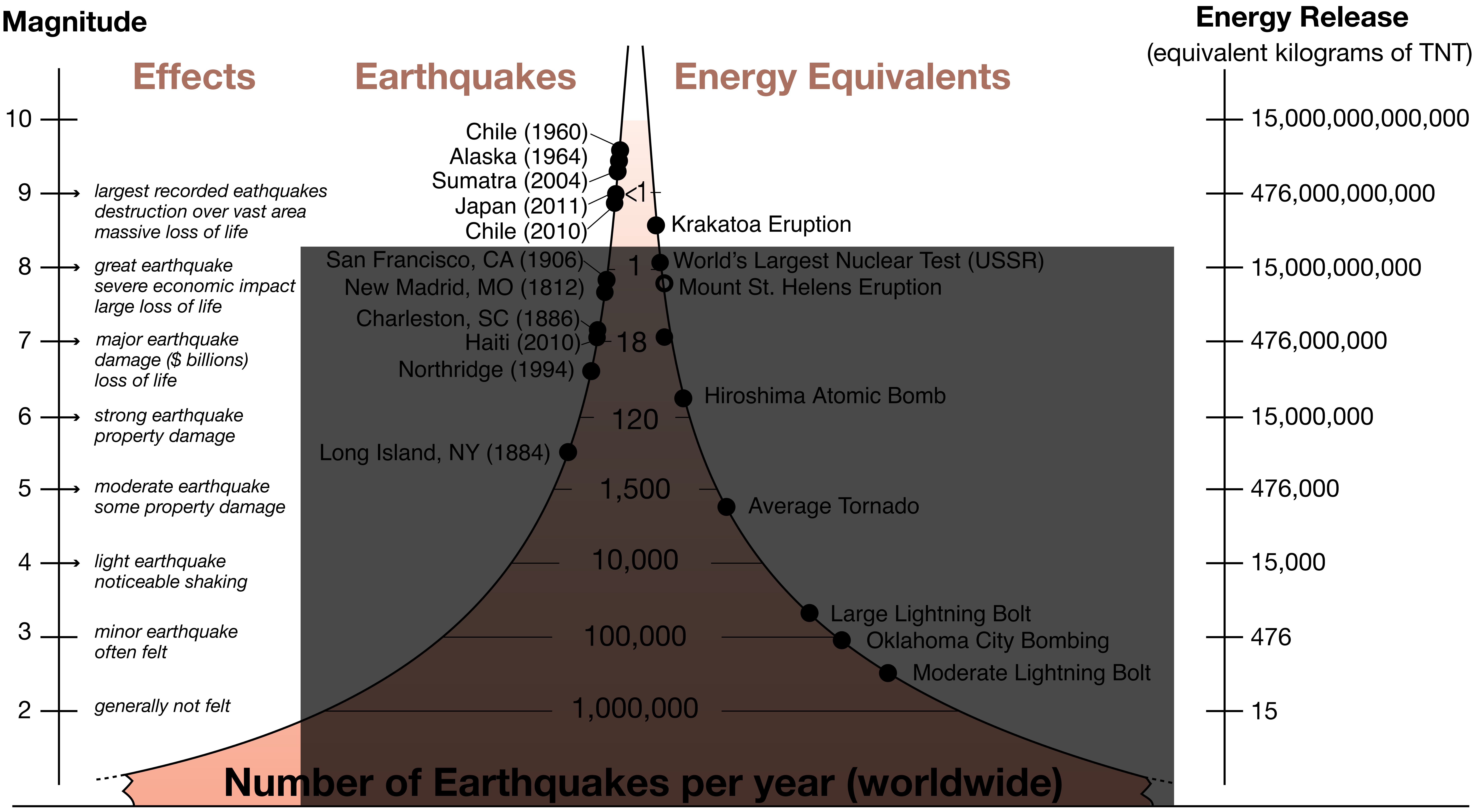
Plenty of earthquakes!

NOAA
PTWC
NATIONAL WEATHER SERVICE
1000 km
March
2010
Magnitude
8
7
6
Earthquake Depth (km)
0
50
100
200
400
800


PTWC
1000 km
March
2010
Magnitude
8
7
6
Earthquake Depth (km)
0
50
100
200
400
800



Source: Incorporated Research Institutions for Seismology (US)



Source: Incorporated Research Institutions for Seismology (US)

Let’s go back in history…

There must be a scientist
we can trust!

GEOLOGY

AND

NATURAL HISTORY

OF THE

VARIOUS COUNTRIES

VISITED BY H. M. S. BEAGLE,

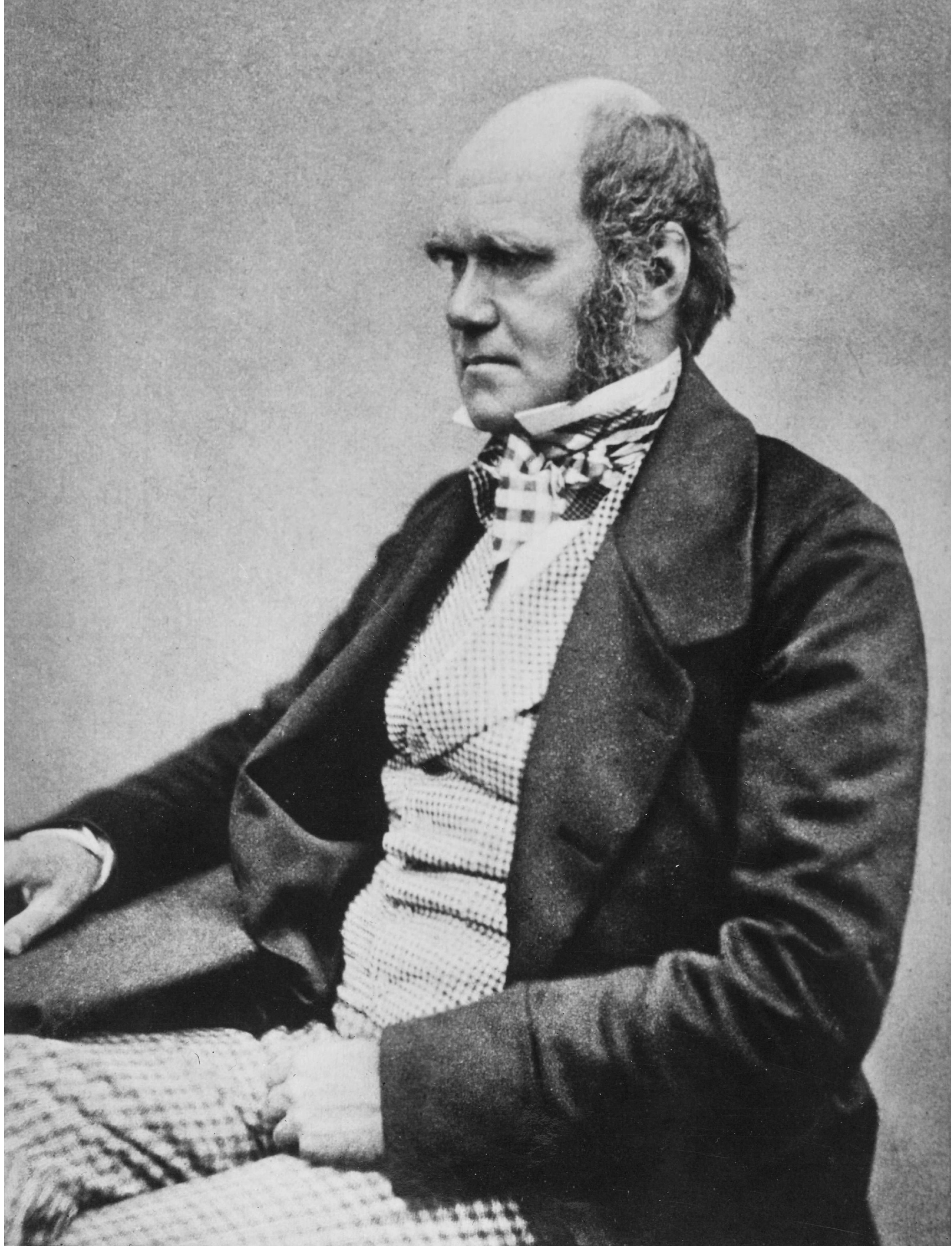
UNDER THE COMMAND OF CAPTAIN FITZROY, R.N

FROM 1832 TO 1836.

BY

CHARLES DARWIN, ESQ., M.A. F.R.S.

SECRETARY TO THE GEOLOGICAL SOCIETY.

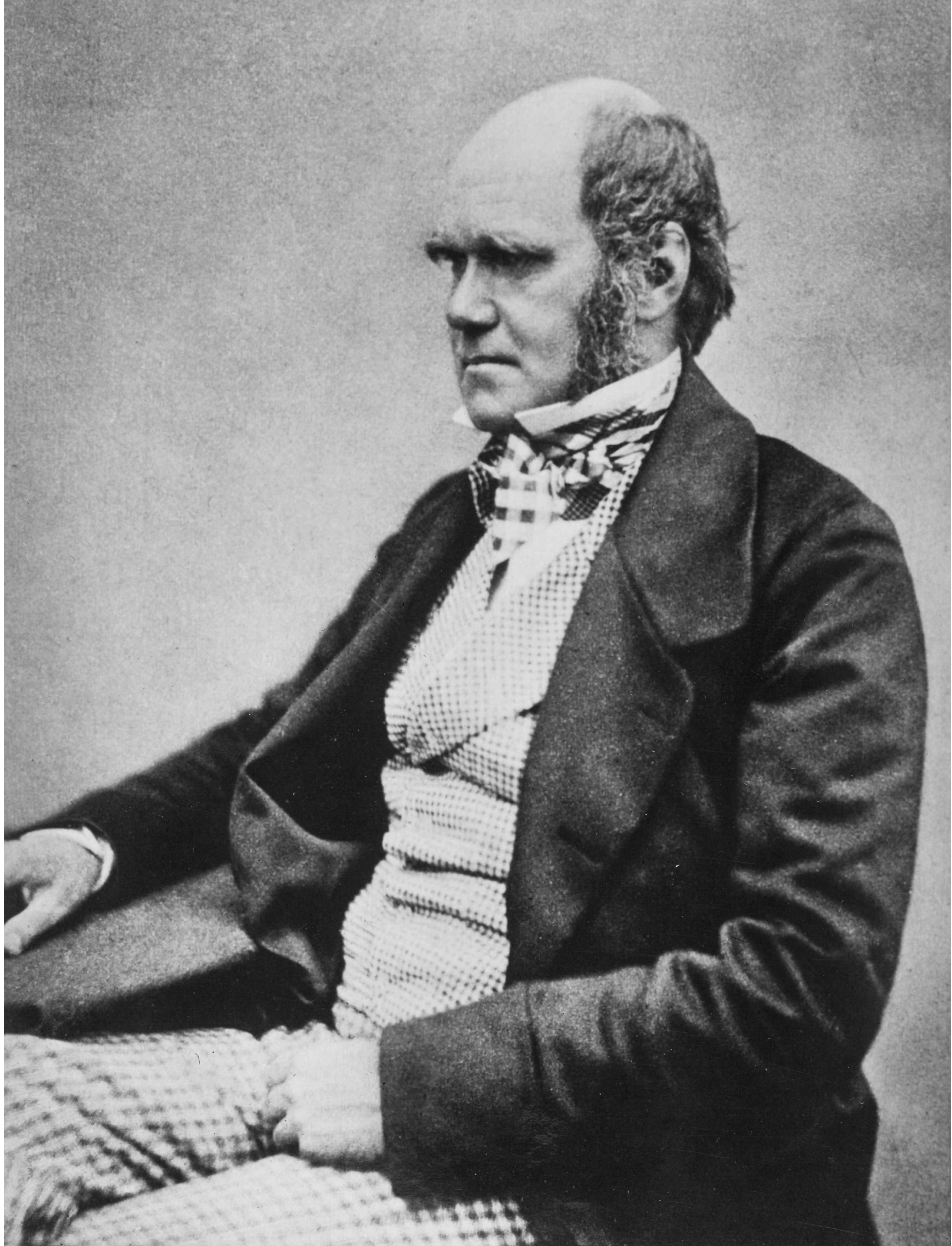


The voyage of the Beagle

a.k.a the “Oh look, Evolution!” world tour

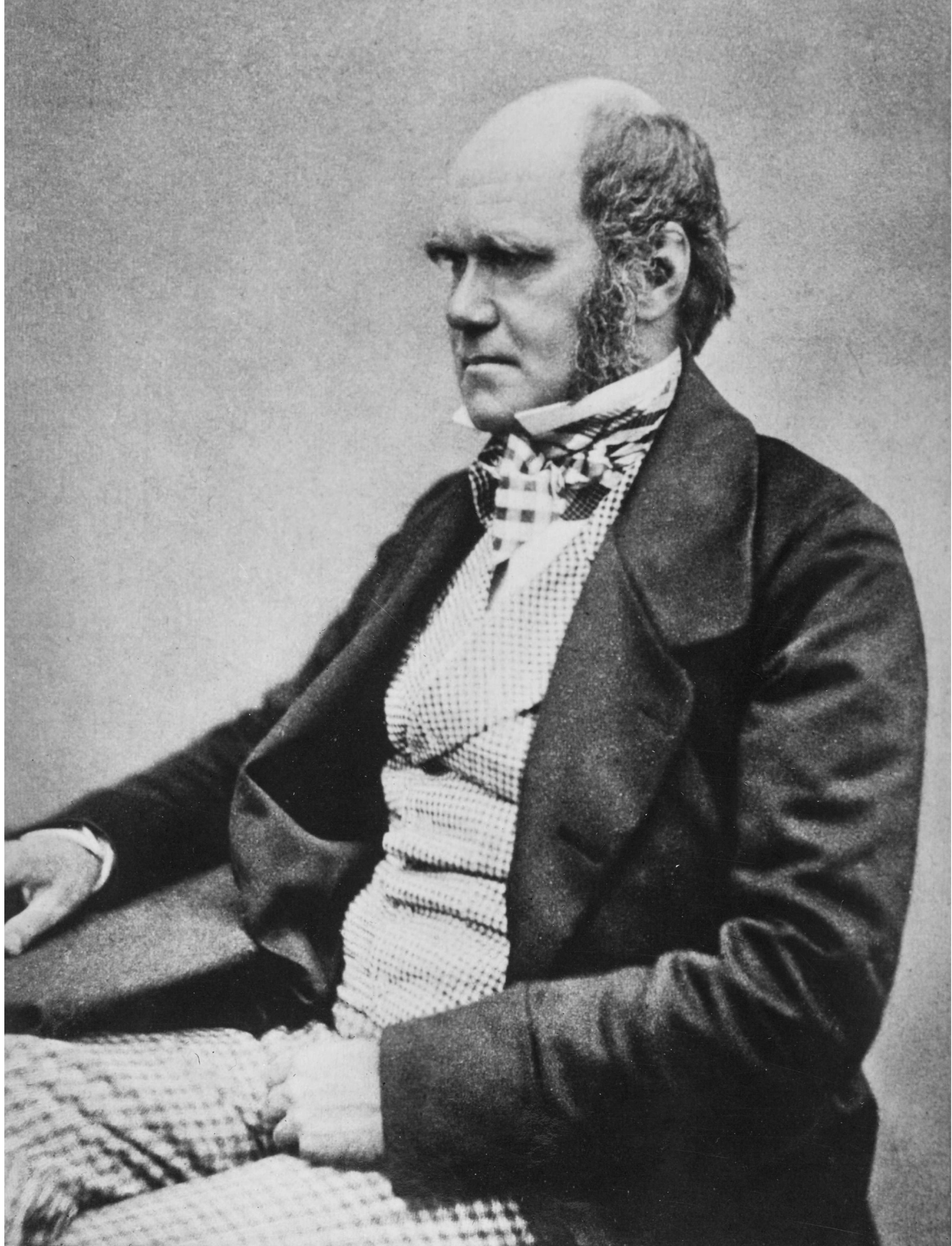

Plymouth
Azores
Tenerife
Cape Verde
Galapagos
Bahia
Callao
Lima
Rio de
Valparaiso
Montevideo
Falkland
Islands
Cape Town
Mauritius
Cocos
(Keeling) Isl.
King George's
Sound
Sydney
Hobart
The voyage of the Beagle
a.k.a the “Oh look, Evolution!” world tour

FEBRUARY 20TH.—The day has been memorable in the annals of Valdivia, for the most severe earthquake experienced by the oldest inhabitant. I happened to be on shore, and was lying down in the wood to rest myself. It came on suddenly, and lasted two minutes; but the time appeared much longer.

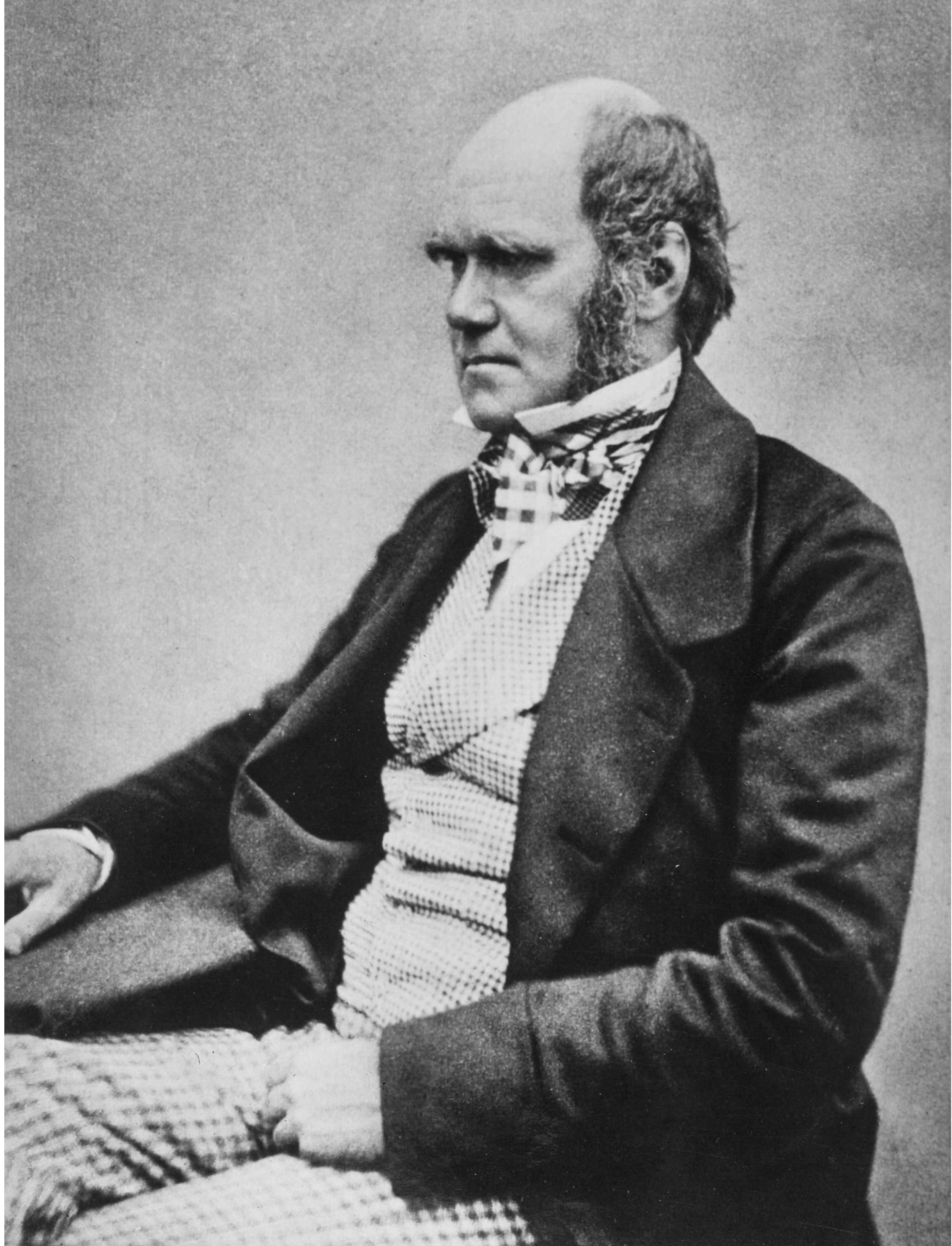


FEBRUARY 20TH.—The day has been memorable in the annals of Valdivia, for the most severe earthquake experienced by the oldest inhabitant. I happened to be on shore, and was lying down in the wood to rest myself. It came on suddenly, and lasted two minutes; but the time appeared much longer.

22D.—We sailed from Valdivia, and on the 4th of March, entered the harbour of Concepcion. ... The mayor-domo of the estate quickly rode down to tell us the terrible news of the great earthquake of the 20th;—"that not a house in Concepcion, or Talcuhano, (the port) was standing; that seventy villages were destroyed; and that a great wave had almost washed away the ruins of Talcuhano." Of this latter fact I soon saw abundant proof; the whole coast being strewed over with timber and furniture, as if a thousand great ships had been wrecked. Besides chairs, tables, bookshelves, &c., in great numbers, there were several roofs of cottages, which had been drifted in an almost entire state.



After viewing Concepcion, I cannot understand how the greater number of inhabitants escaped unhurt.



Big earthquakes (since Darwin) (>= 8.0)

In current Chile

- 1835, Concepción, 8.1 (est)
- 1837, Valdivia, 8.8-9.5 (est)
- 1868, Arica, 8.5-9.0 (est)
- 1877, Iquique, 8.7-8.9
  (Tsunami killed 5000 in Fiji and 5 in Hawaii)

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- 1939, Chillán, 8.3
- 1943, Ovalle, 7.9-8.2
- 1960, Concepción, 8.3
- **1960, Valdivia, 9.4-9.6** (1st prize!)


BRITISH PATHÉ
BRITISH PATHÉ


BRITISH PATHÉ
BRITISH
PATHÉ


Ruta 206
Los Ríos
Google
Street View
Ruta 206
Google
Image capture: Oct 2015
© 2020 Google
Canada
Terms
Report

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- **1960, Valdivia, 9.4-9.6** (1st prize!)
- 1985, Algarrobo, 8.0
- 1995, Antofagasta, 8.0
- 2010, Concepción, 8.8 (6th prize!)
- 2014, Iquique, 8.2
- 2015, Illapel, 8.5

Big earthquakes (since Darwin) (>= 8.0)

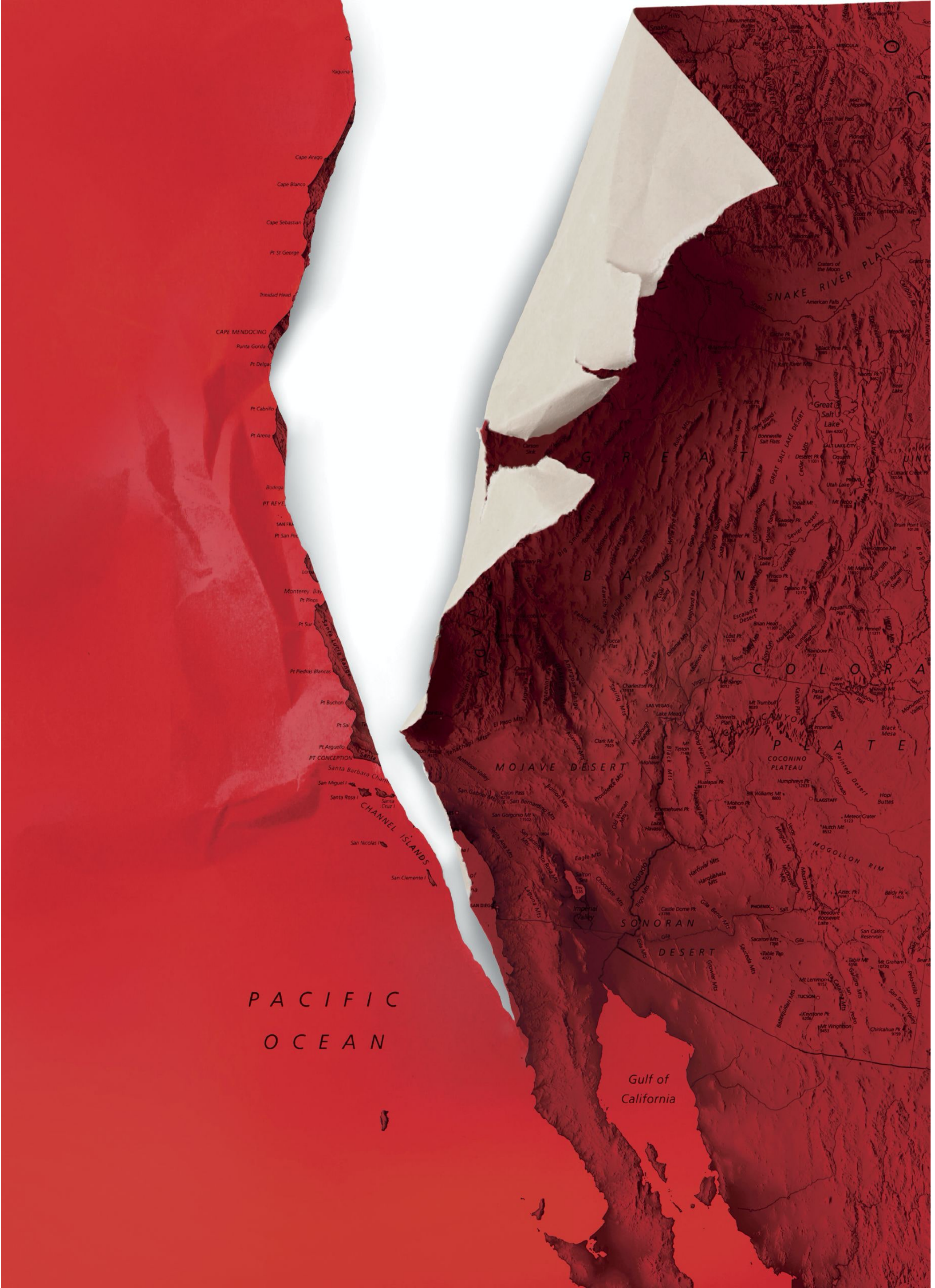
In Canada and Contiguous United States

- 1899 Yukon-Alaska Border, 8.0
- 1949 Haida Gwaii, 8.1

Big earthquakes (since Darwin) (>= 8.0)

In Canada and Contiguous United States

- 1899 Yukon-Alaska Border, 8.0
- 1949 Haida Gwaii, 8.1
- That's it.



THE NEW YORKER

ANNALS OF SEISMOLOGY JULY 20, 2015 ISSUE

THE REALLY BIG ONE

An earthquake will destroy a sizable portion of the coastal Northwest. The question is when.

By Kathryn Schulz

July 13, 2015

Big earthquakes (since Darwin) (>= 8.0)

In current Chile

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- 2014, Iquique, 8.2
- 2015, Illapel, 8.5

February 27th, 2010
(a Saturday)

August

~~February~~ 27th, 2010

(a Saturday)

03:34 AM

03:34 AM

03:34 AM

03:34 AM

(If the roof collapses over my bed, can I easily get out of the rubble? ...

03:34 AM

(If the roof collapses over my bed, can I easily get out of the rubble? ...

03:34 AM

(If the roof collapses over my bed, can I easily get out of the rubble? …

Yes.

03:34 AM

(If the roof collapses over my bed, can I easily get out of the rubble? …

Yes.

03:34 AM

(If the roof collapses over my bed, can I easily get out of the rubble? …

Yes. Let’s ride it out and go back to sleep.

03:34 AM

(If the roof collapses over my bed, can I easily get out of the rubble? …

Yes. Let’s ride it out and go back to sleep.

03:34 AM

03:34 AM

03:34 AM

Sister: “Is everybody alright???
Where’s Felipe??”

03:34 AM

Sister: “Is everybody alright???
 Where’s Felipe??”
Me:

Sister: “Is everybody alright???
Where’s Felipe??”
Me: (Damn, I’ll have to get up now.)

Sister: “Is everybody alright???
Where’s Felipe??”
Me: “I’m ok, I’m up!”

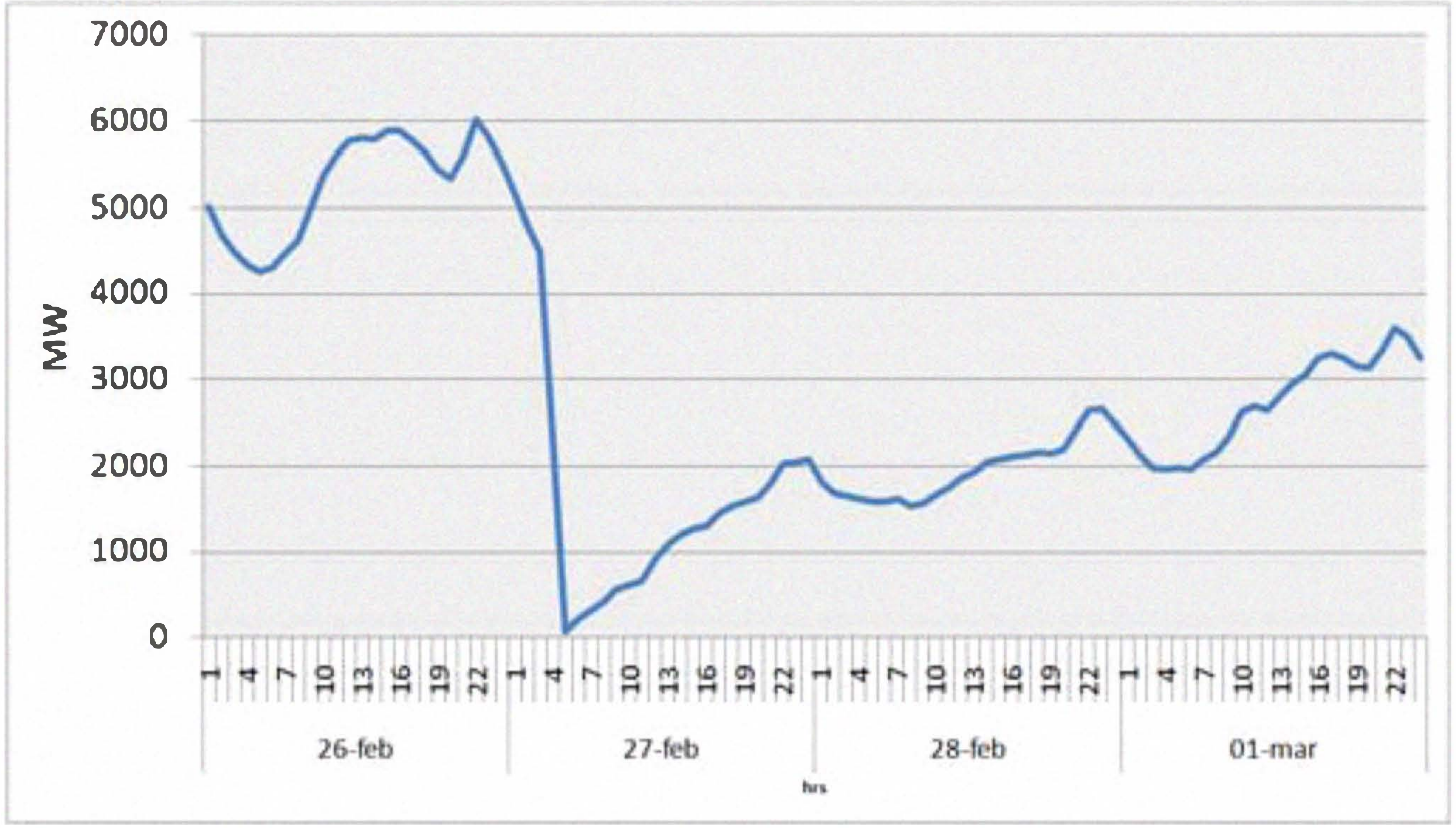
03:35 AM

There’s **no power.**

Power is gone
[Araneda et al. 2010]

- Immediate blackout with 4.5 GW out of the power grid (for reference, that's the **total** power generation capacity of the province of Saskatchewan)

- Distribution (transformers, power lines etc) in several places take days or even weeks to repair.



BC Hydro

TRANSMISSION SYSTEM

	EXISTING O/HEAD	EXISTING CABLE	FUTURE APPROX. ROUTING	OTHER UTILITIES
500 kV				
360 kV				
287 kV				
230 kV				
161 kV				
138 kV				
69 KV	DE-ENERGIZED			

NOTE: FUTURE TRANSMISSION LINES ARE SUBJECT TO INPUT AT THE PUBLIC CONSULTATION STAGE.

- SUBSTATION
- HYDRO GENERATING STATION
- THERMAL GENERATING STATION
- DIESEL GENERATING STATION
- CAPACITOR STATION

BCH DWG. NO. G-T06-00010

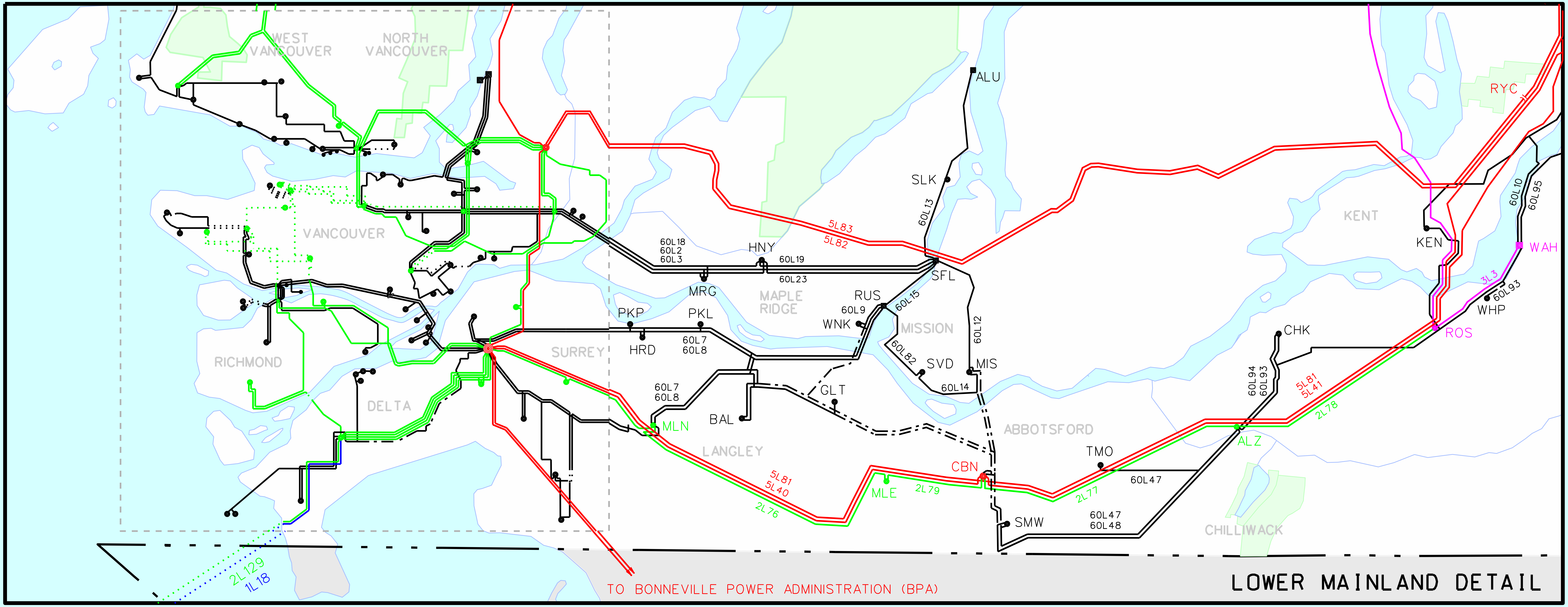
- 2019 / 20 -

STATION PLANNING
TRANSMISSION & STATIONS
PLANNING

Scale: 1:2,000,000 — 0 50 100 150 200 Kilometers

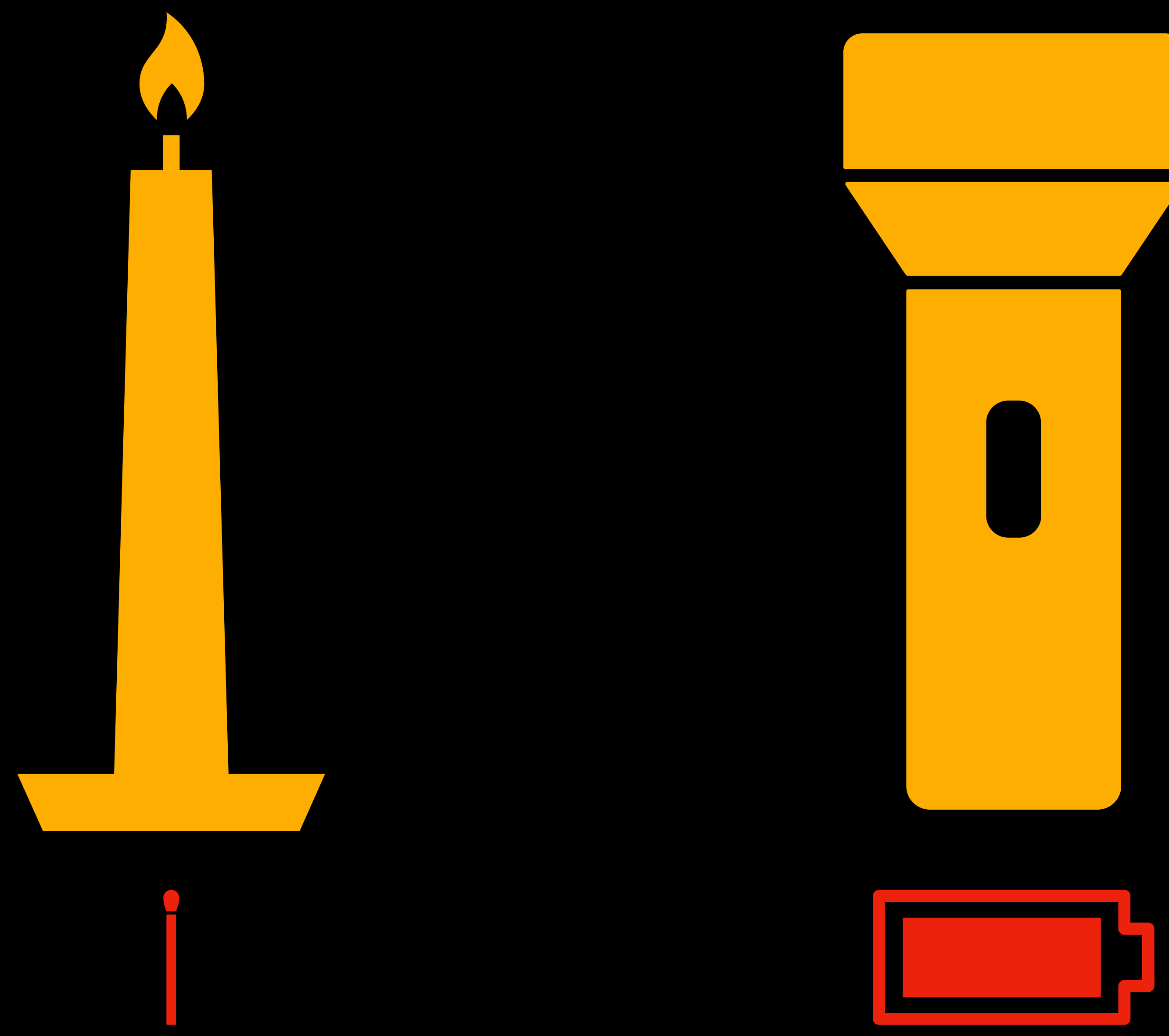
BC Hydro

TRANSMISSION SYSTEM




VANCOUVER

There’s **no power.**



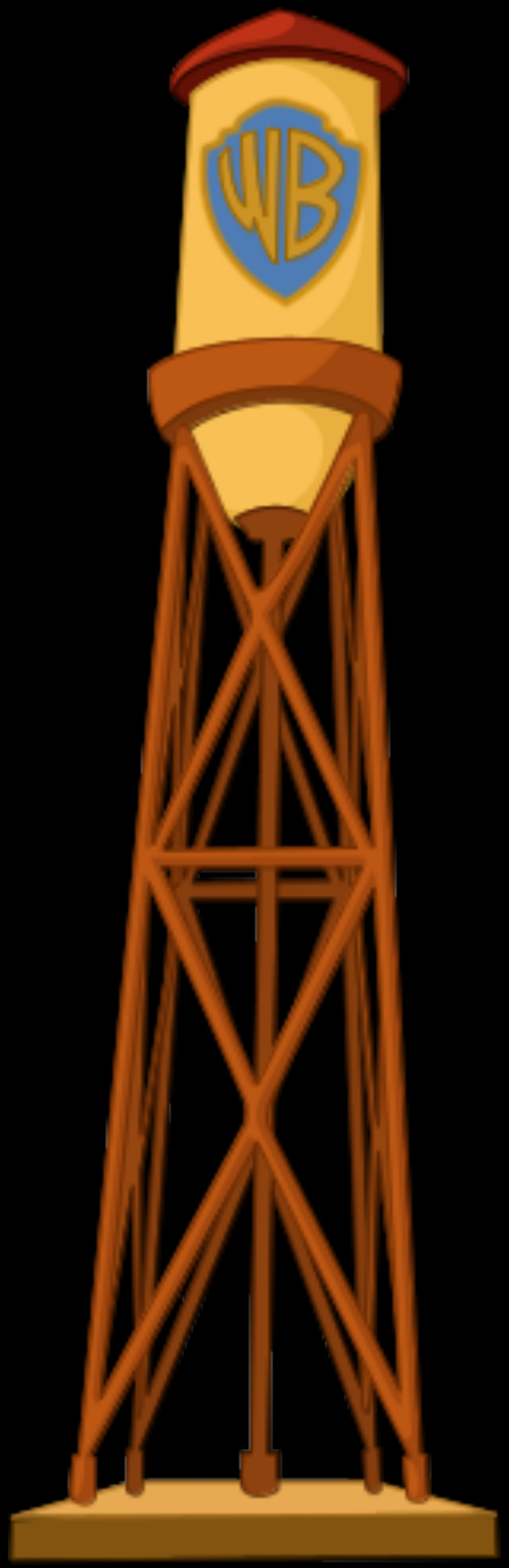
Lesson 1:

You’ll need a light source

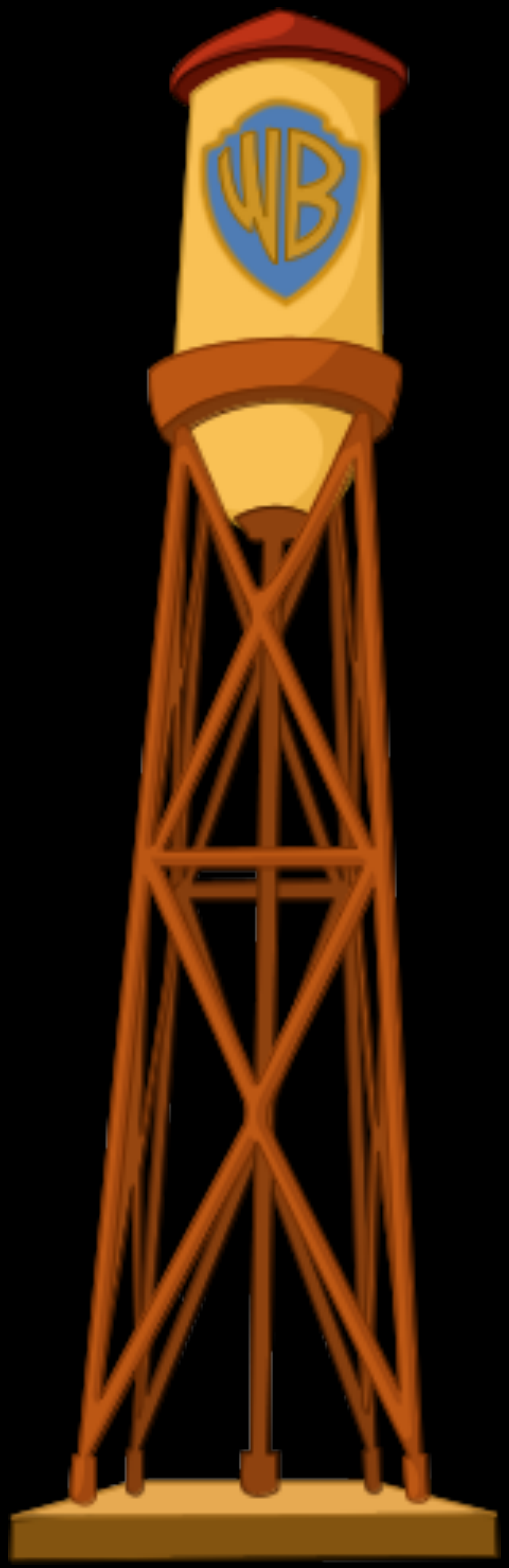
Mom: “Get all the pots and fill them with water, also the tub.”

There’s **no power.**

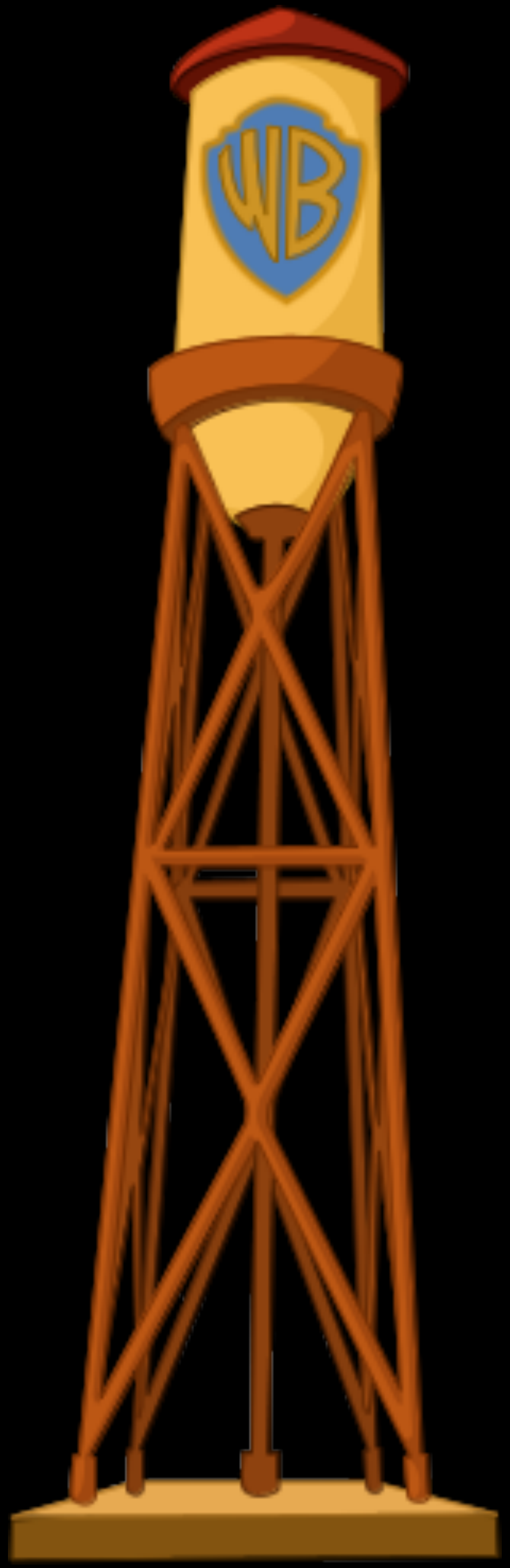
There’s **no power.**

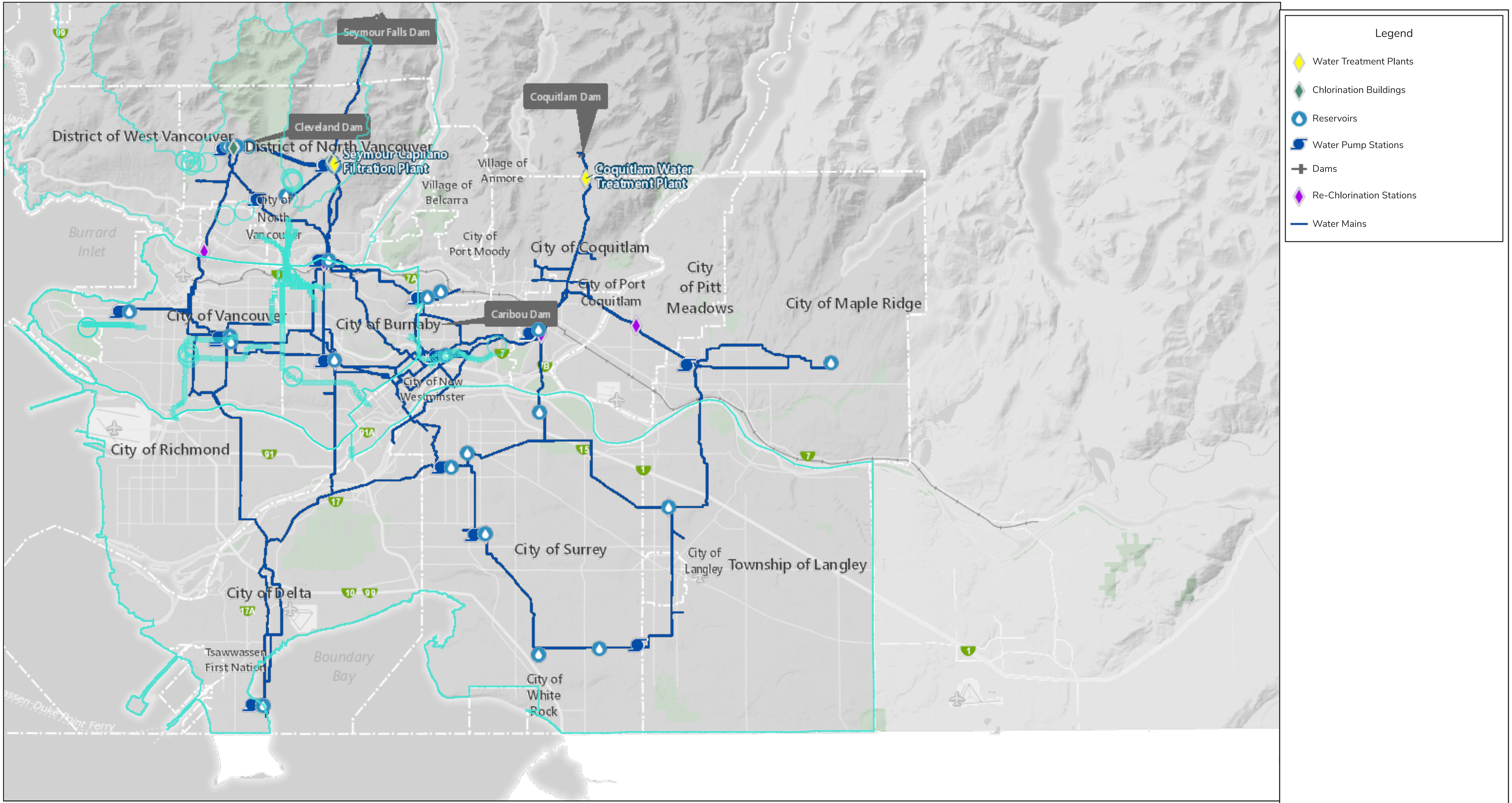


There’s no power,
There’s no water.



There’s **no power,**
There’s **no water.**





N

6km

1:250000

The water mains of Metro Vancouver

Map created on Fri Nov 27 2020

Cleveland Dam
District of West Vancouver
District of North Vancouver
Seymour Capilano
Filtration Plant
Village of
Anmore
Village of
Belcarra
City of
North
Vancouver
Burrard
Inlet
City of
Port Moody
City of Vancouver
City of Burnaby
Caribou Dam
City of New
Westminster
7A
7
7B

Lesson 2:

You’ll need water.

about 4lt per person per day

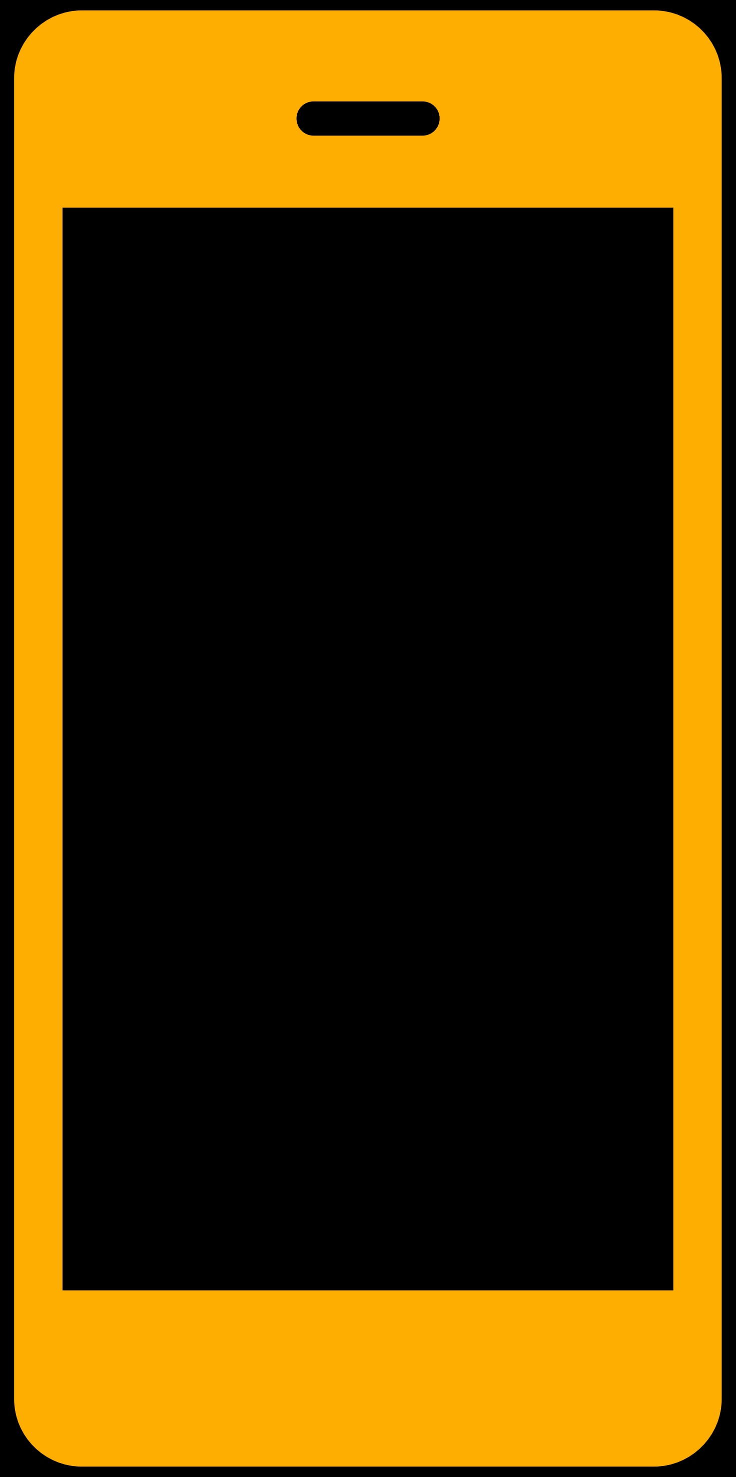
(plan for 3 days min)

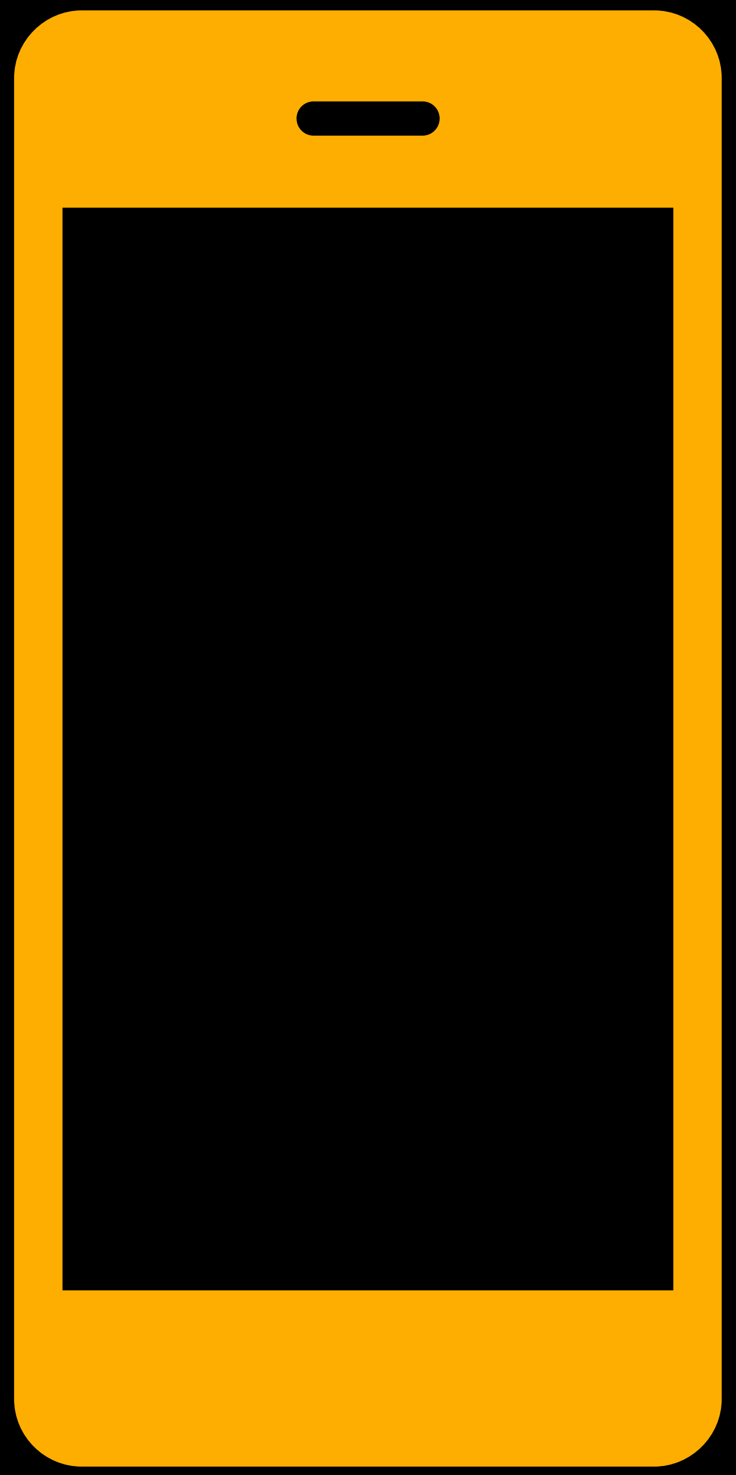
plus the toilet

Everybody is safe, we have (some) light,
we have water.

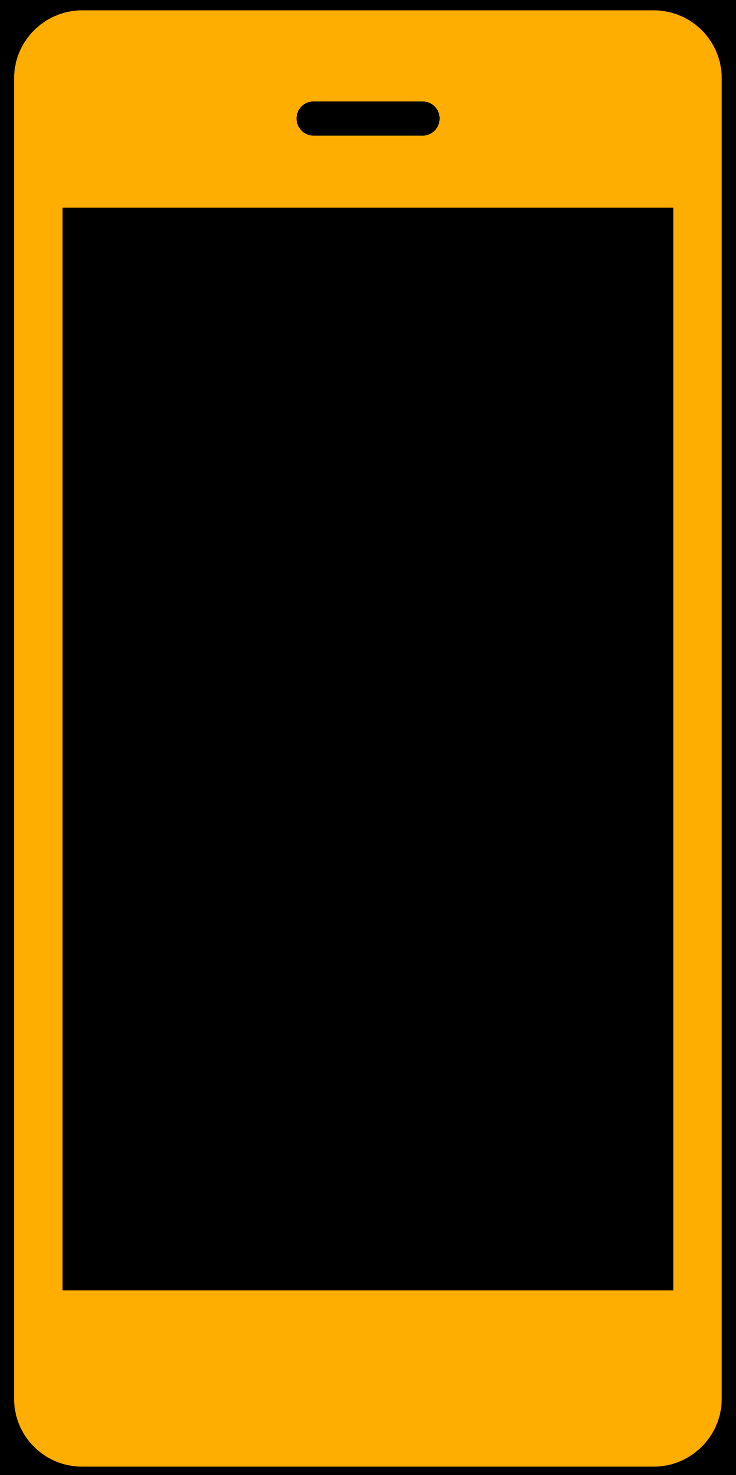
03:40 AM

Everybody is safe, we have (some) light,
we have water.
Q: Is everybody else safe?



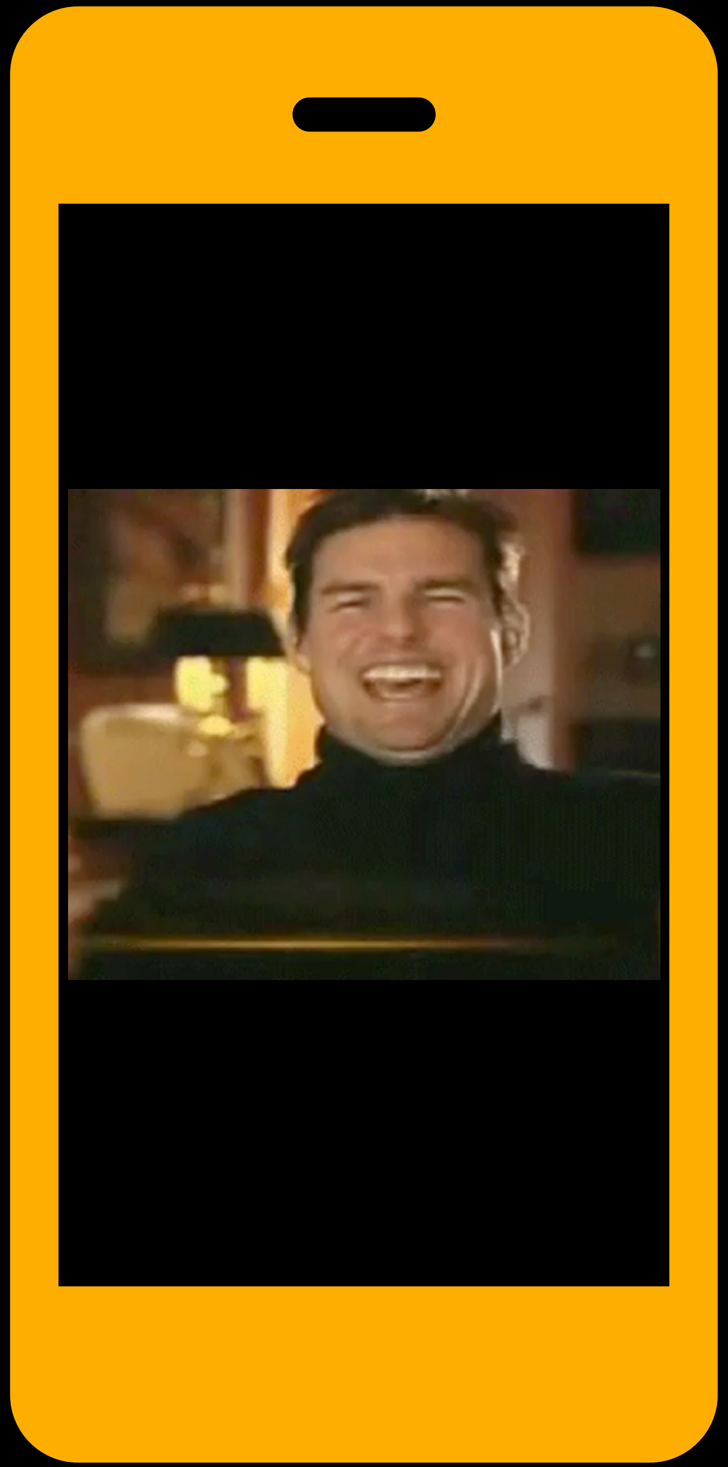


Text “We are safe” to someone out of the area



Text “We are safe” to someone out of the area

The internet should work



should
should
should
should
should
should
Text “We are safe” to someone out of the area
should
should
should

The internet **should** work

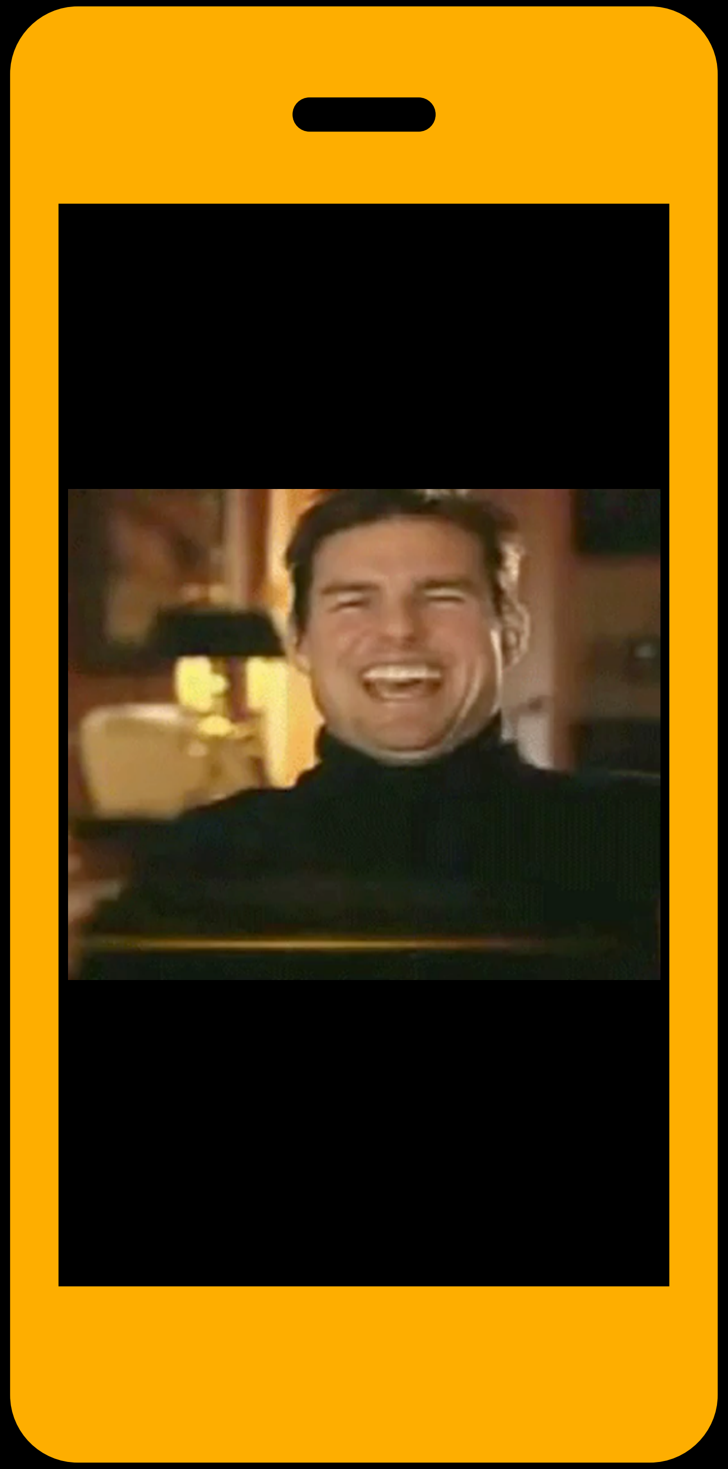
should
should
should

should
should
should
should
should
should

Text “We are safe” to someone out of the area

should
should
should

The internet **should** work



should
should
should

“I’ll check on the news sites some info about the earthquake”

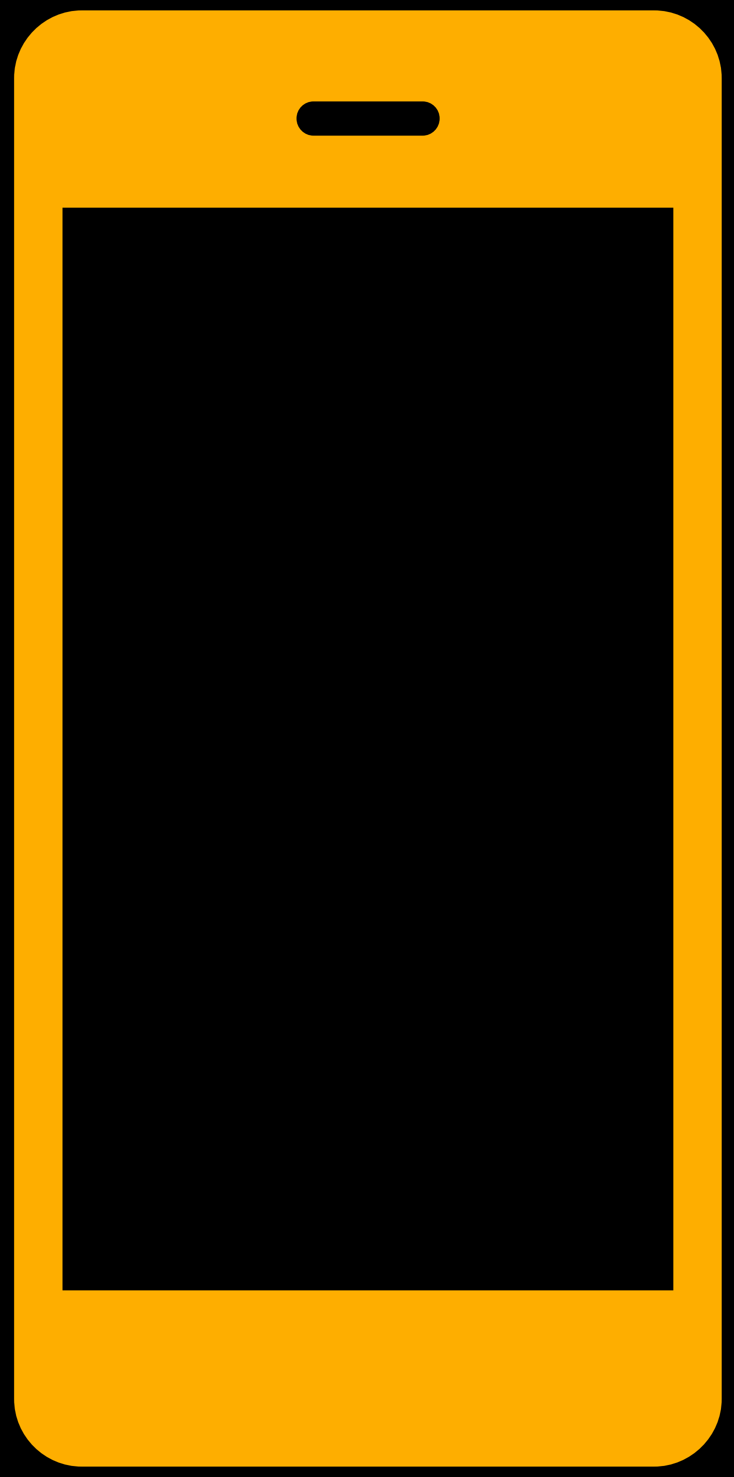
(1 min for page loading)
(generalities about the earthquake)

03:55 AM

(refresh)
Network connection error.

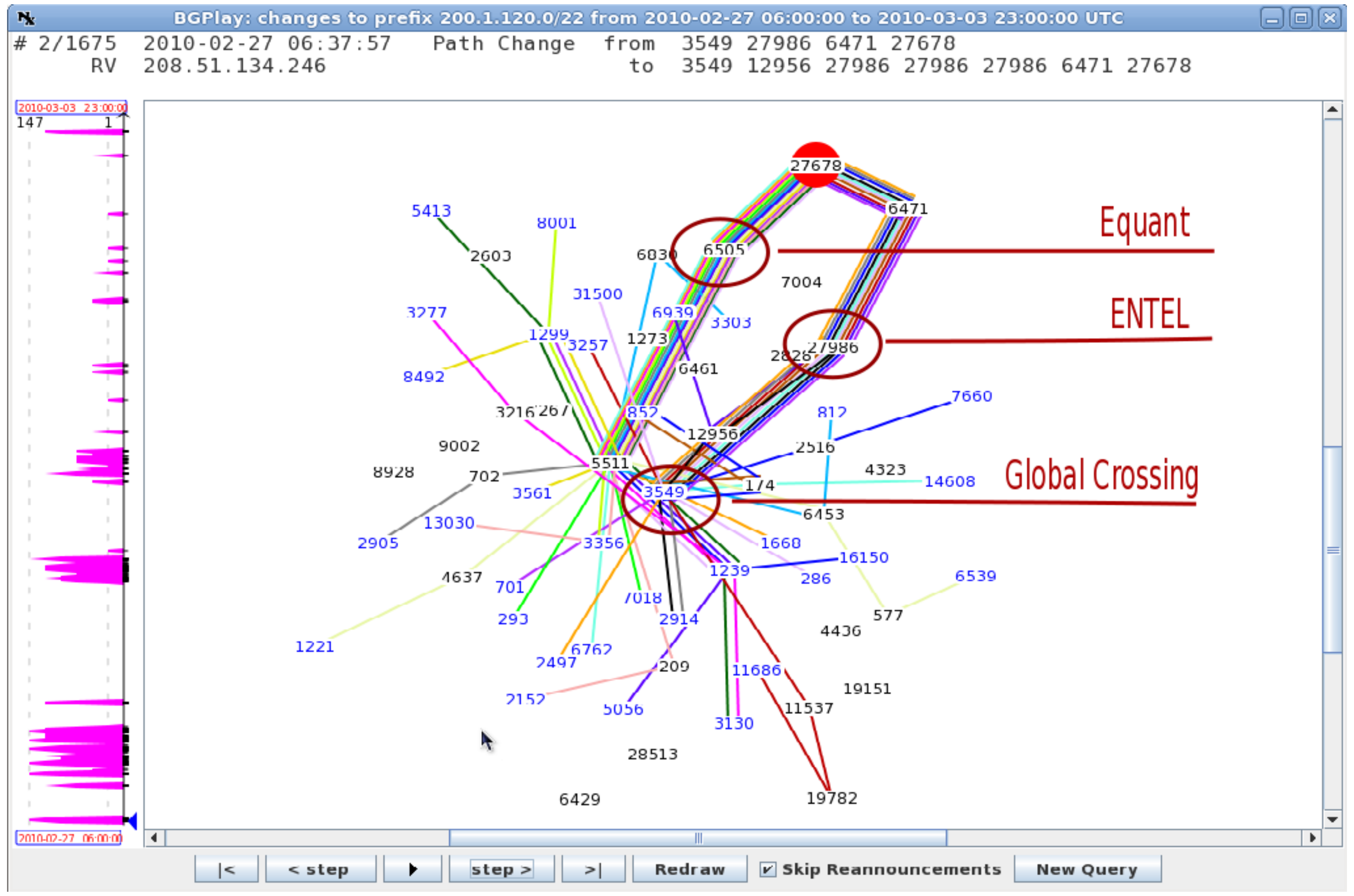
There’s **no power.**

There's no power in the whole country



Vista de Rutas

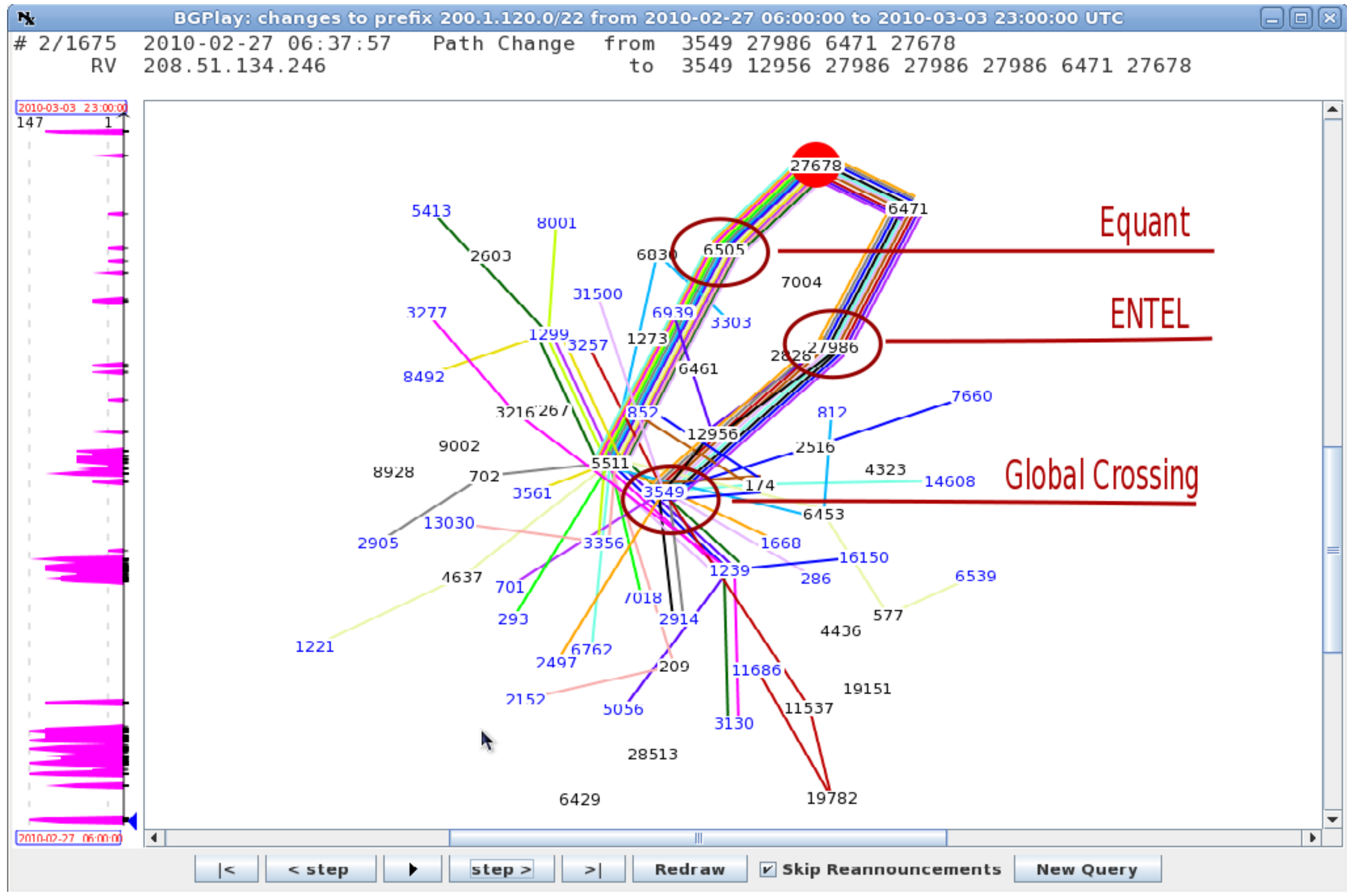
NIC Chile 3:37 AM



Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

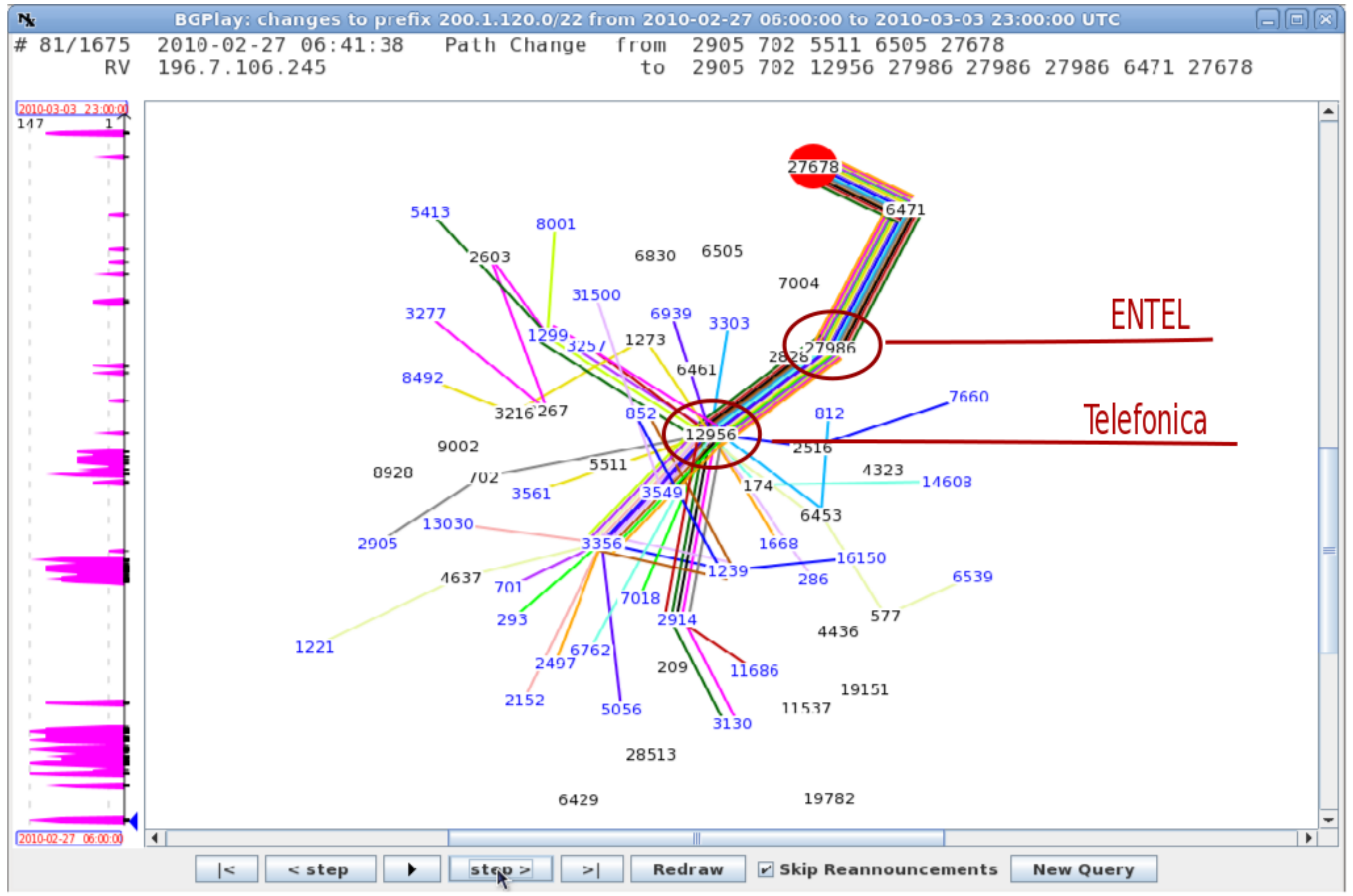
Vista de Rutas

NIC Chile 3:37 AM



Vista de Rutas

NIC Chile 3:41 AM

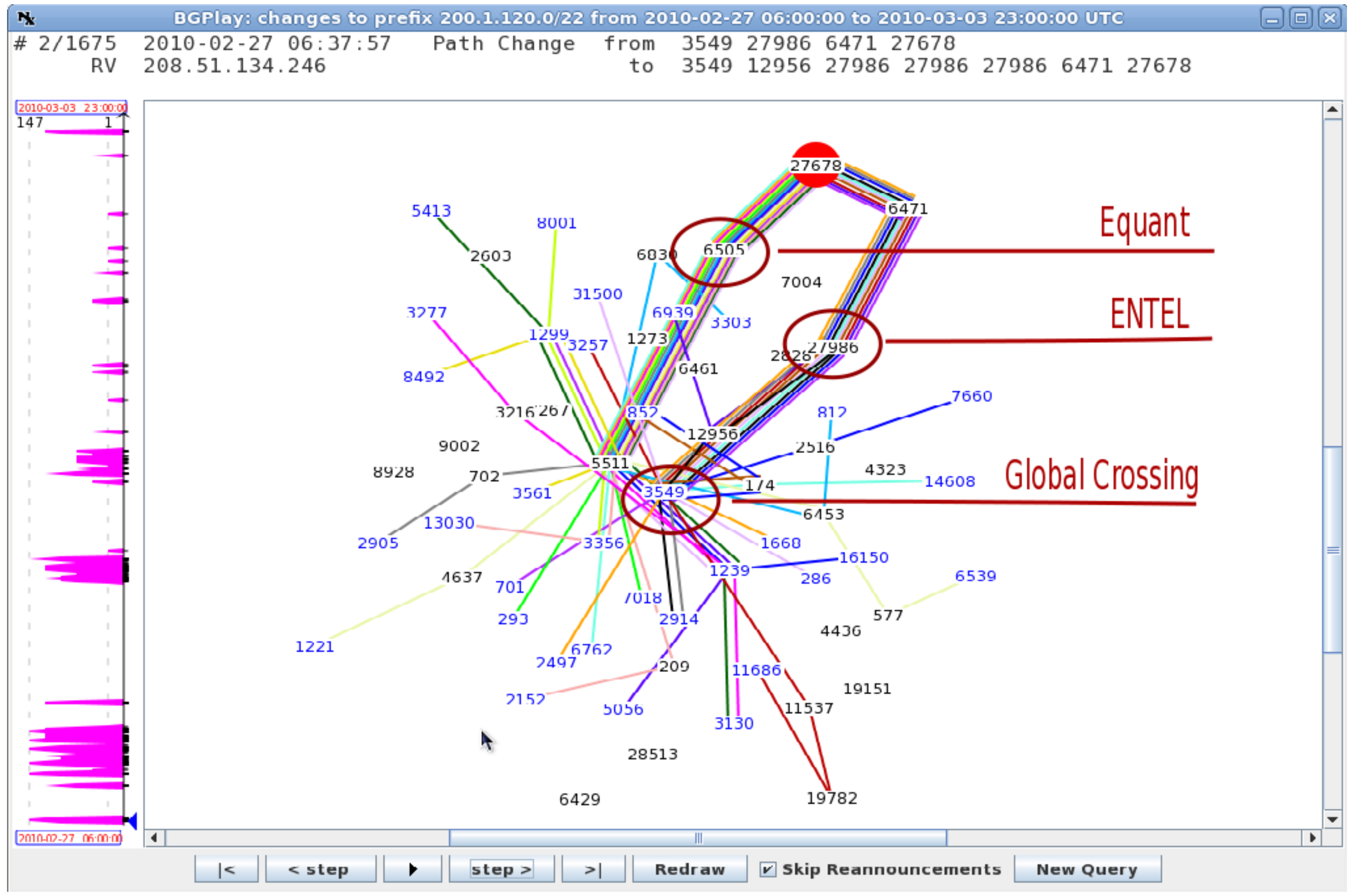


Internet y el Terremoto 2010

Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

Vista de Rutas

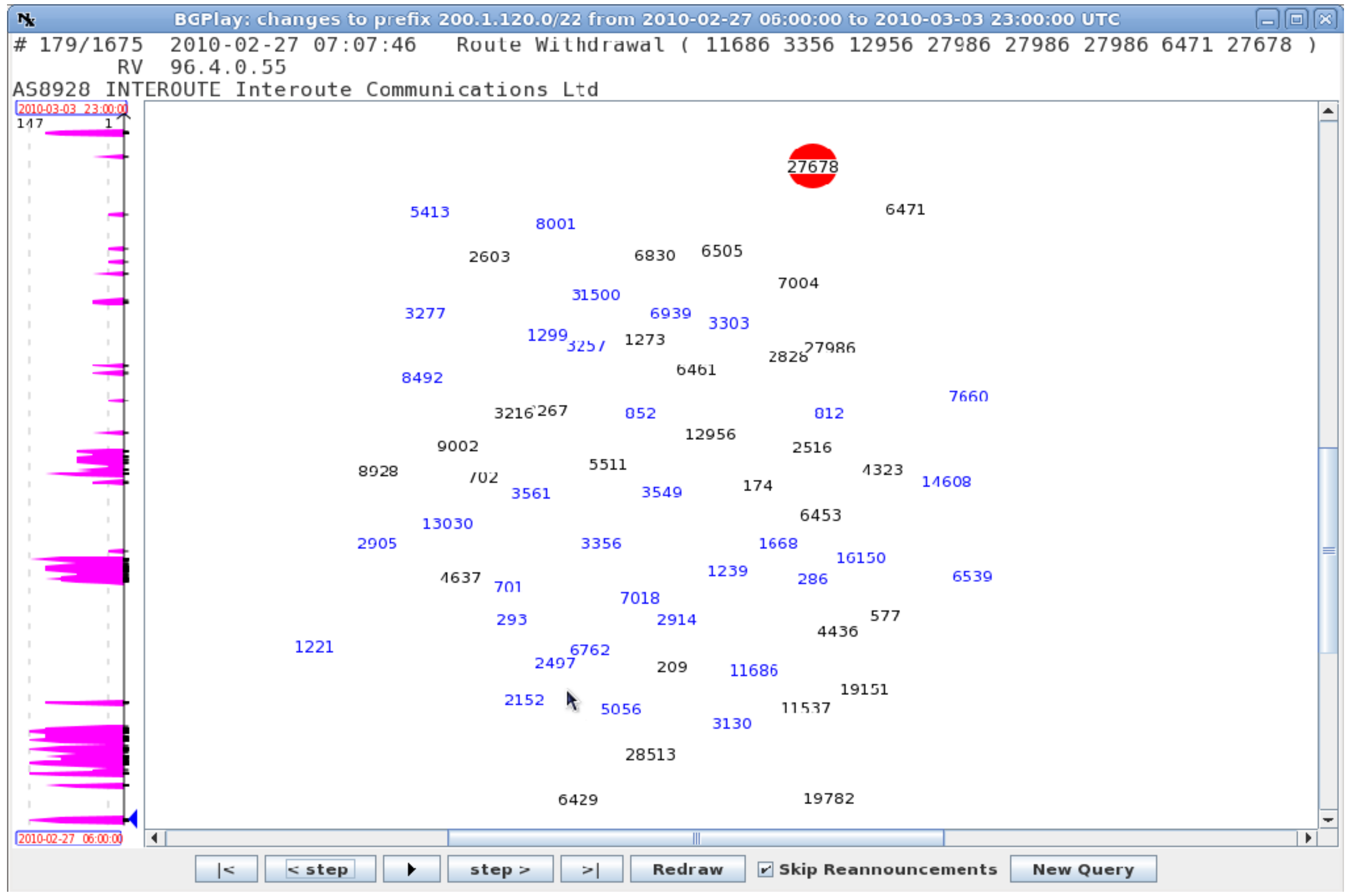
NIC Chile 3:37 AM



Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

Vista de Rutas

NIC Chile 4:07 AM



Internet y el Terremoto 2010

Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

03:40 AM

Everybody is safe, we have (some) light,
we have water.
Is everybody else safe?

03:42 AM

Mom: Get the Battery Radio

03:42 AM

Mom: Get the Battery Radio

Not much going on in the radio, but there is one radio transmitting: Not knowing much, but calming people.

03:45 AM

THIS IS IMPORTANT:

If you live alone, you will want to hear from someone, and there might be NO INTERNET.

Also you want to know:
Tsunami? Is water potable?
Evacuation alerts? etc.

03:45 AM

Lesson 3:

Get a battery-powered FM/AM radio.

ESPECIALLY IF YOU LIVE ALONE

4:00 AM

Agreement: There’s nothing else we can do now. Let’s go to bed.

9:00 AM

There is no power, but
the houses around look all OK

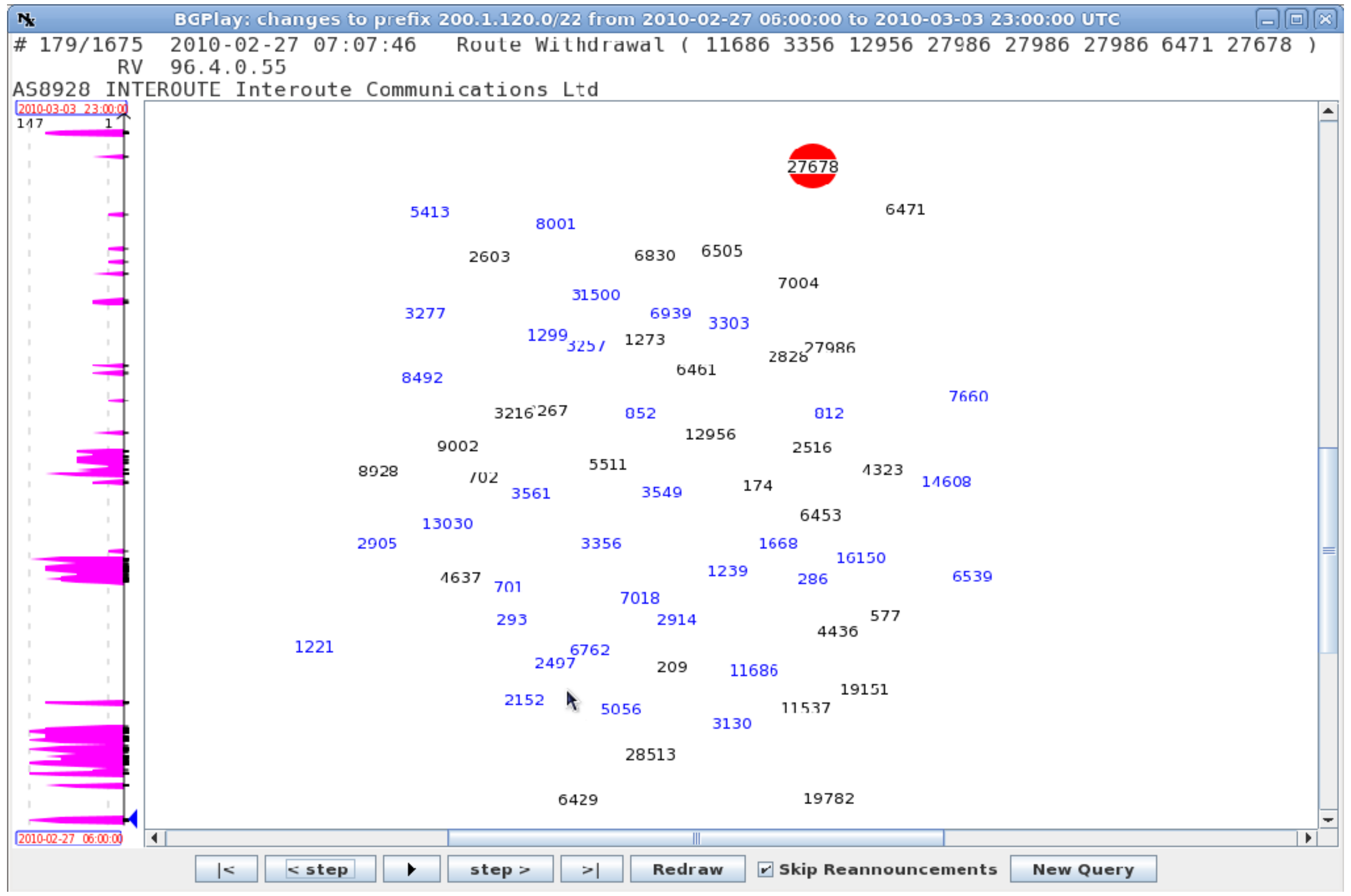
11:00 AM

11:00 AM

Power comes back.

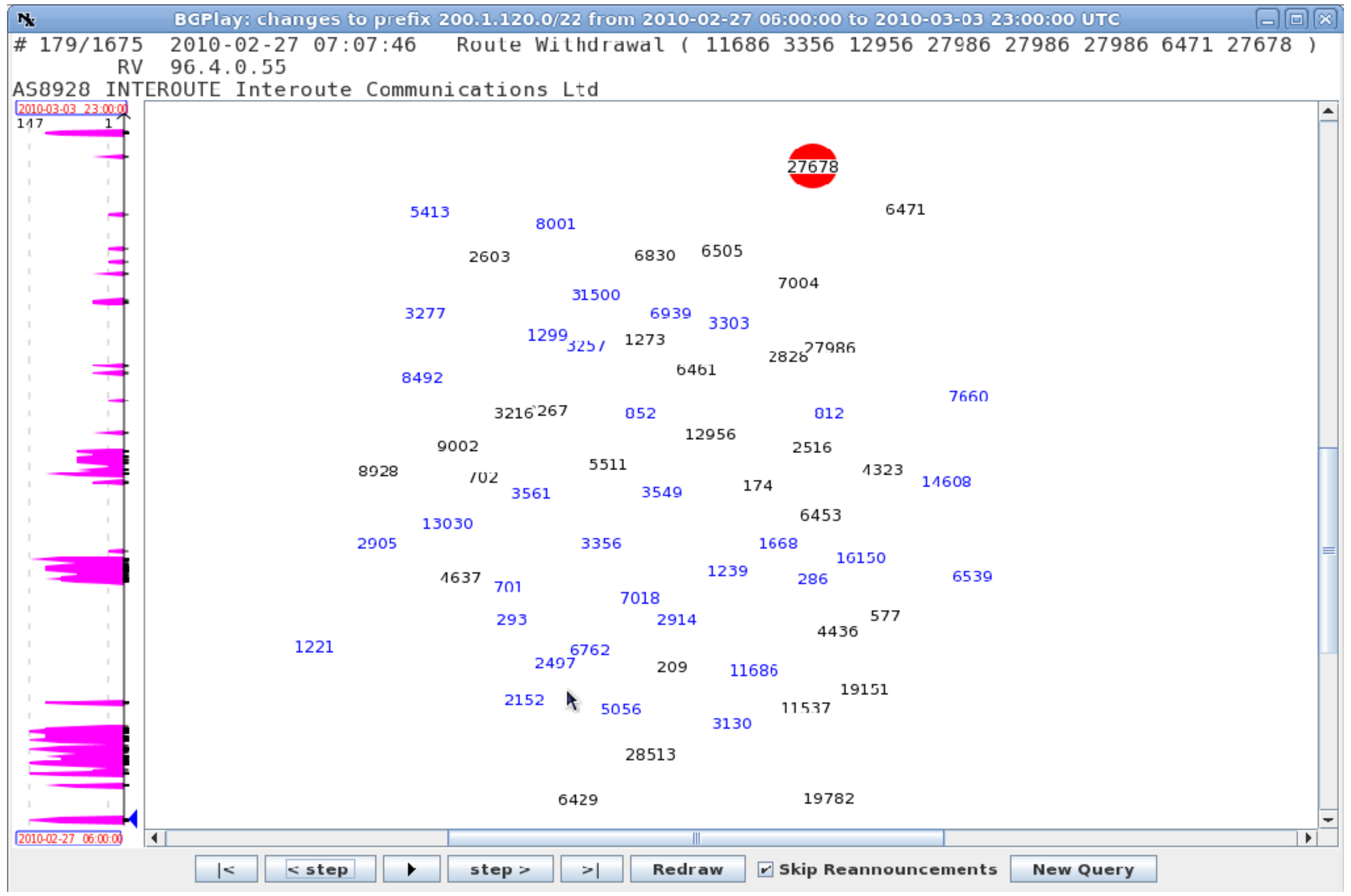
Vista de Rutas

NIC Chile 4:07 AM



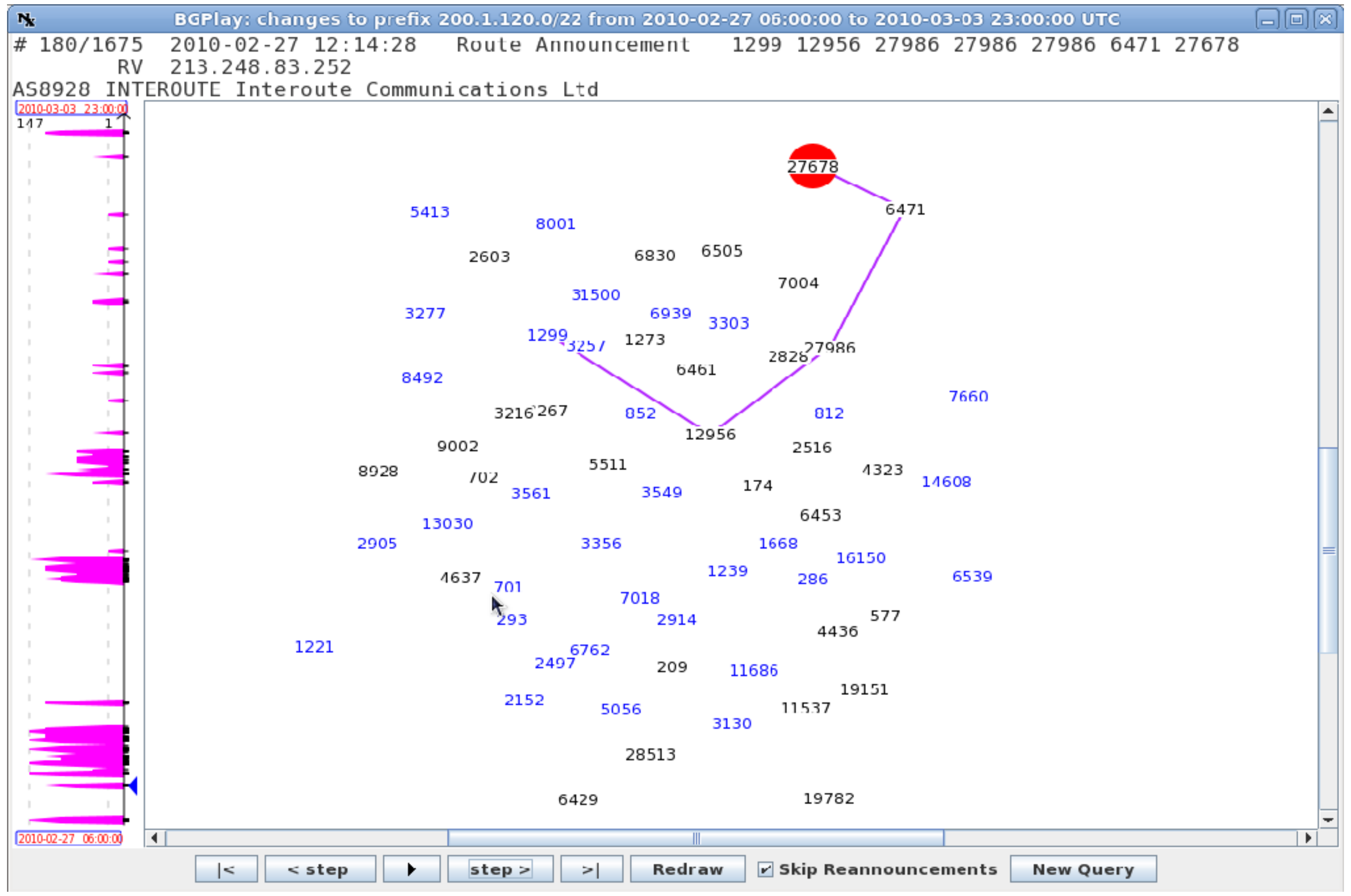
Vista de Rutas

NIC Chile 4:07 AM



Vista de Rutas

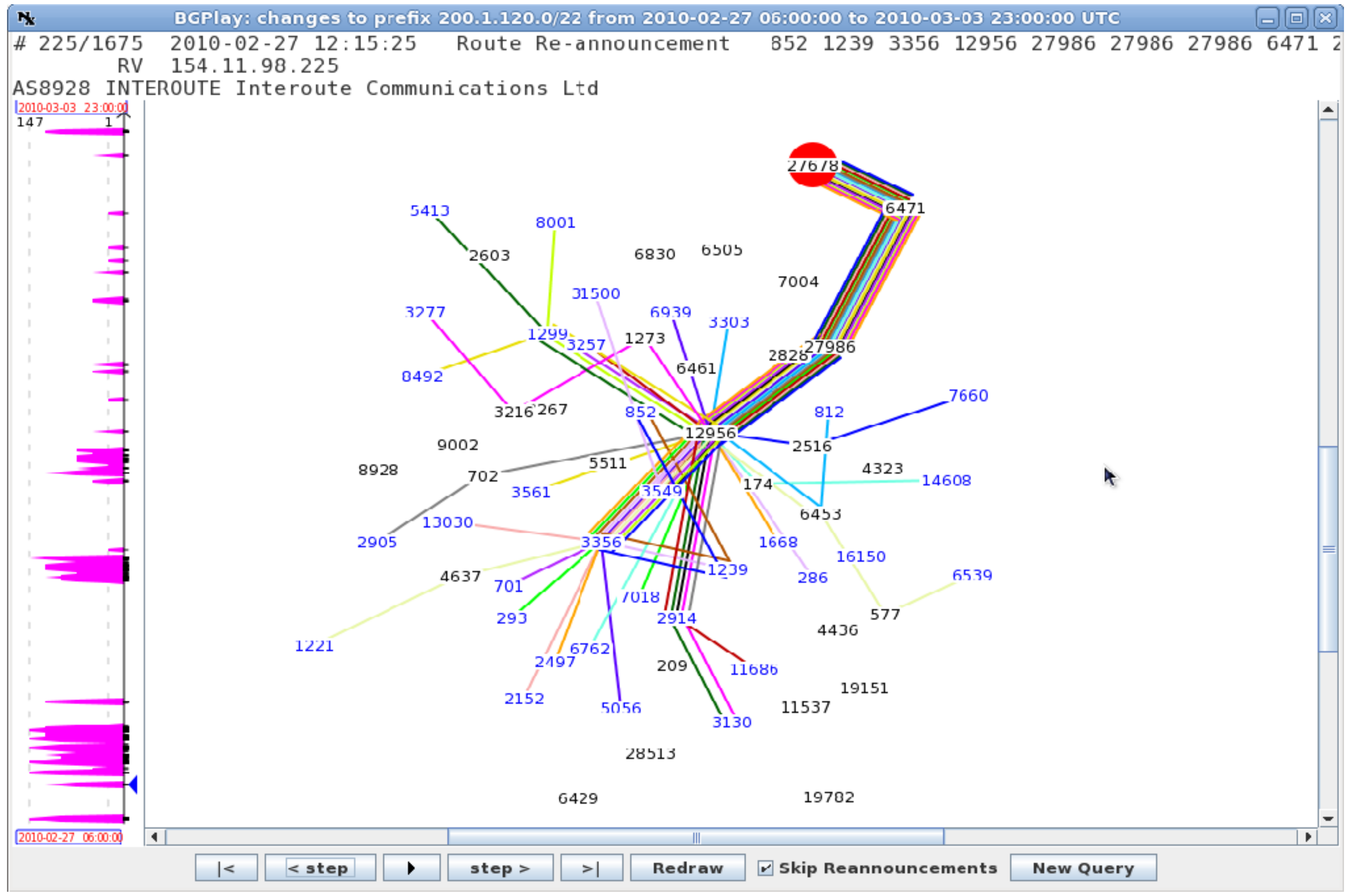
NIC Chile 9:14 AM



Internet y el Terremoto 2010

Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

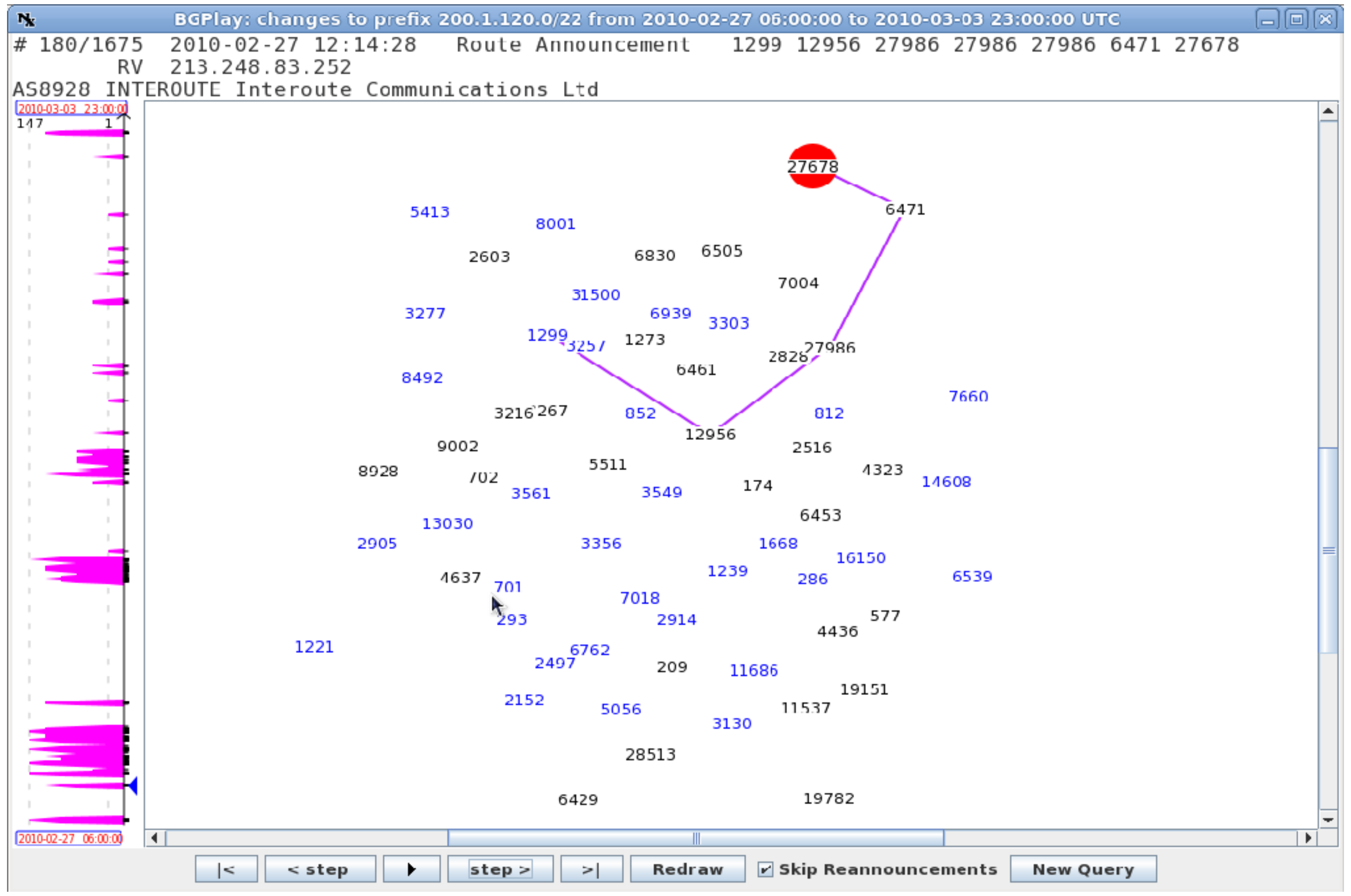
Vista de Rutas
NIC Chile 9:15 AM



Internet y el Terremoto 2010

Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

Vista de Rutas
NIC Chile 9:14 AM



Internet y el Terremoto 2010

Tomás Barros, José Piquer, Victor Ramiro, Pablo Sepúlveda

11:00 AM

Internet comes back.

12:00 AM

12:00 AM

TV comes back.


Isla San Félix
Isla San Ambrosio
Huasco
Coquimbo
Nevado Ojos del Salado
SOUTH PACIFIC OCEAN
SANTIAGO
ARGENTINA
Temuco
Puerto Montt

We are here

Table 1-1 Summary of Ground Motion Recordings from the 2010 Maule Earthquake (Boroschek et al., 2010)

No.	Station	Region	Latitude	Longitude	Station Type[1]	Peak Ground Acceleration, g	
						Dir.	*Value*
1	Angol[2]	IX	-37.7947º (S)	-72.7081º (W)	QDR	NS	0.928
2	Concepción	VIII	-36.8261º (S)	-73.0547º (W)	SMA-1	Long.	0.402
3	Constitución	VII	-35.3401º (S)	-72.4057º (W)	SMA-1	Trans.	0.640
4	Copiapo	III	-27.355º (S)	-70.3413º (W)	QDR	NS	0.030
5	Curico	VII	-34.9808º (S)	-71.2364º (W)	QDR	NS	0.470
6	Hualane	VII	-34.95º (S)	-71.80º (W)	SMA-1	Trans.	0.461
7	Llolleo	V	-33.6167º (S)	-71.6176º (W)	SMA-1	Trans.	0.564
8	Matanzas	VI	-33.9593º (S)	-71.8727º (W)	SMA-1	Long.	0.342
9	Papudo	V	-32.5114º (S)	-71.4471º (W)	SMA-1	Trans.	0.421
10	Santiago- Centro	RM	-33.46º (S)	-70.69º (W)	SSA-2	Trans.	0.309
11	Santiago- La Florida	RM	-33.5248º (S)	-70.5383º (W)	K2	NS	0.236
12	Santiago- Maipu	RM	-33.5167º (S)	-70.7667º (W)	QDR	NS	0.562
13	Santiago- Penalolen	RM	-33.50º (S)	-70.579º (W)	QDR	NS	0.295
14	Santiago- Puente Alto	RM	-33.5769º (S)	-70.5811º (W)	QDR	NS	0.265
15	Talca	VII	-35.4233º (S)	-71.66º (W)	SMA-1	Long.	0.477
16	Vallenar	III	-28.5716º (S)	-70.759º (W)	QDR	NS	0.020
17	Valparaiso- UTFSM	V	-33.0356º (S)	-71.5953º (W)	SMA-1	Trans.	0.304
18	Valparaiso- Almendral	V	-33.0458º (S)	-71.6068º (W)	SMA-1	Trans.	0.265
19	Valvidia	X	-39.8244º (S)	-73.2133º (W)	QDR	EW	0.138
20	Viña del Mar- Centro	V	-33.0253º (S)	-71.5508º (W)	QDR	EW	0.334
21	Viña del Mar- El Salto	V	-33.0469º (S)	-71.51º (W)	Etna	NS	0.351

[1] QDR: Free-field analog, U. Chile; SMA-1: Free-field analog, U. Chile; Etna: Free-field digital, U. Chile; SSA-2: Free-field digital, U. Chile; K2: Free-field digital, METRO S.A.

[2] Station soil-structure interaction under evaluation.

We are here


Isla San Félix
Isla San Ambrosio
Huasco
Nevado Ojos del Salado
Coquimbo
SOUTH PACIFIC OCEAN
.56g
.6g
.4g
.9g
ARGENTINA
Temuco
.1g

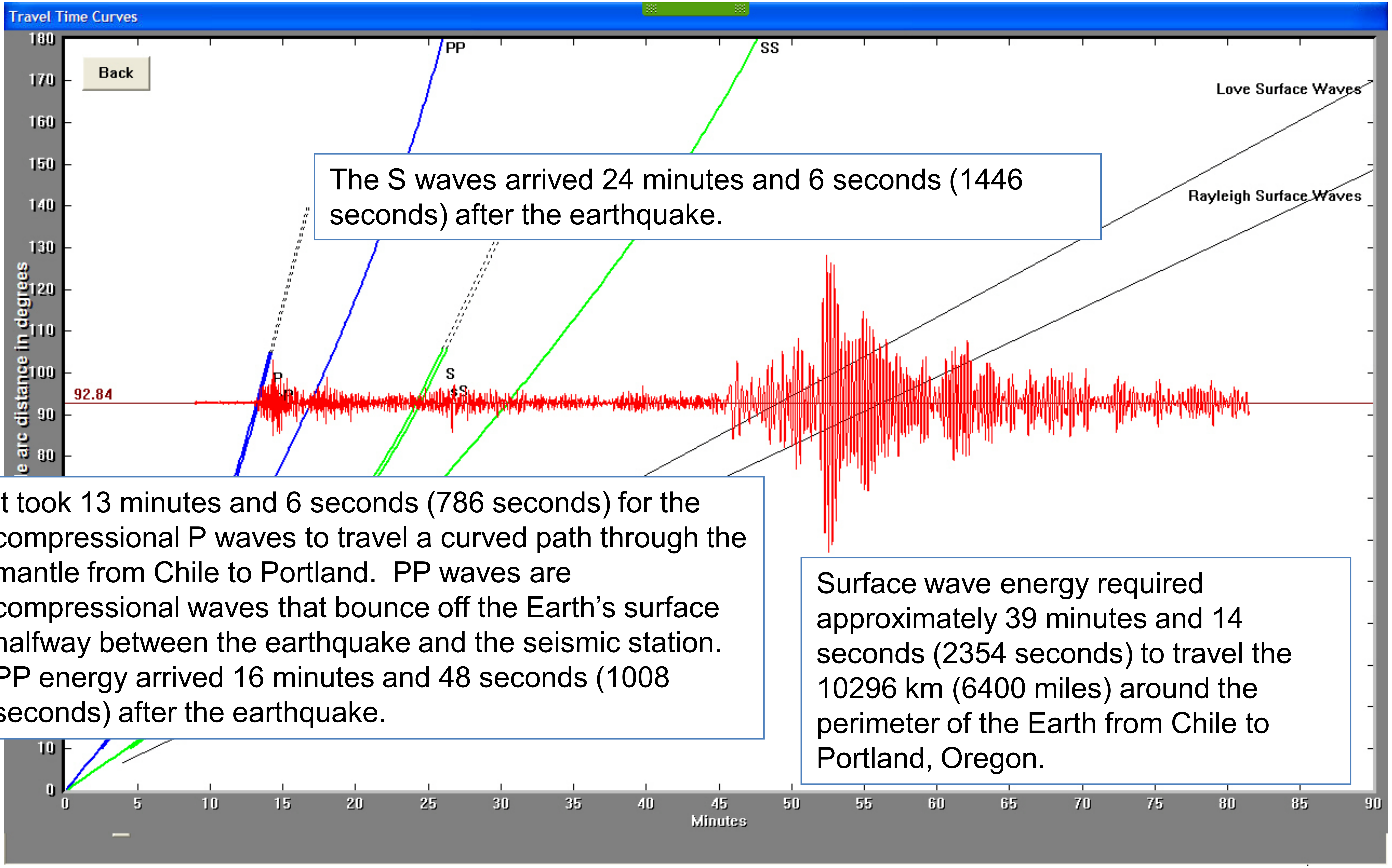
“Vancouver”

Isla San Félix
Isla San Ambrosio
Nevado Ojos del Salado
Huasco
Coquimbo
SOUTH PACIFIC OCEAN
ARCHIPIÉLAGO JUAN FERNÁNDEZ
ARGENTINA
Temuco
30
40
.56g
.6g
.4g
.9g
.1g
“San Francisco”
“Portland”
“Vancouver”

Magnitude 8.8 OFFSHORE MAULE, CHILE
Saturday, February 27, 2010 at 06:34:17 UTC

IRIS Teachable Moments

Portland is about 10296 km (6400 miles, 92.76°) from the location of this earthquake.



The S waves arrived 24 minutes and 6 seconds (1446 seconds) after the earthquake.

It took 13 minutes and 6 seconds (786 seconds) for the compressional P waves to travel a curved path through the mantle from Chile to Portland. PP waves are compressional waves that bounce off the Earth's surface halfway between the earthquake and the seismic station. PP energy arrived 16 minutes and 48 seconds (1008 seconds) after the earthquake.

Surface wave energy required approximately 39 minutes and 14 seconds (2354 seconds) to travel the 10296 km (6400 miles) around the perimeter of the Earth from Chile to Portland, Oregon.

Isla San Félix
Isla San Ambrosio
Nevado Ojos del Salado
Huasco
Coquimbo
SOUTH PACIFIC OCEAN
SANTIAGO
.56g
.6g
.4g
.9g
.1g
Temuco
ARGENTINA
ARCHIPIÉLAGO JUAN FERNÁNDEZ
Puerto Montt
“San Francisco”
“Portland”
“Vancouver”


SV-62 04


NISSAN

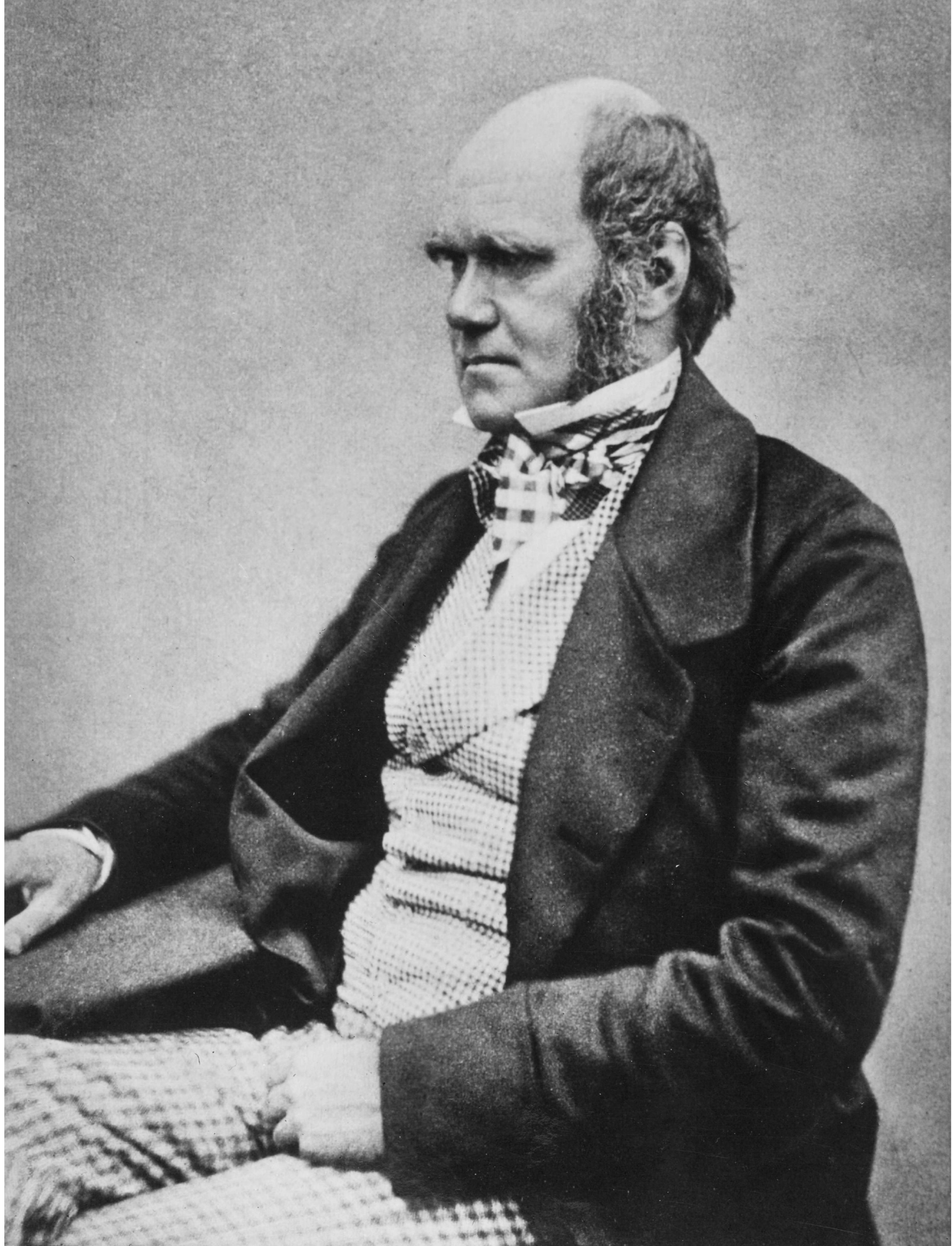

NISSAN
Fixed in 8 months


SONY

“San Francisco”
“Portland”
“Vancouver”
.56g
.6g
.4g
.9g
.1g
SOUTH PACIFIC OCEAN
ARGENTINA
SANTIAGO
Huasco
Coquimbo
Temuco
Puerto Montt
Nevado Ojos del Salado
Isla San Félix
Isla San Ambrosio
ARCHIPIÉLAGO JUAN FERNÁNDEZ

FEBRUARY 20TH.—The day has been memorable in the annals of Valdivia, for the most severe earthquake experienced by the oldest inhabitant. I happened to be on shore, and was lying down in the wood to rest myself. It came on suddenly, and lasted two minutes; but the time appeared much longer.

22D.—We sailed from Valdivia, and on the 4th of March, entered the harbour of Concepcion. ... The mayor-domo of the estate quickly rode down to tell us the terrible news of the great earthquake of the 20th;—"that not a house in Concepcion, or Talcuhano, (the port) was standing; that seventy villages were destroyed; and that a great wave had almost washed away the ruins of Talcuhano." Of this latter fact I soon saw abundant proof; the whole coast being strewed over with timber and furniture, as if a thousand great ships had been wrecked. Besides chairs, tables, book-shelves, &c., in great numbers, there were several roofs of cottages, which had been drifted in an almost entire state.



Earthquake-safe buildings:
You will be able to get out

Figure 5-3 Transverse elevation of the case study building showing differential vertical displacements following the 2010 Maule earthquake (photo courtesy of Patricio Bonelli).

Figure 5-3 Transverse elevation of the case study building showing differential vertical displacements following the 2010 Maule earthquake (photo courtesy of Patricio Bonelli).

Figure 5-4 Overall damage sustained in the first-story transverse shear walls of the case study building (photo courtesy of Patricio Bonelli).

Figure 5-5 Cracking, spalling, crushing, and bar buckling in the transverse shear wall on Line 9 (photo courtesy of Patricio Bonelli).

Figure 5-6 Cracking, spalling, crushing, and bar buckling in the transverse shear wall on Line 5 (photo courtesy of Patricio Bonelli).

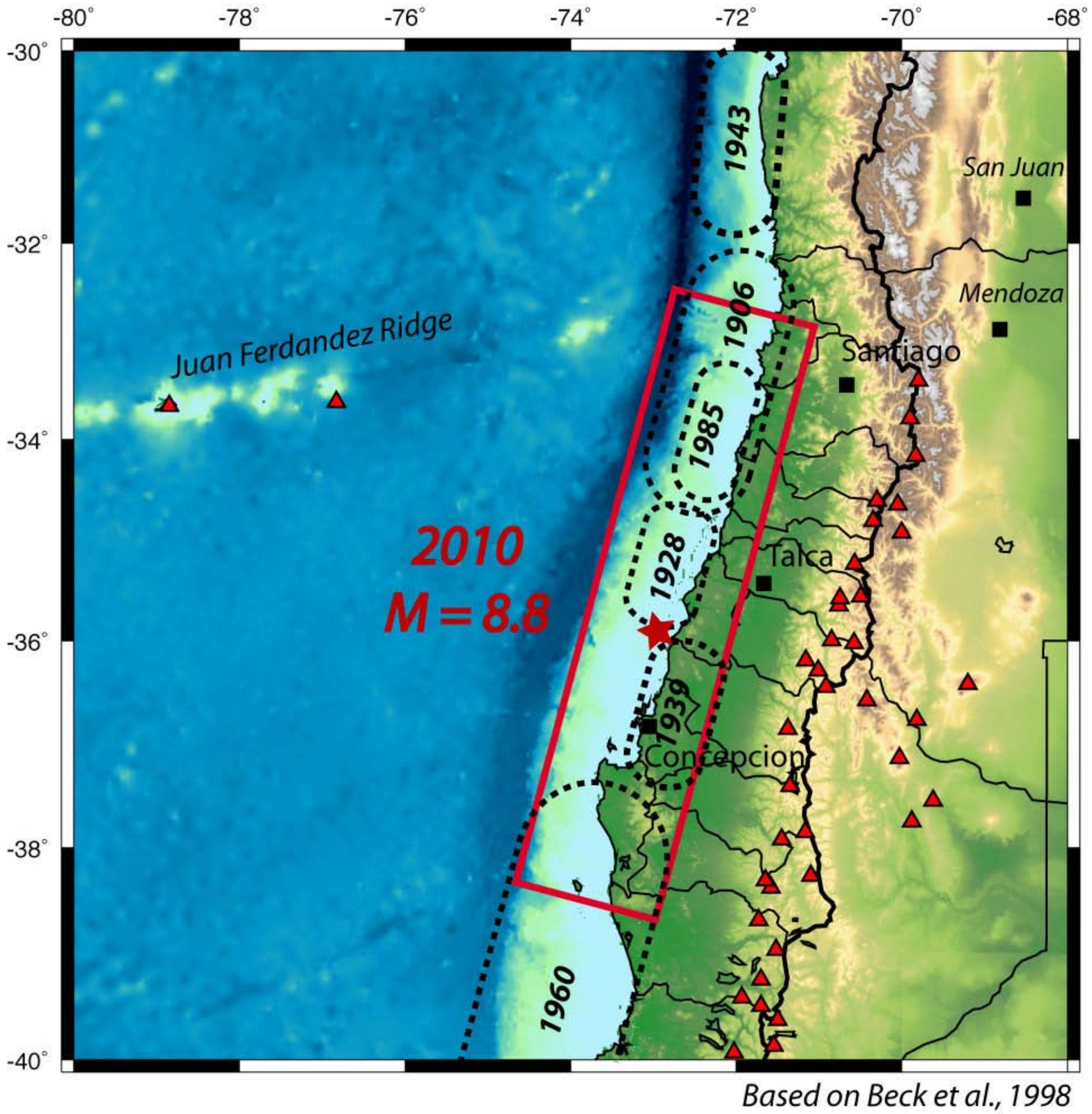
Figure 5-7 Crushing and bar buckling in the transverse shear wall on Line 1 resulting in significant differential vertical displacement (photo courtesy of Patricio Bonelli).


VENTA OFICINAS
Ministerio de Obras Públicas
GOBIERNO DE CHILE



Magnitude 8.8 OFFSHORE MAULE, CHILE

Saturday, February 27, 2010 at 06:34:17 UTC



Coastal Chile has a history of very large earthquakes. Since 1973, there have been 13 events of magnitude 7.0 or greater.

The February 27 shock originated about 230 km north of the source region of the magnitude 9.5 earthquake of May, 1960 – the largest earthquake worldwide in the last 200 years or more.

An outline of the approximate rupture from this Magnitude 8.8 earthquake and it's relationship to the largest earthquakes along the coast of Chile this century.

The 2010 Chile (Concepción) earthquake

- By GPS, Concepción moved 10 feet (~3m) west. Santiago, 24cm west, Buenos Aires, 4cm west.
- Shortened the day by 1.26 microseconds
- Moved the earth’s axis by ~8cm
- Seiches in Lake Pontchartrain, New Orleans.


CNN CNN CNN CNN CNN CNN
CNN
WSROOM
ROOM


CNN

The 2010 Chile (Concepción) earthquake

And Tsunami

- By GPS, Concepción moved 10 feet (~3m) west. Santiago, 24cm west, Buenos Aires, 4cm west.
- Shortened the day by 1.26 microseconds
- Moved the earth's axis by ~8cm
- Seiches in Lake Pontchartrain, New Orleans.

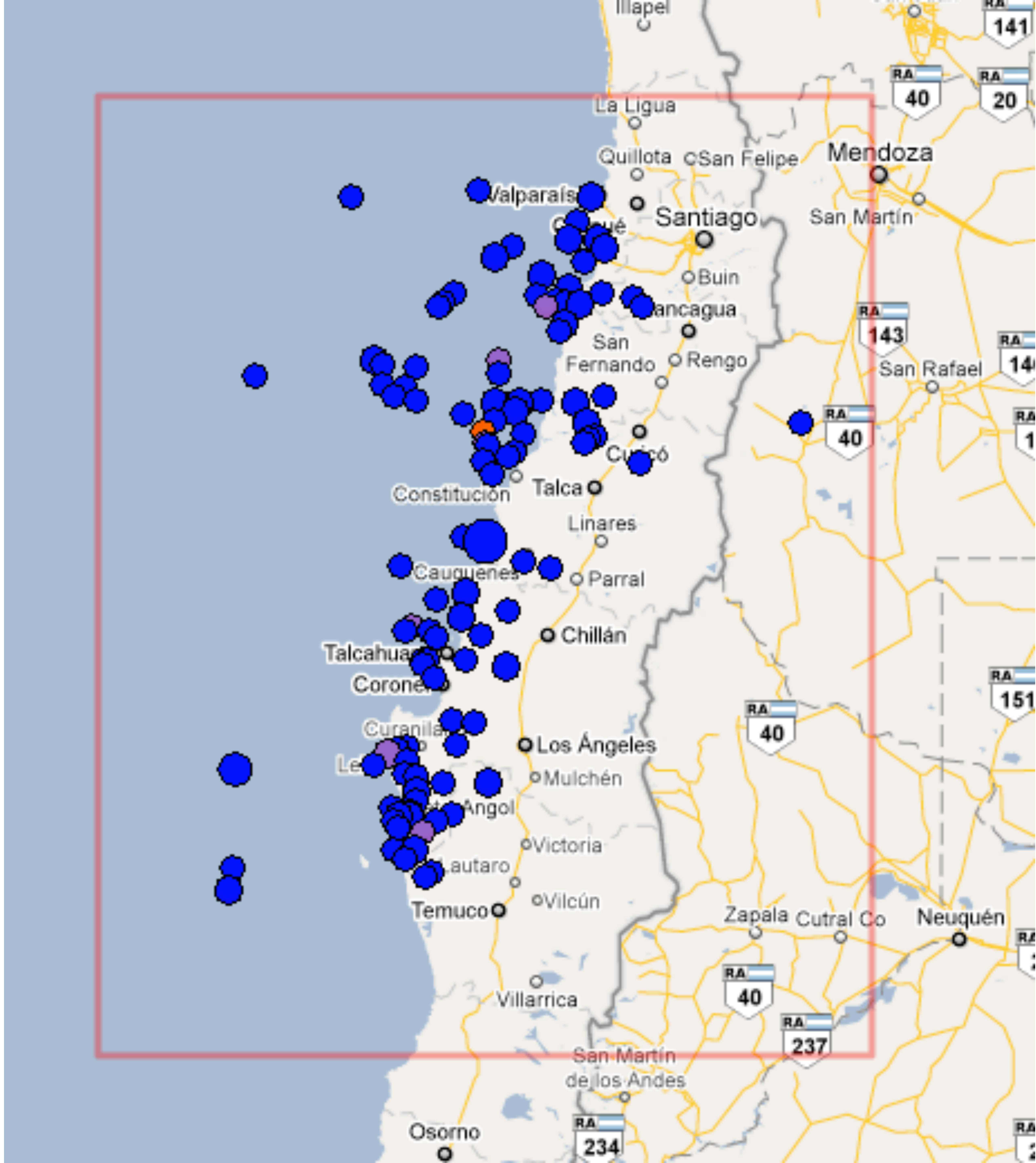

PARABRISAS


A research product from NOAA PMEL
Issued Feb 28, 2010 02:00 (local time)
Hilo, HI
Wailoa River
Tsunami WARNING
Flooding Forecast
Flooding: Feb 28, 2010
1130-1430 (local time)


A research product from NOAA PMEL
Issued Feb 28, 2010 02:00 (local time)
Hilo, HI
Wailoa River
Tsunami WARNING
Flooding Forecast
Flooding: Feb 28, 2010
1130-1430 (local time)

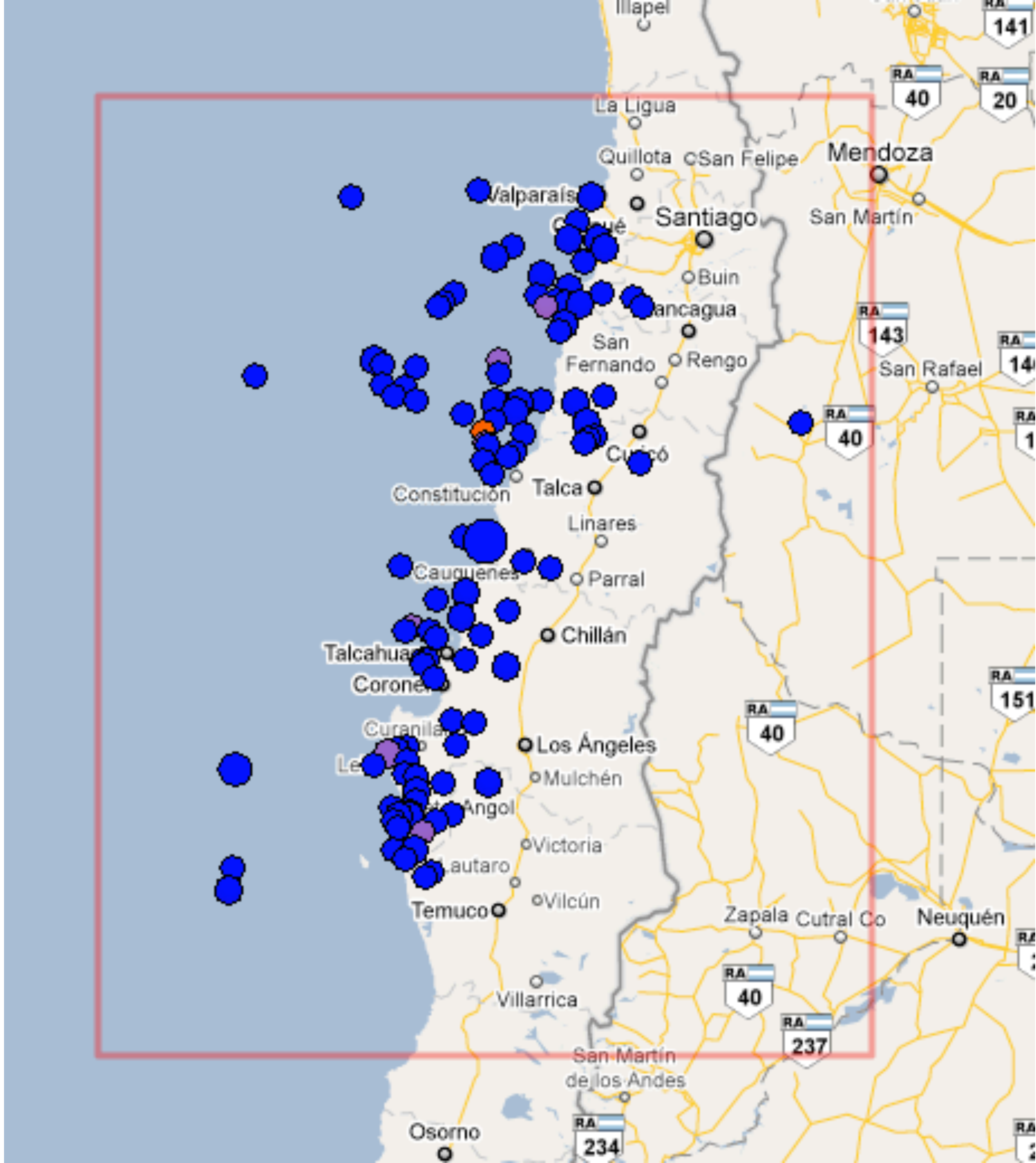
If the earthquake is strong enough that you can’t stand, Tsunami risk is high

Aftershocks



Aftershocks

- 130 by March 6th, 13 over 6.0 .
- 6.9 on March 11th
- 6.7 on March 15th
-



Aftershocks

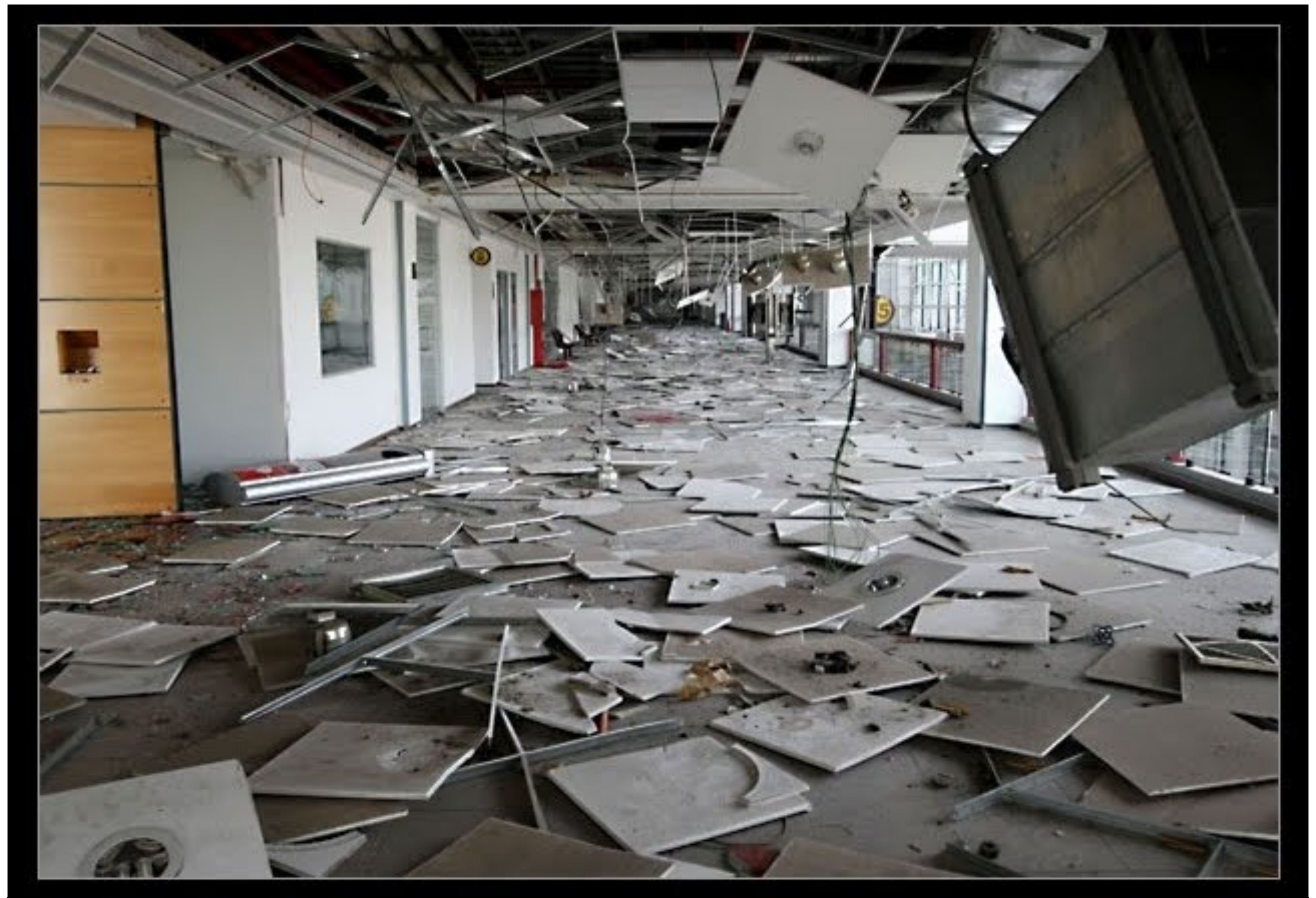
- 130 by March 6th, 13 over 6.0 .
- 6.9 on March 11th
- 6.7 on March 15th
- *That's an aftershock the size of Los Angeles' 1994 earthquake*

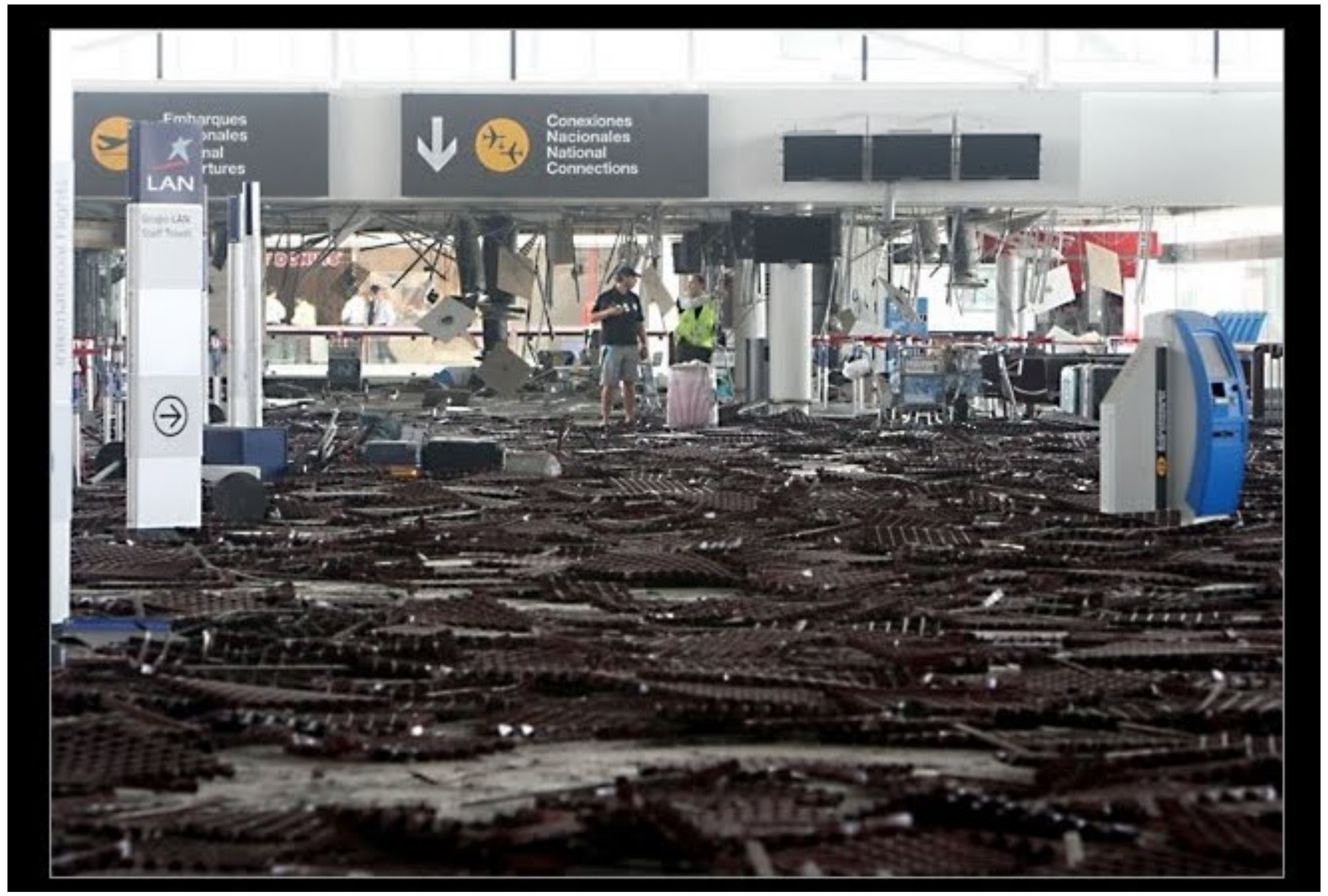

A QUAKE,
A QUAKE
WRITTEN BY
RANDY ROGEL
DIRECTED BY
AL ZEGLER


A QUAKE,
A QUAKE
WRITTEN BY
RANDY ROGEL
DIRECTED BY
AL ZEGLER

Airport

- No damage on runways or control tower



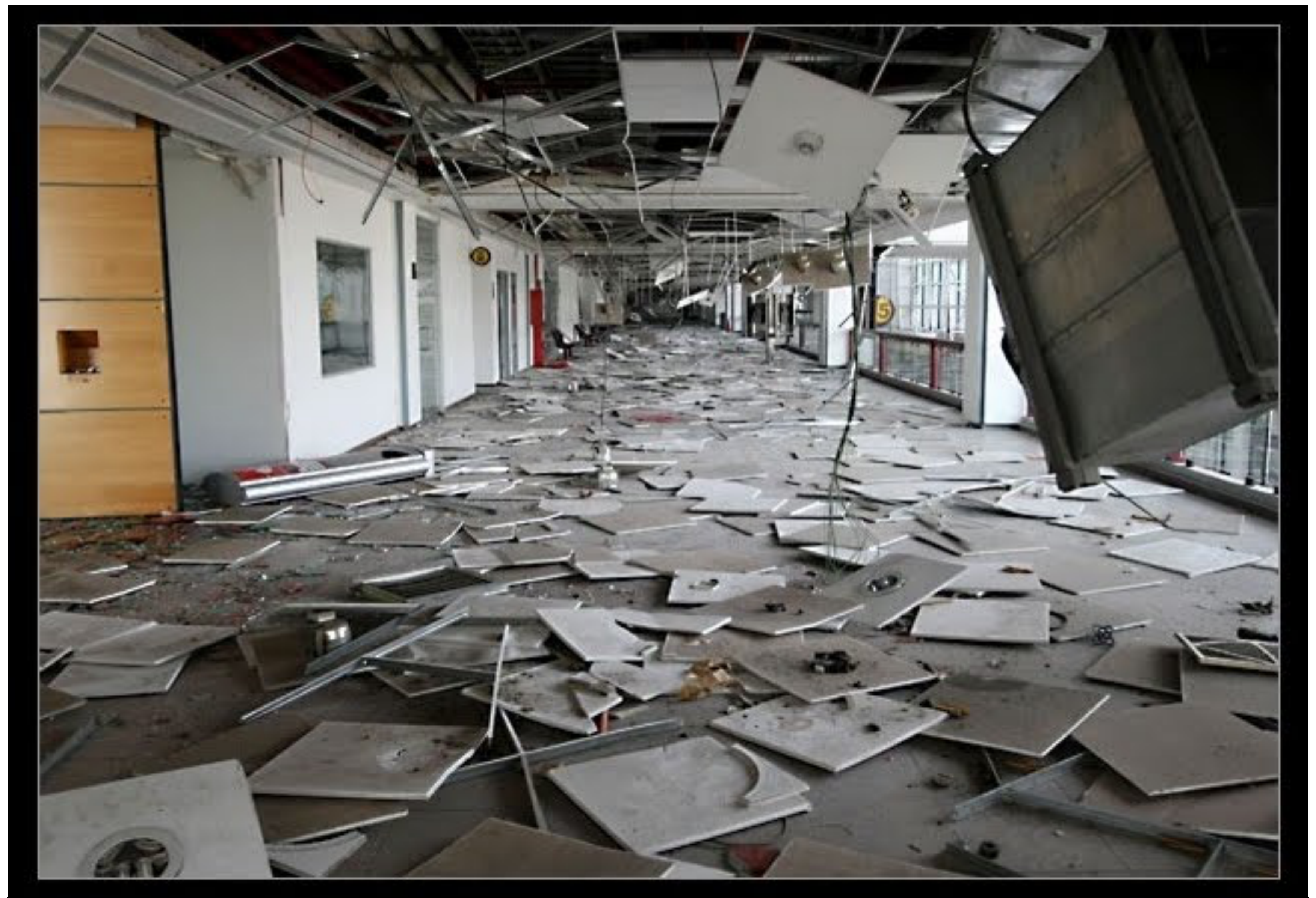


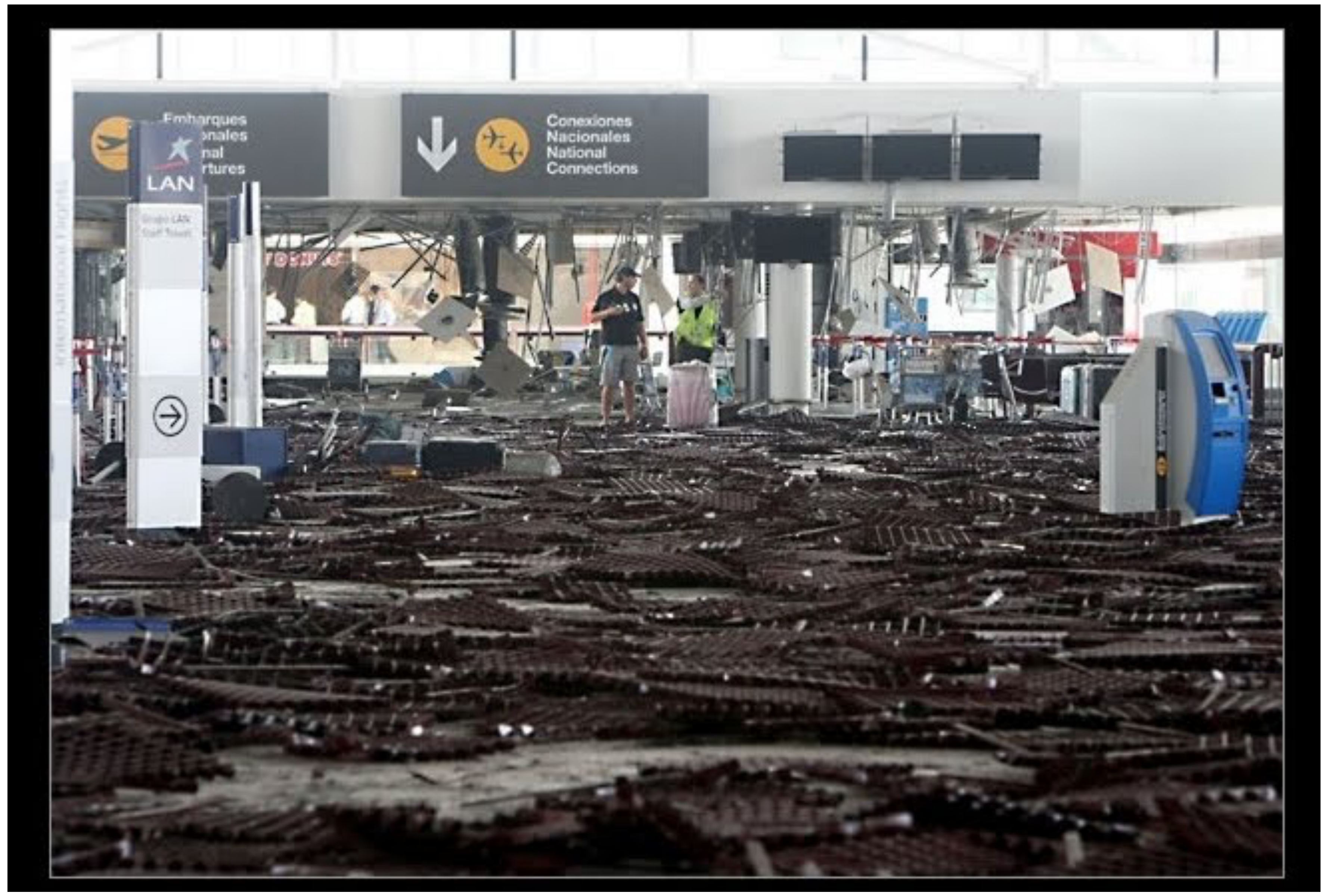
Graves daños en el aeropuerto

Fotos: Hector Aravena, El Mercurio | Publicado el 27/02/2010

Airport

- No damage on runways or control tower
- Time to commercial flight reopening:
  3 days (March 1st)





Graves daños en el aeropuerto

Fotos: Hector Aravena, El Mercurio | Publicado el 27/02/2010

The university term back in Santiago

Delayed by …

The university term back in Santiago

Delayed by **3 weeks.**

BRITISH COLUMBIA | PreparedBC

BASIC EMERGENCY KIT SUPPLIES

gov.bc.ca/PreparedBC

- First aid kit, prescriptions and other personal items
- Battery-powered or hand-crank radio
- Battery-powered or hand-crank flashlight
- Whistle
- Emergency plan, copies of important documents and cash
- Phone charger and battery bank
- Non-perishable food for at least three days
- Garbage bags, moist towelettes and plastic ties
- Blanket, seasonal clothing and footwear
- Water for at least three days; four litres per person per day


Pen &
notepad
Phone
charger &
battery
bank
Flashlight
Radio
First aid kit
Personal
toiletries
Seasonal
clothing
Food & water
Batteries
Whistle
Emergency
plan

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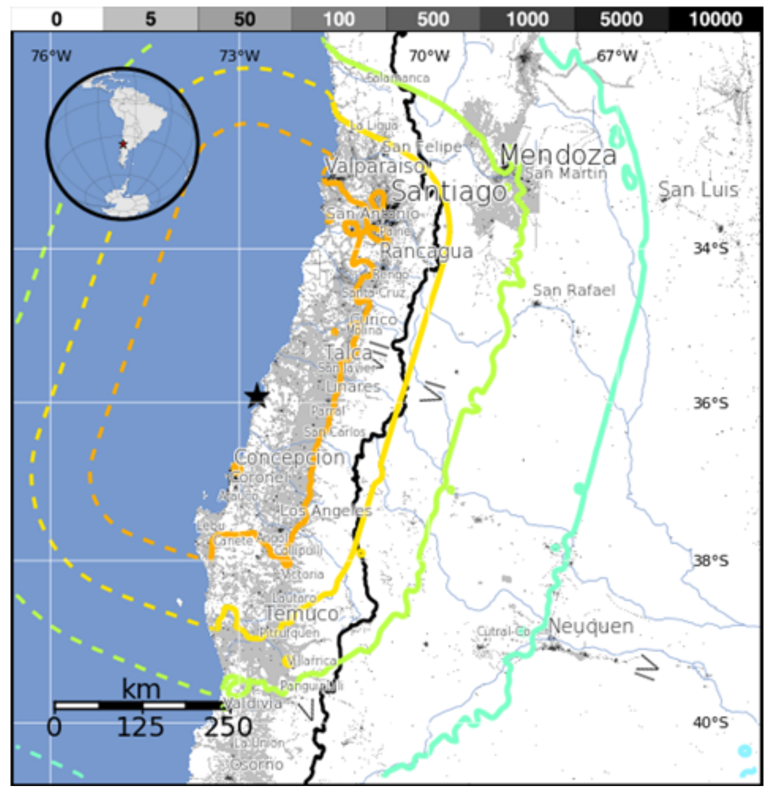
NIST GCR 12-917-18



Comparison of U.S. and Chilean Building Code Requirements and Seismic Design Practice 1985-2010

NEHRP Consultants Joint Venture

A partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering

nehrp

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

specified compressive strength f'_c = 4,000 psi.

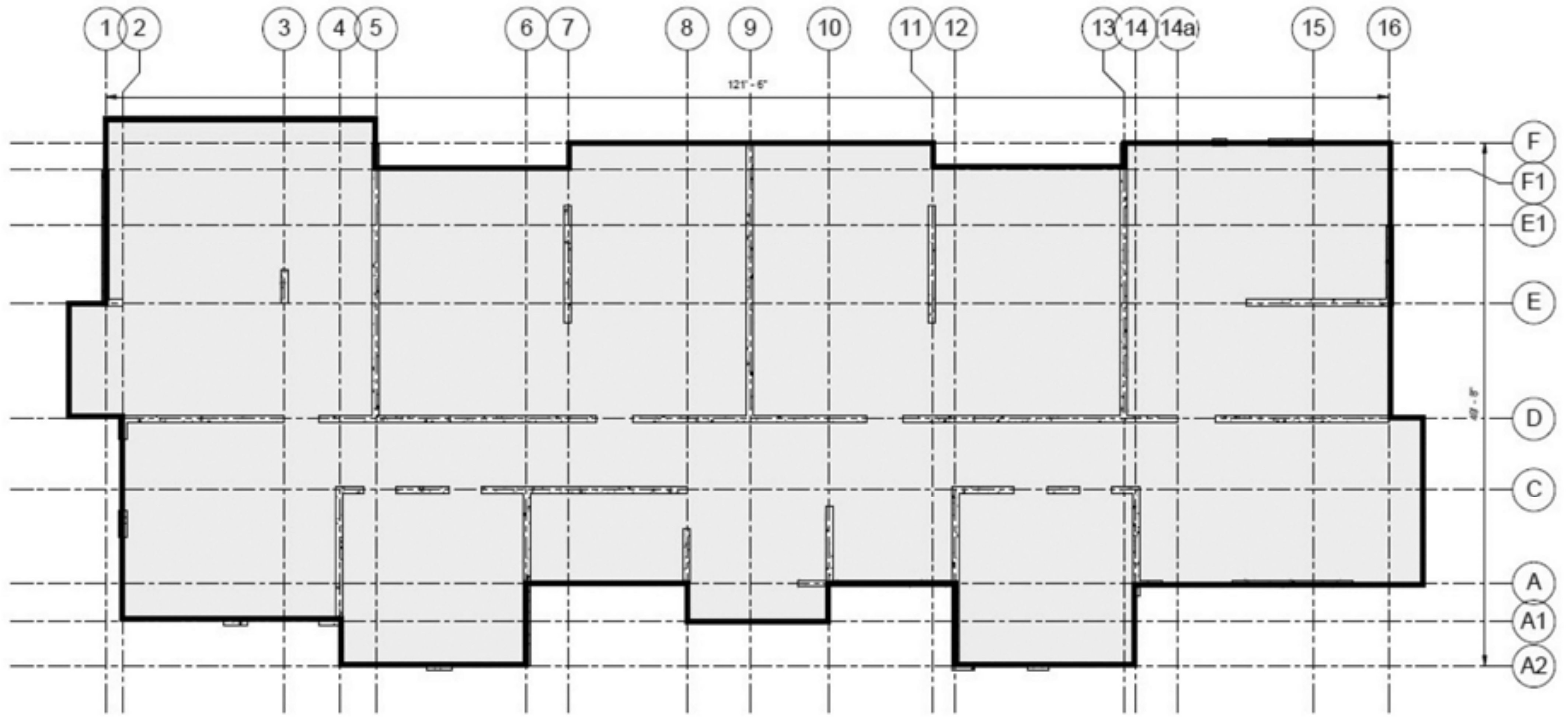


Figure 5-1 Typical floor plan, Chilean case study building.

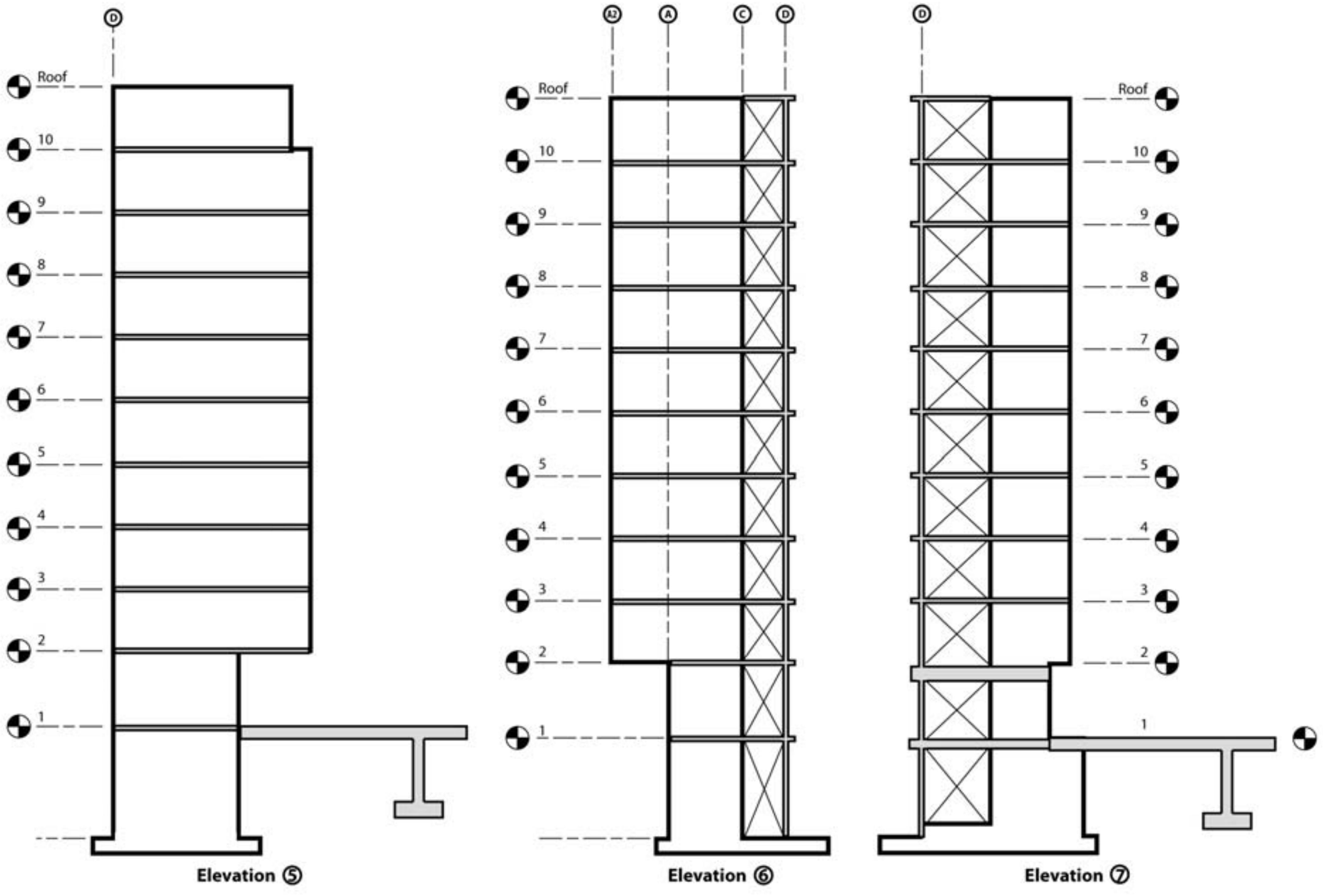


Figure 5-2 Transverse wall elevations, Chilean case study building.

Figure 5-3 Transverse elevation of the case study building showing differential vertical displacements following the 2010 Maule earthquake (photo courtesy of Patricio Bonelli).

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Figure 5-7 Crushing and bar buckling in the transverse shear wall on Line 1 resulting in significant differential vertical displacement (photo courtesy of Patricio Bonelli).

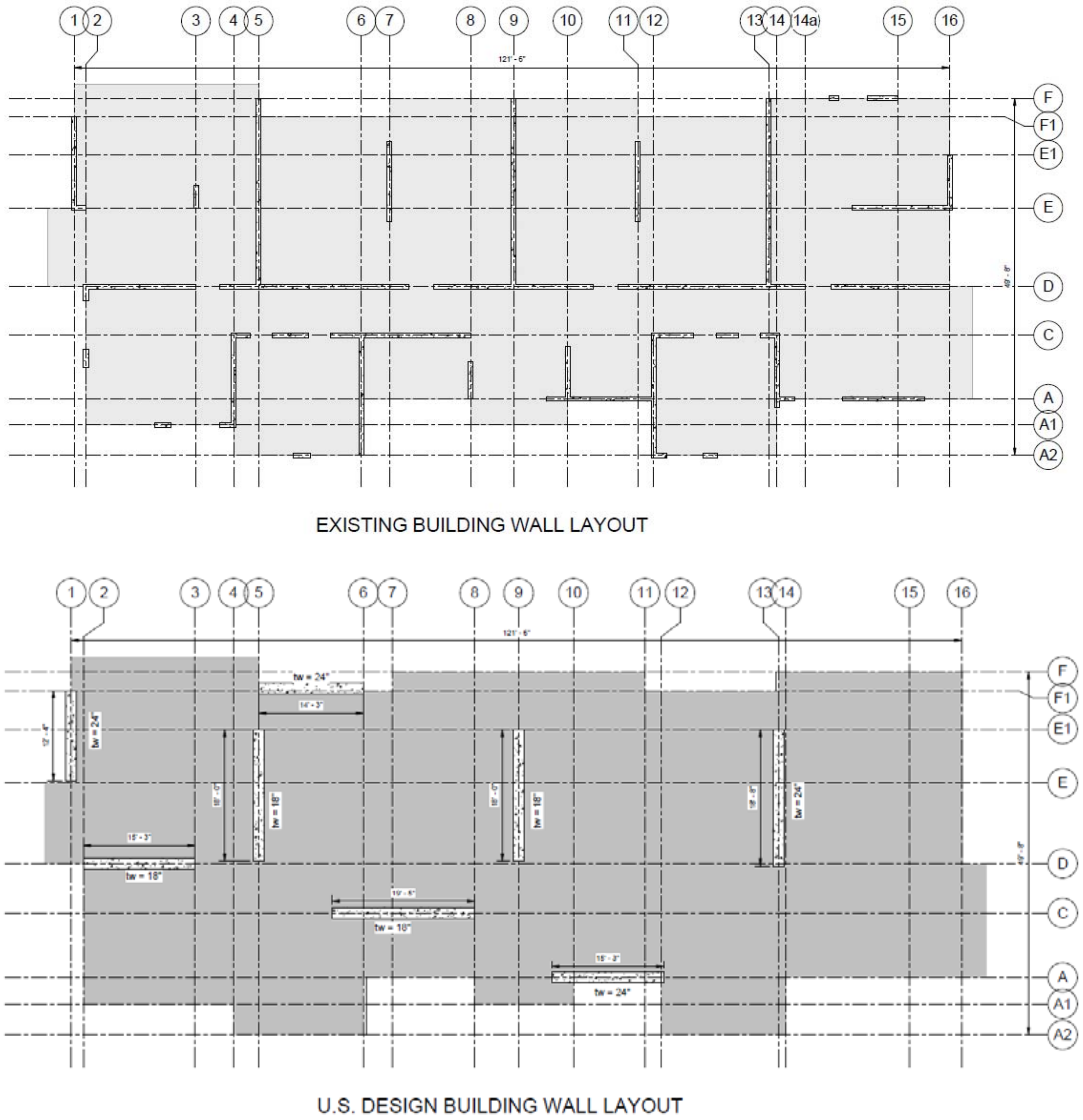


Figure 5-24 Comparison of U.S. configuration with Chilean shear wall layout.

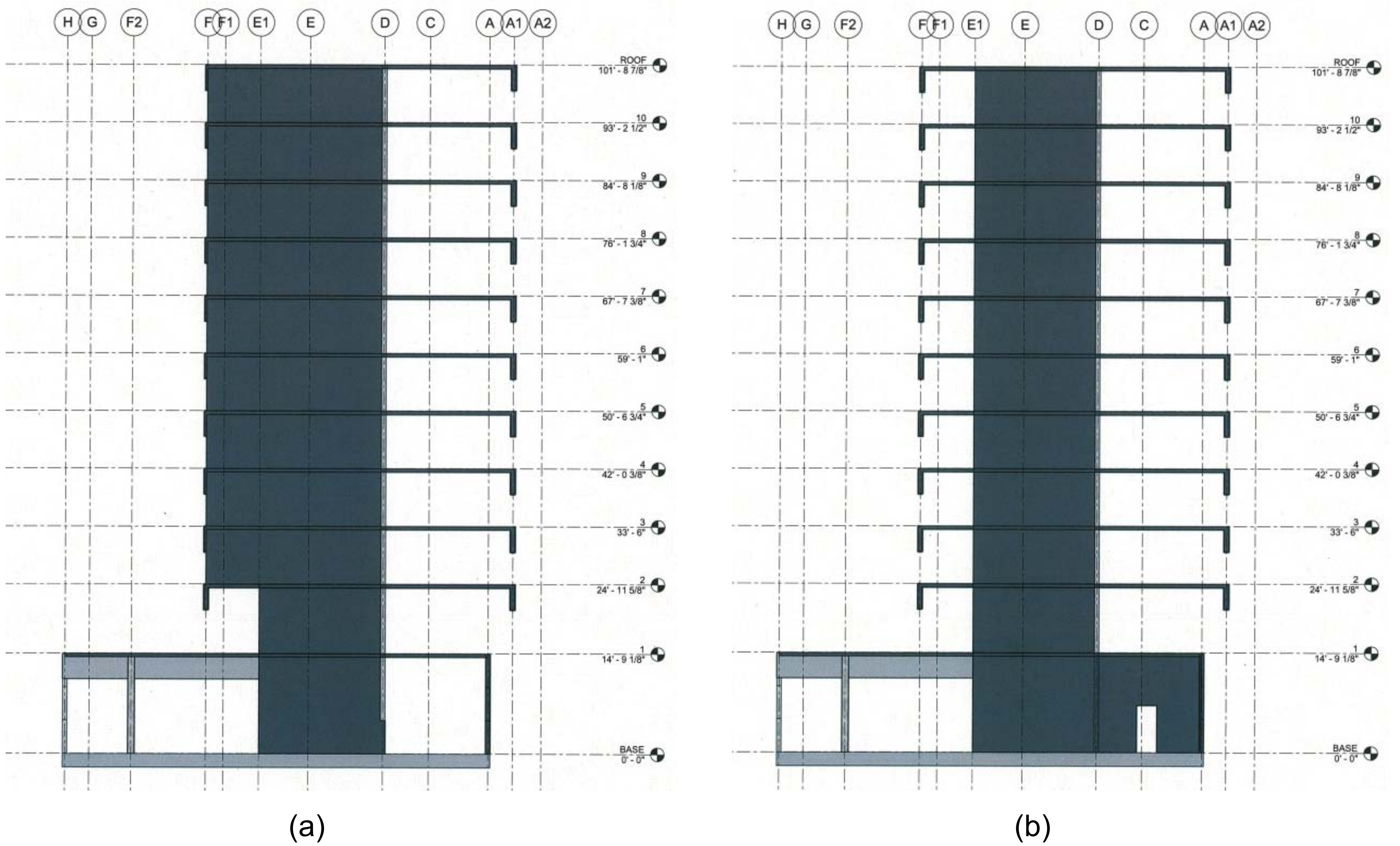


Figure 5-25 Comparison of typical transverse wall elevations: (a) Chilean configuration; and (b) U.S. configuration.

5.5 Observations and Conclusions on U.S. and Chilean Seismic Design Practice

Differences in U.S. and Chilean seismic design practice are the result of evolution in construction techniques, differences in labor costs as a portion of total construction costs, and differences in the roles that structural engineers play in the building design process. Traditional Chilean practice is to configure buildings with relatively short floor spans and many load-bearing walls providing gravity and seismic force resistance. As a result, typical Chilean buildings have highly redundant configurations. This practice likely contributed to the ability of many buildings to withstand severe damage without collapse. As a consequence of this redundancy, and past experience with typical building configurations, requirements for ductile detailing in Chile are relaxed relative to U.S. requirements.

In contrast, U.S. practice is to configure buildings with longer spans and fewer structural walls. As a result, walls are thicker, allowing for easier placement of confinement reinforcing, and increased ductility capacity. As a consequence, U.S. designs have comparatively less redundancy than Chilean designs.

The Chilean case study building experienced severe damage and differential vertical displacement in the transverse shear walls as a result of the 2010 Maule earthquake. Cracking and spalling were attributed to the “flag-shaped” configuration of the shear walls, and crushing and bar buckling were attributed to a lack of confinement reinforcing in the form of closed hoops and cross ties in the shear wall boundary zones. In spite of this damage, the building did not collapse.

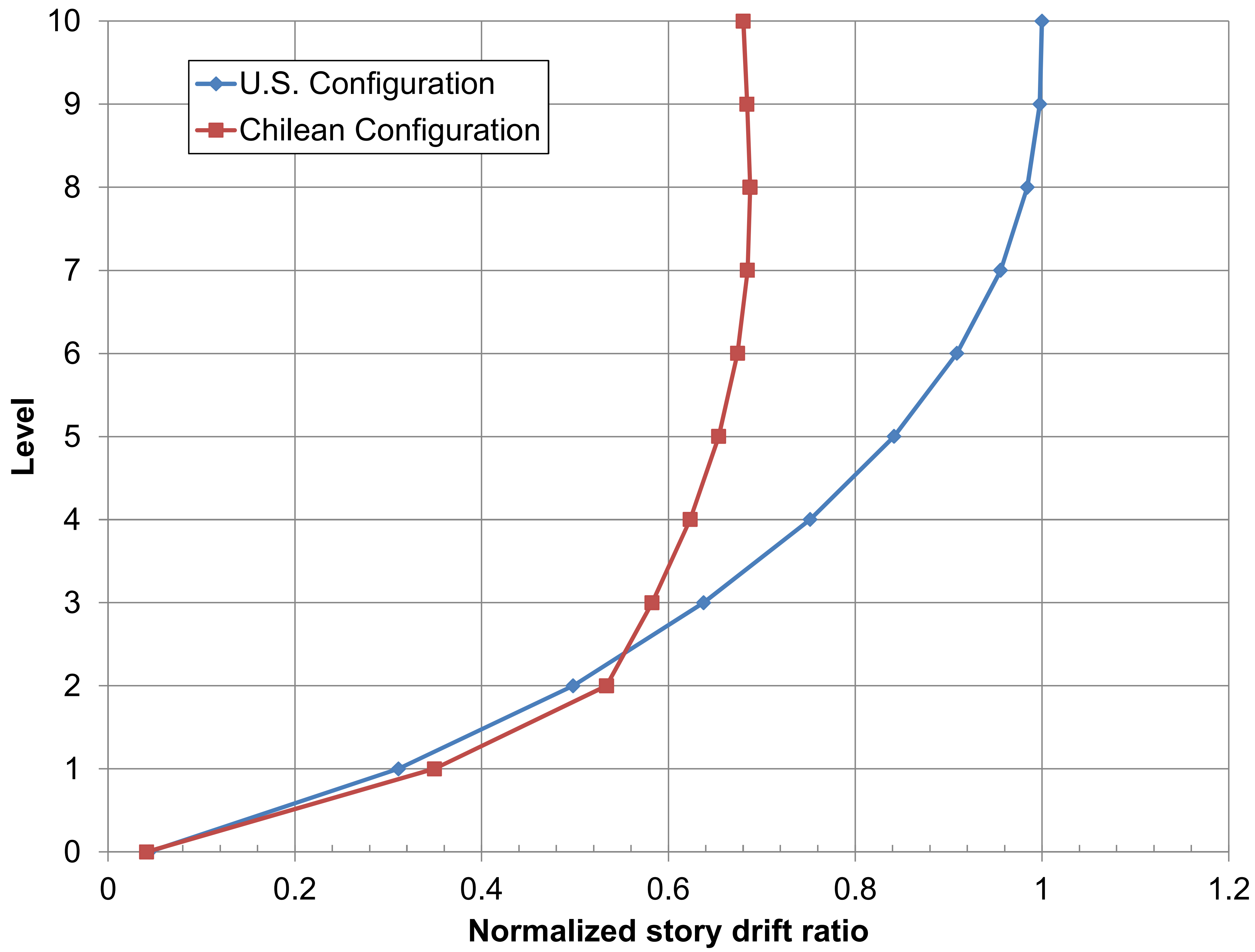
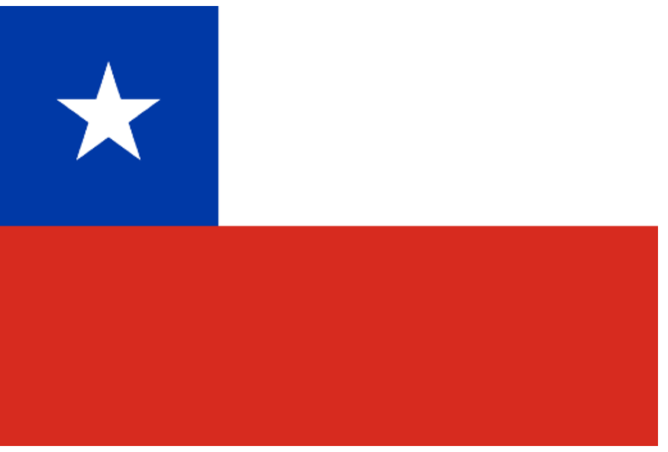


Figure 5-28 Comparison of normalized story drift ratios for the U.S. configuration and the Chilean configuration, in the transverse direction at the center of mass.

In all cases, an accidental torsional eccentricity of 5% has been included.



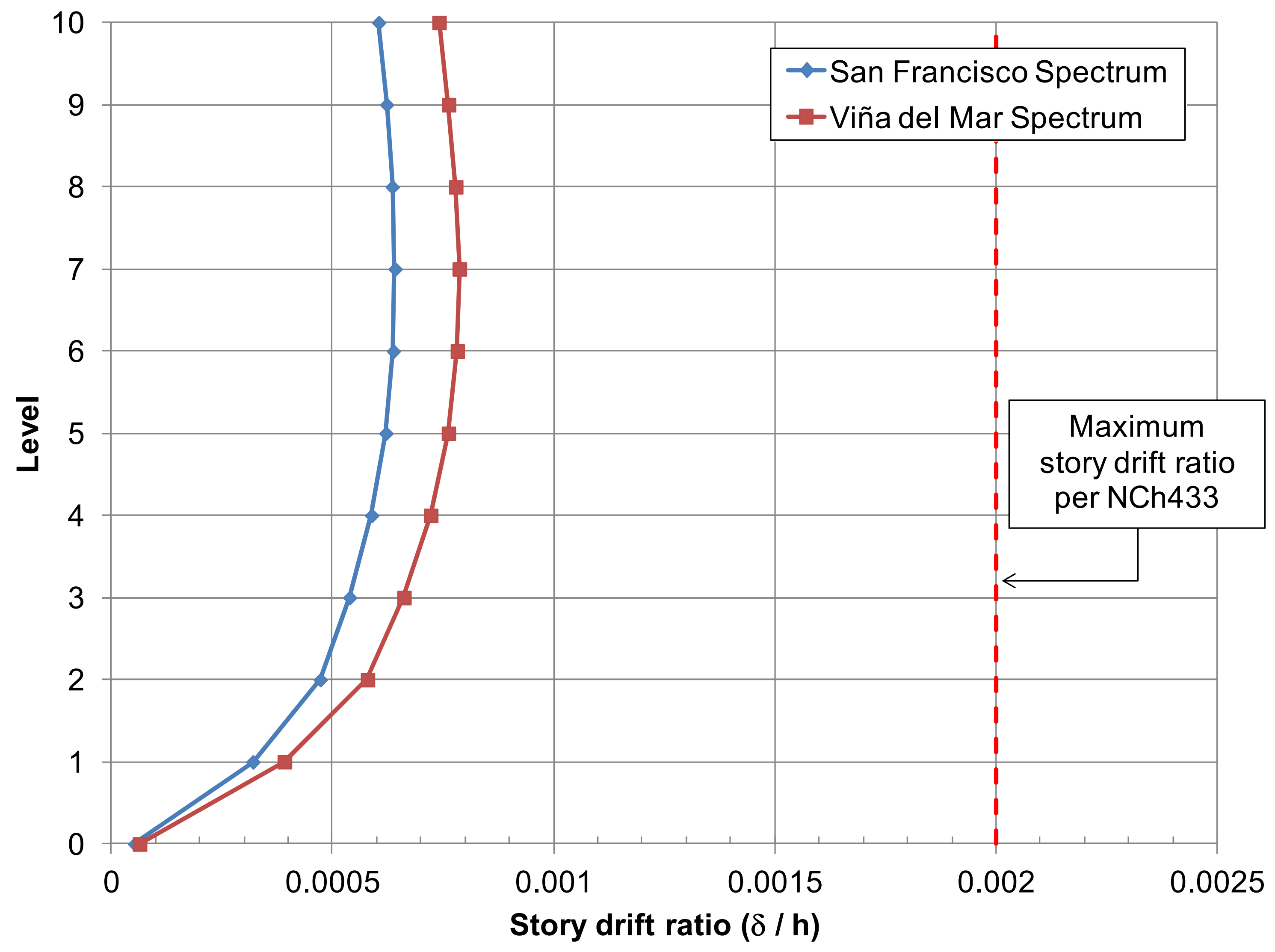


Figure 5-12 Maximum story drift ratios in the longitudinal direction at the center of mass, calculated per NCh433.Of96.

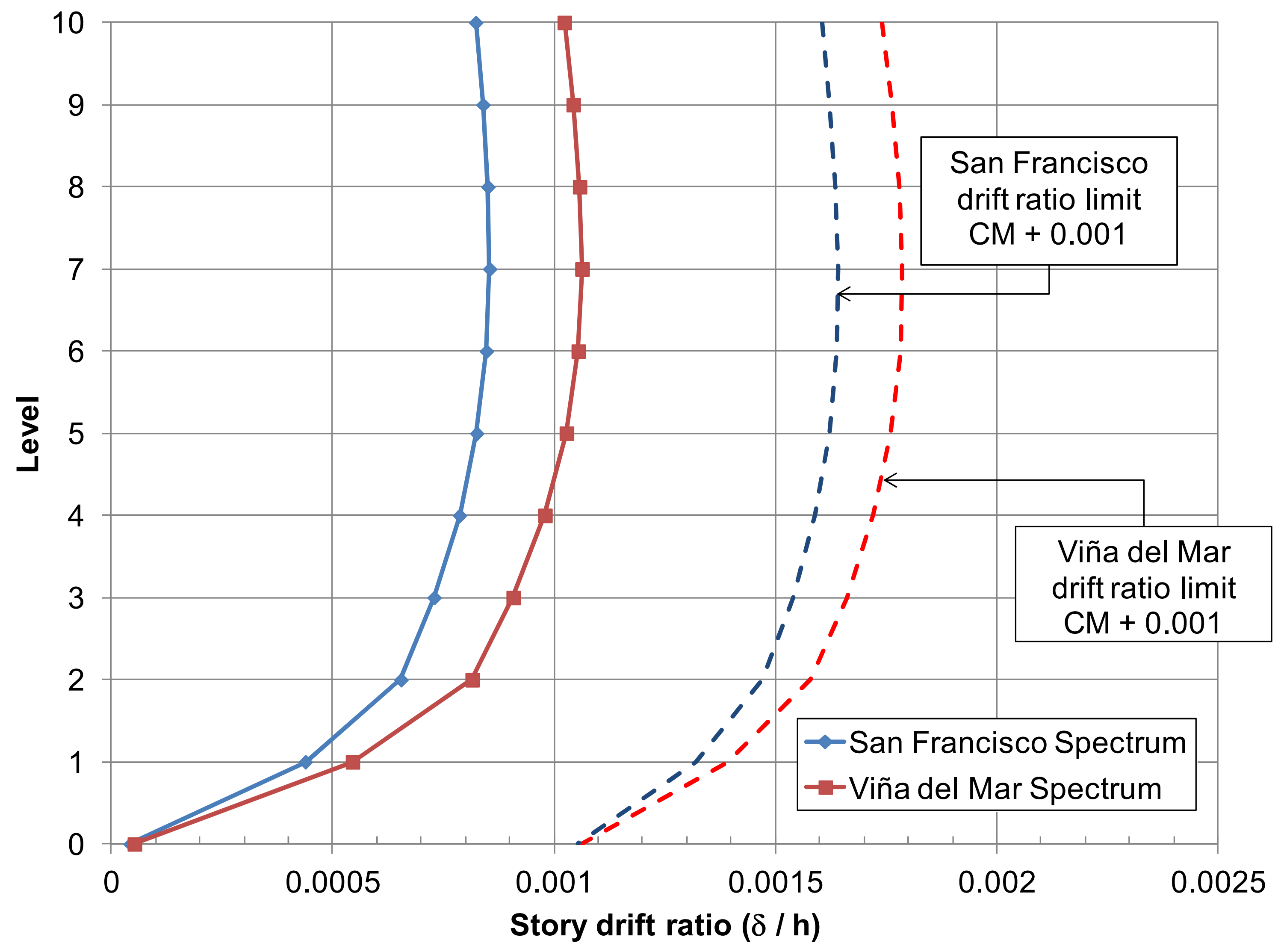


Figure 5-13 Maximum story drift ratios in the longitudinal direction at an extreme corner, calculated per NCh433.Of96.

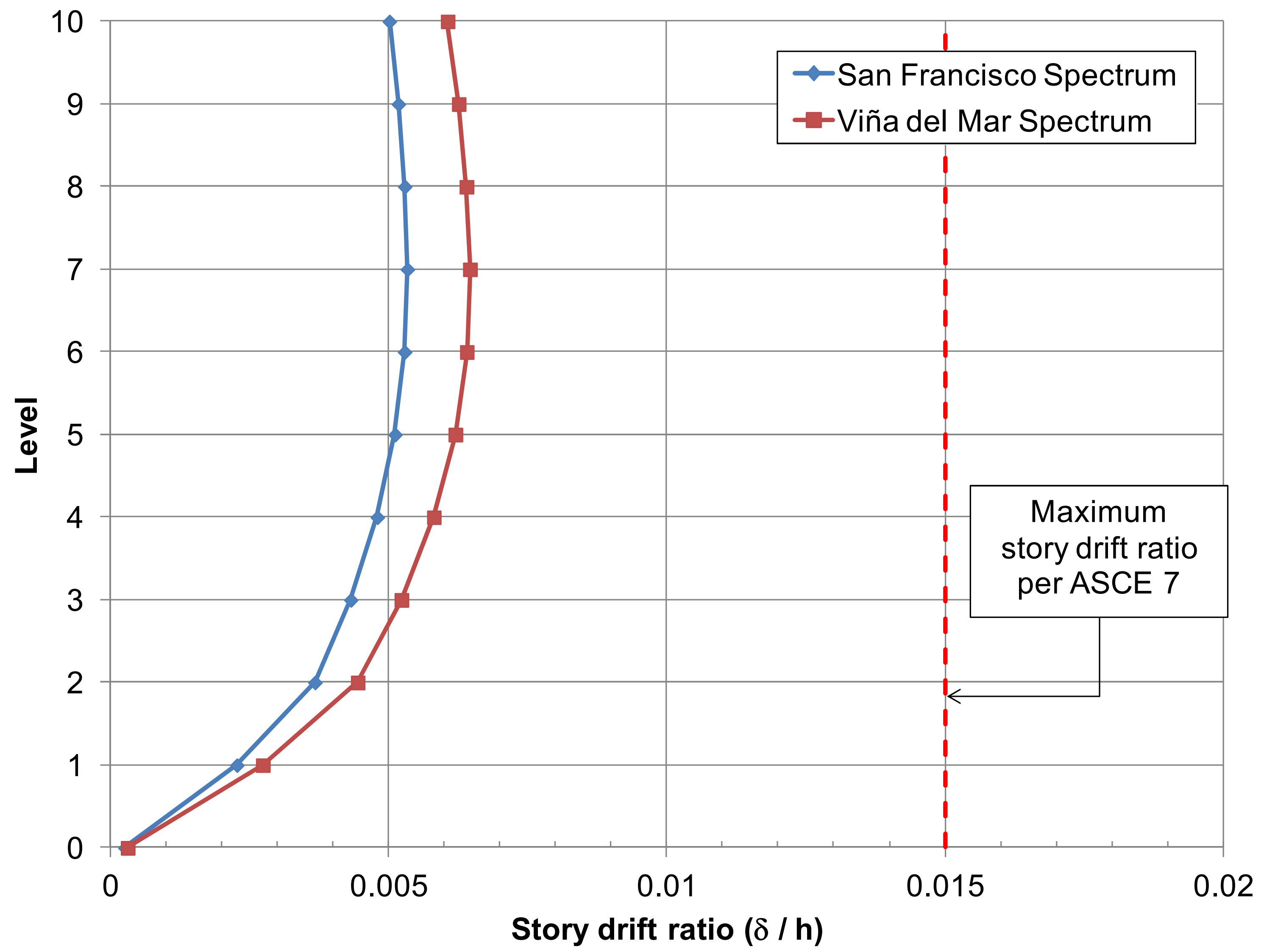


Figure 5-16 Maximum story drift ratios in the longitudinal direction at the center of mass, calculated per ASCE/SEI 7-05.

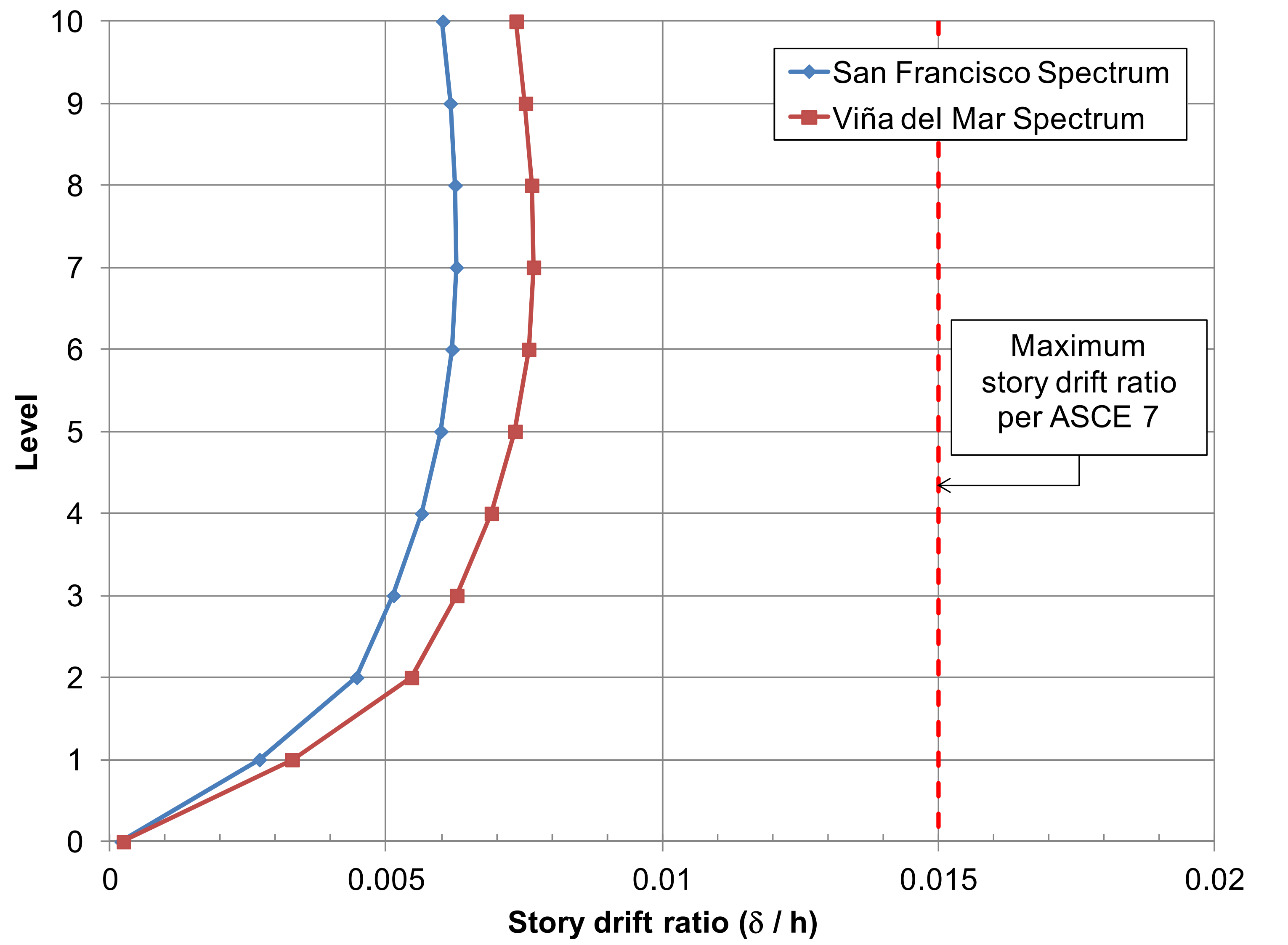
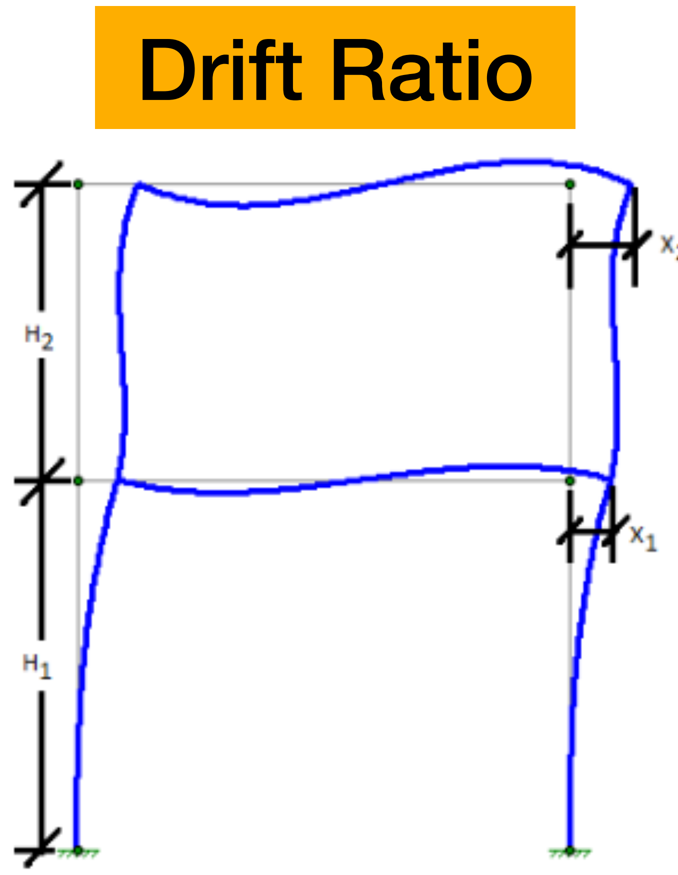


Figure 5-17 Maximum story drift ratios in the longitudinal direction at an extreme corner, calculated per ASCE/SEI 7-05.



In all cases, an accidental torsional eccentricity of 5% has been included.

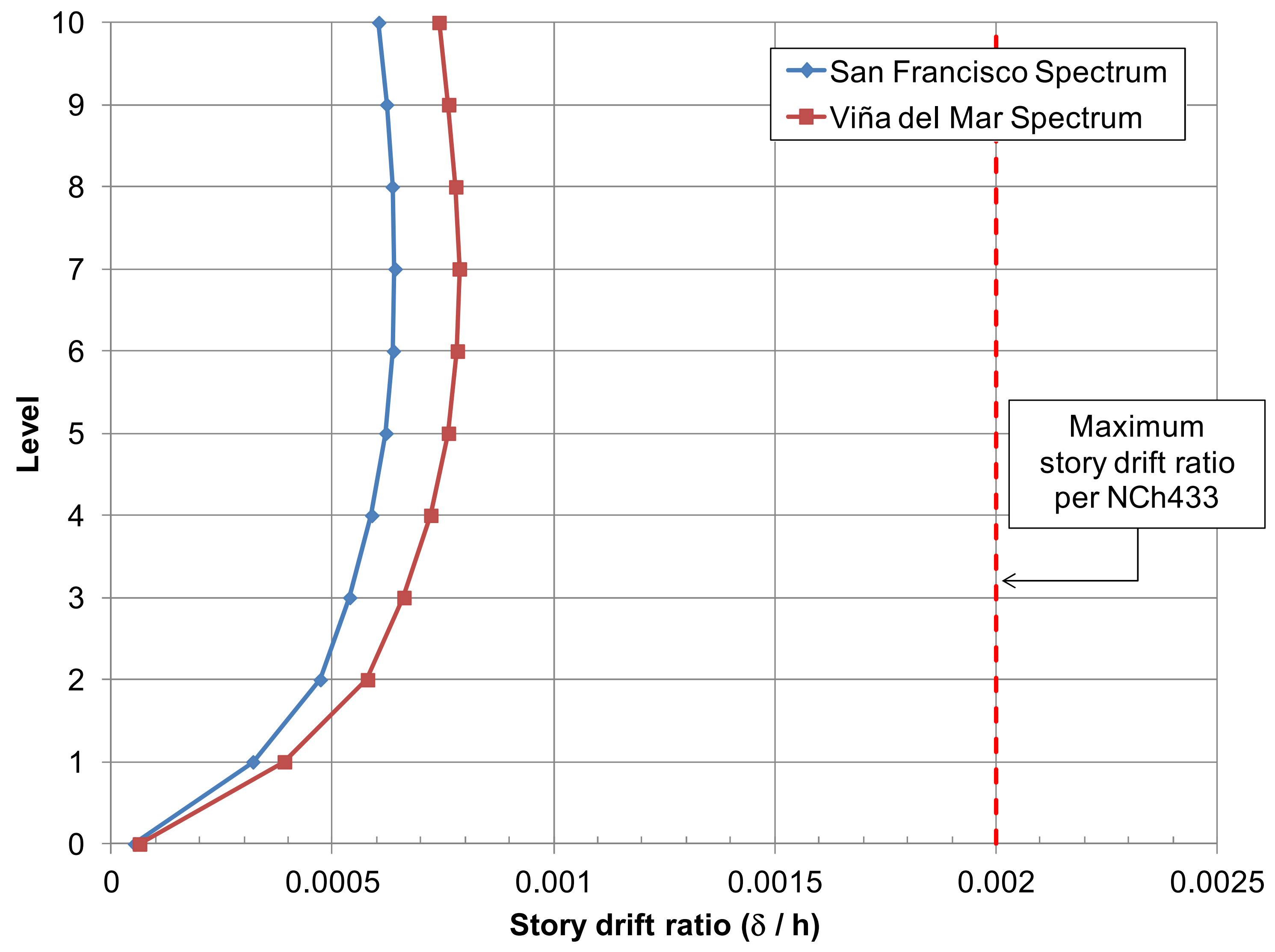


Figure 5-12 Maximum story drift ratios in the longitudinal direction at the center of mass, calculated per NCh433.Of96.

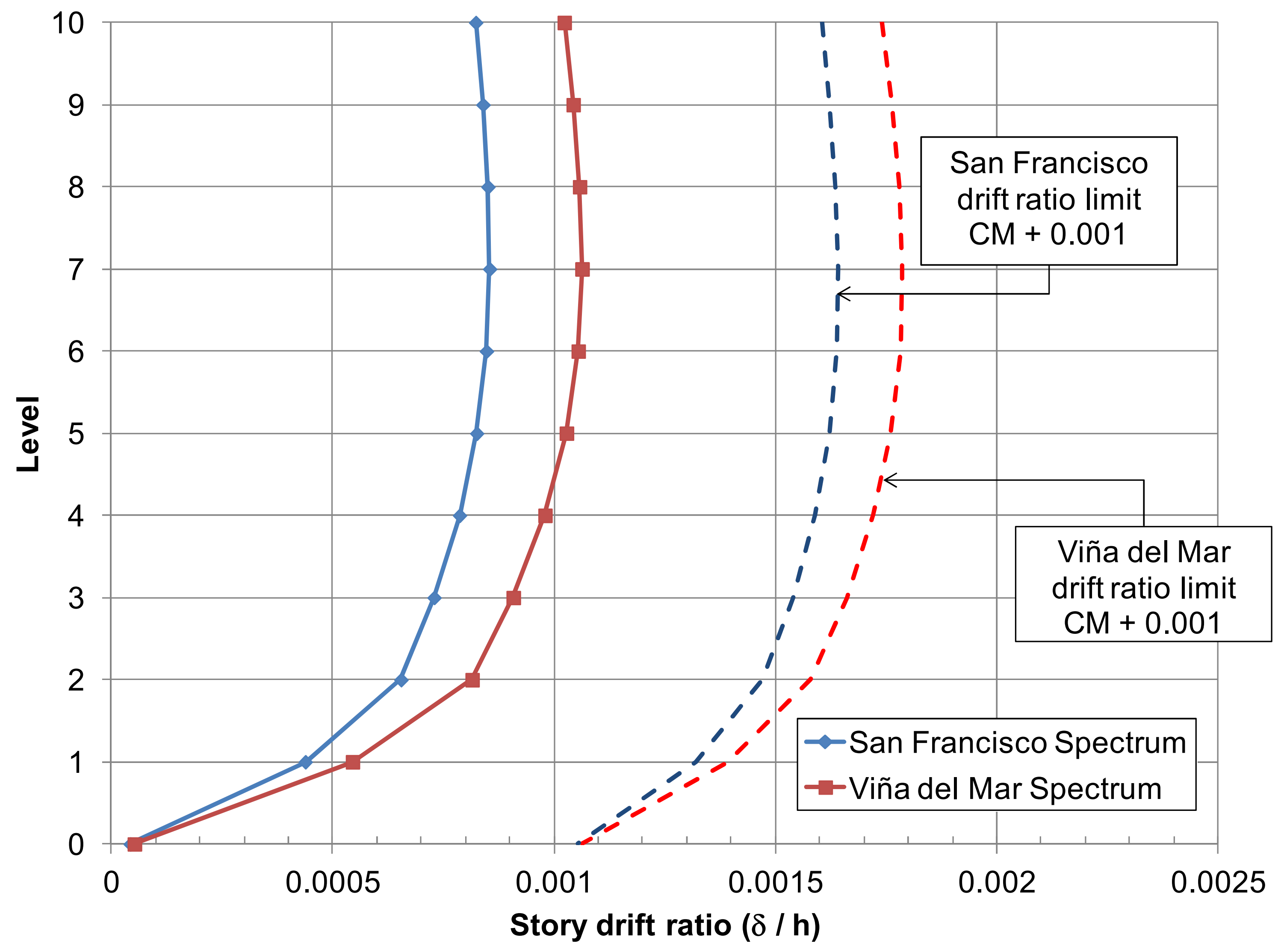


Figure 5-13 Maximum story drift ratios in the longitudinal direction at an extreme corner, calculated per NCh433.Of96.

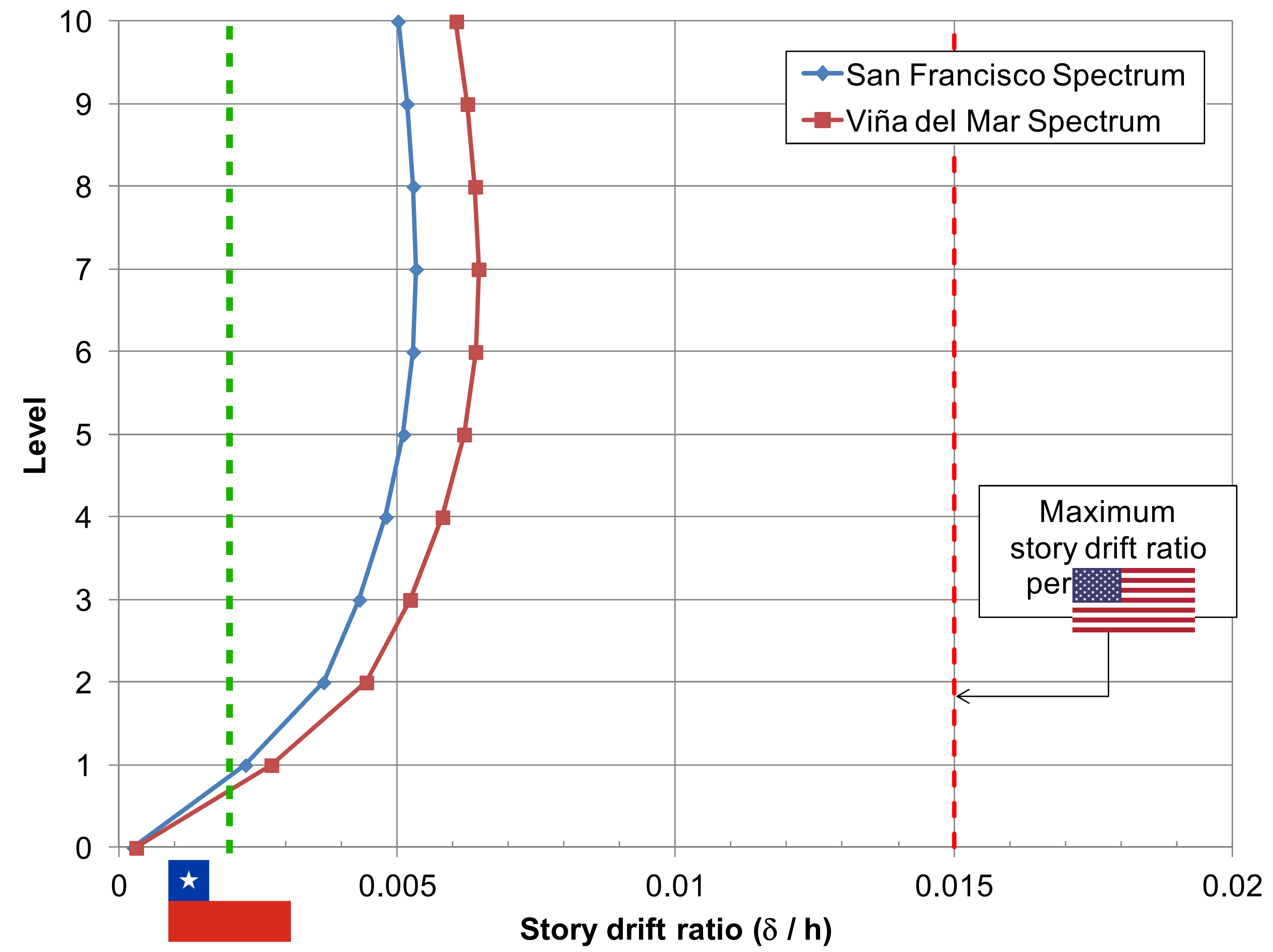


Figure 5-16 Maximum story drift ratios in the longitudinal direction at the center of mass, calculated per ASCE/SEI 7-05.

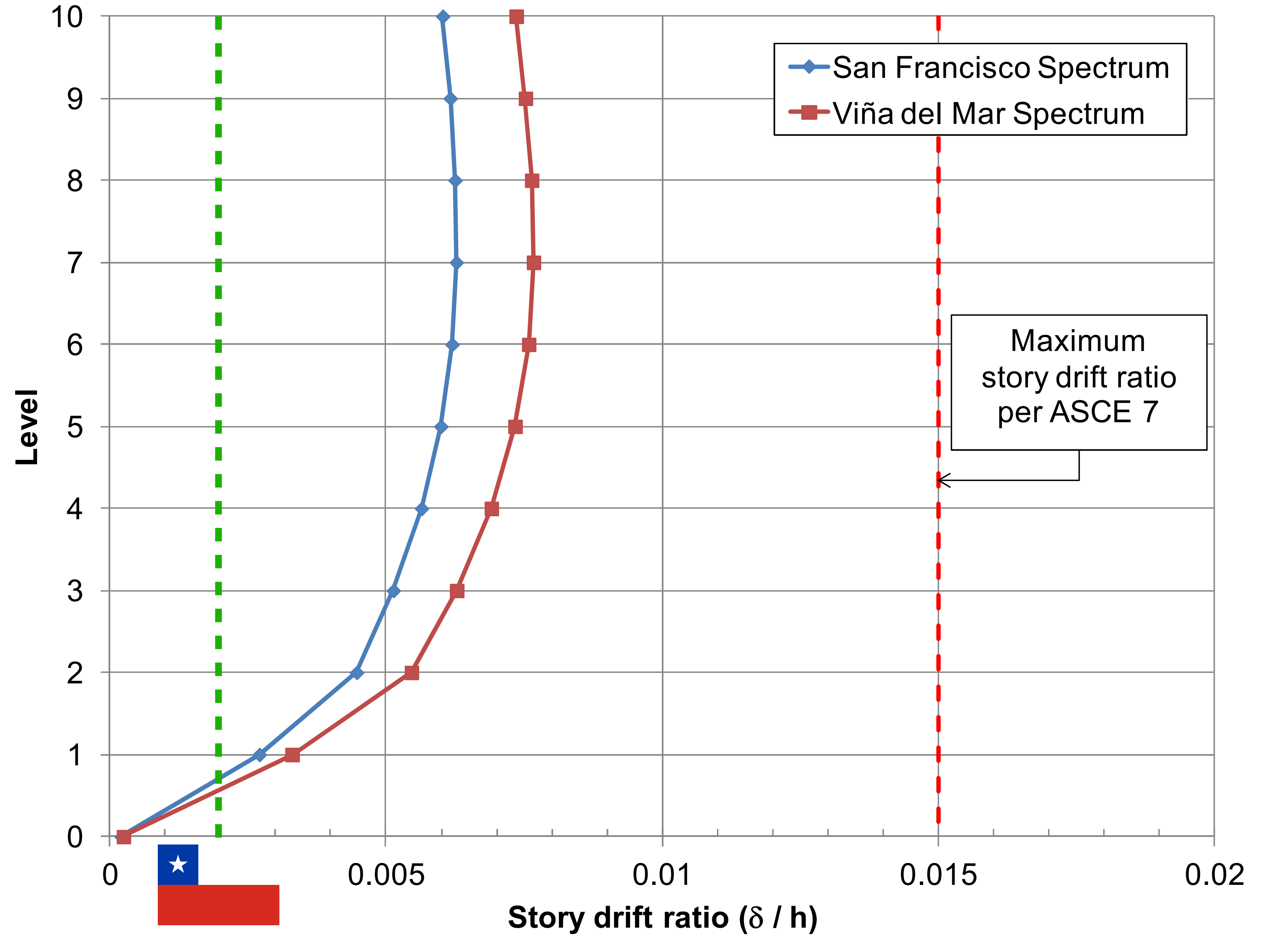


Figure 5-17 Maximum story drift ratios in the longitudinal direction at an extreme corner, calculated per ASCE/SEI 7-05.

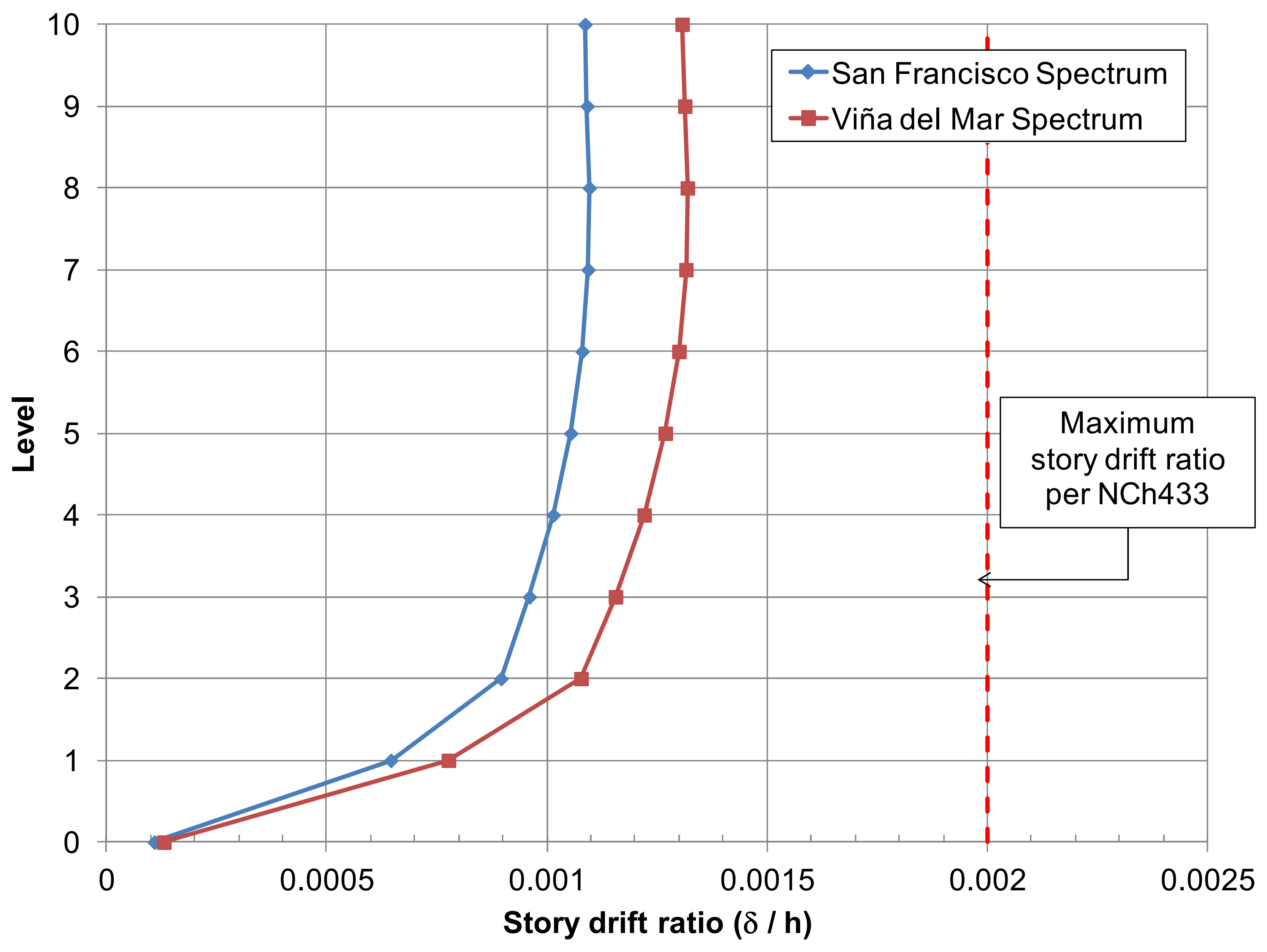


Figure 5-14 Maximum story drift ratios in the transverse direction at the center of mass, calculated per NCh433.Of96.

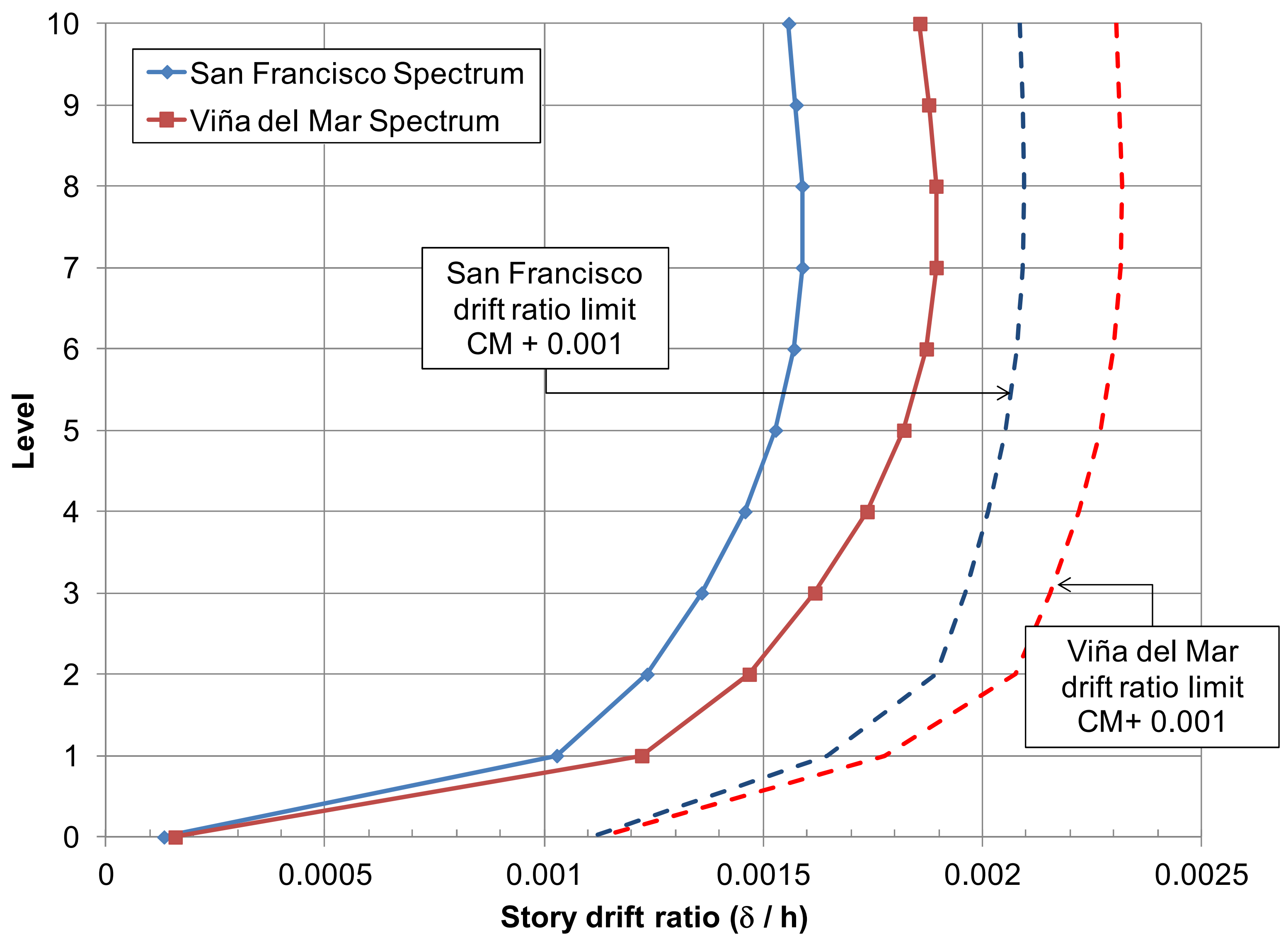


Figure 5-15 Maximum story drift ratios in the transverse direction at an extreme corner, calculated per NCh433.Of96.

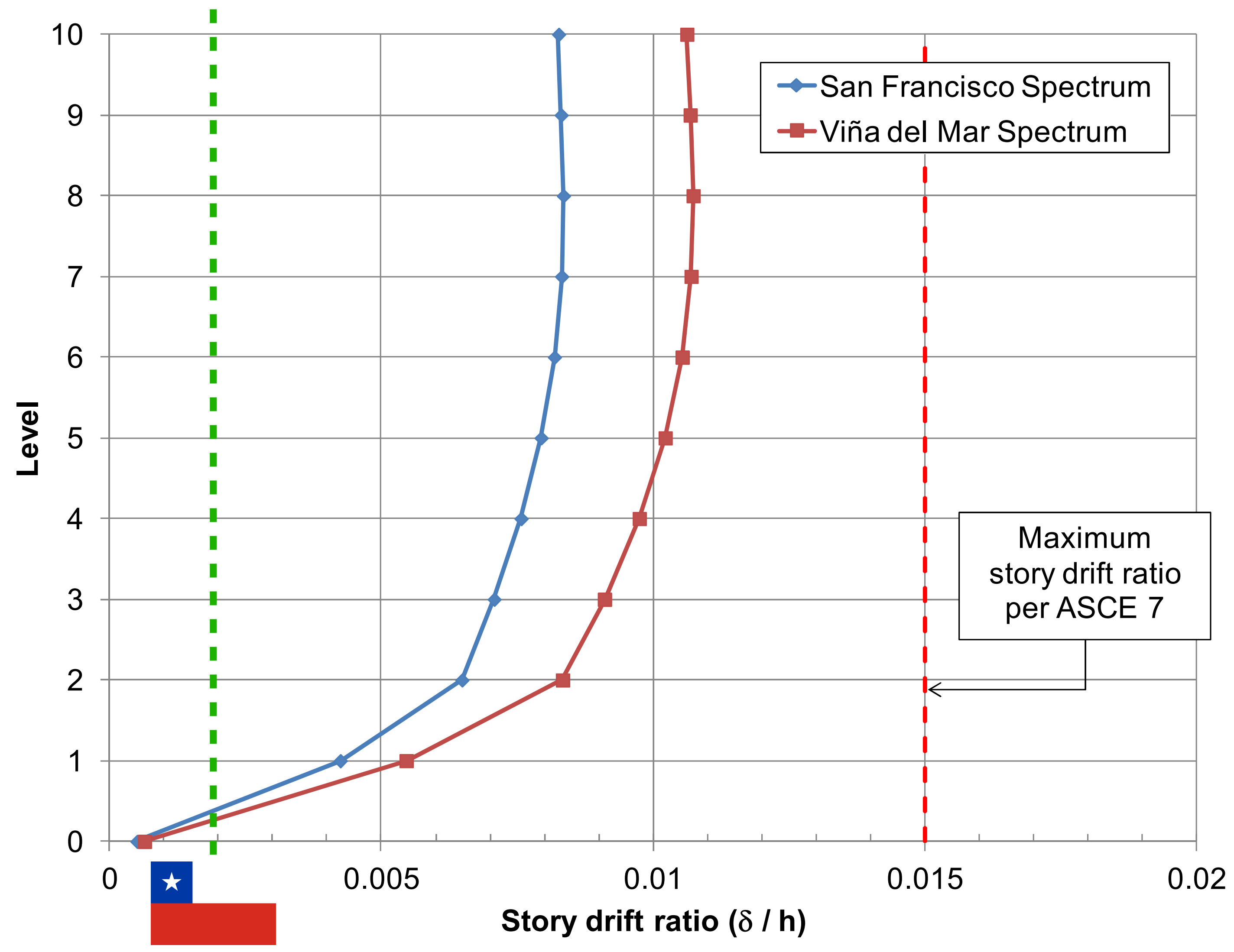


Figure 5-18 Maximum story drift ratios in the transverse direction at the center of mass, calculated per ASCE/SEI 7-05.

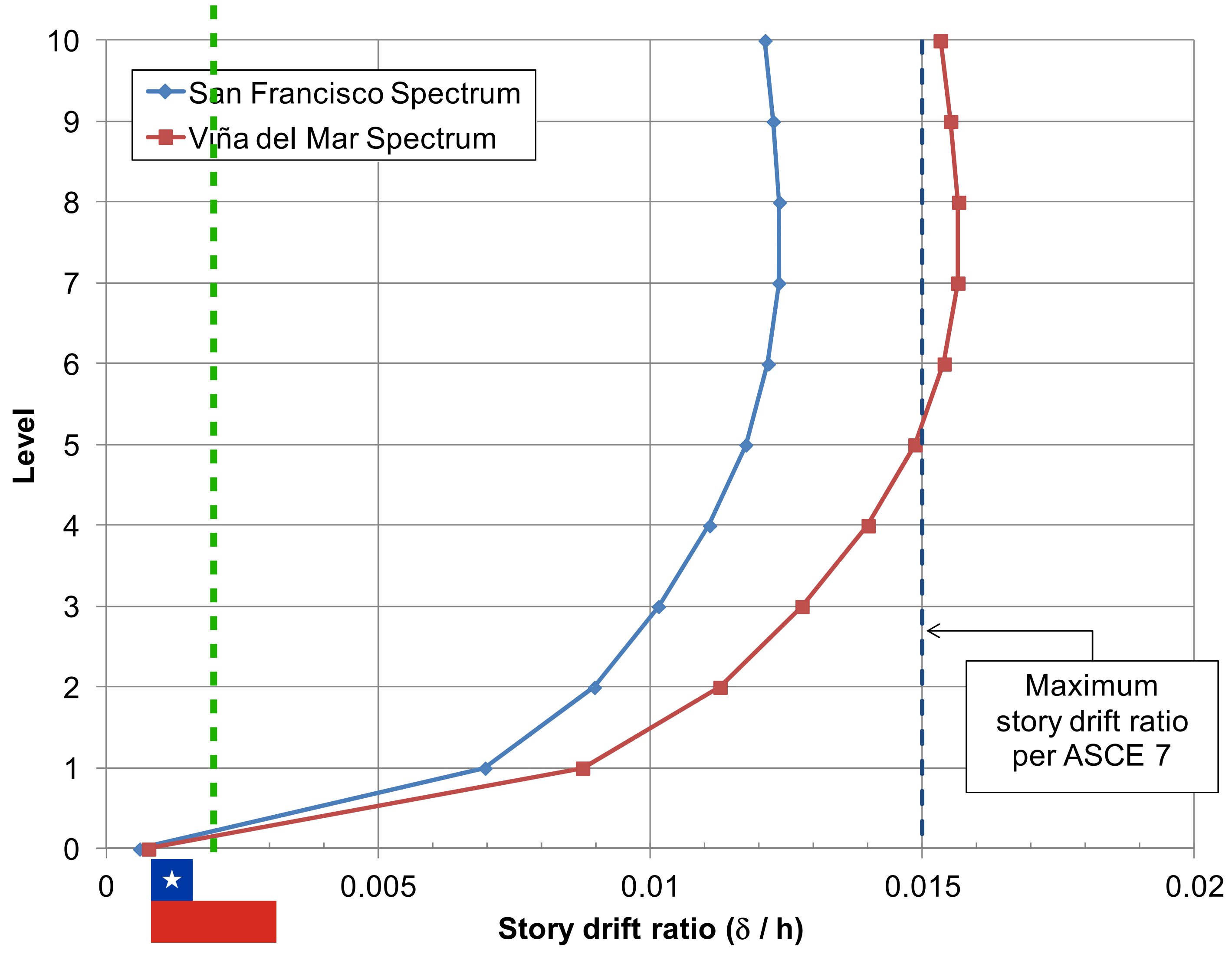


Figure 5-19 Maximum story drift ratios in the transverse direction at an extreme corner, calculated per ASCE/SEI 7-05.

Because the San Francisco spectrum includes a short period plateau, the Viña del Mar spectrum produced higher drifts in all cases. Although NCh433.Of96 specifies

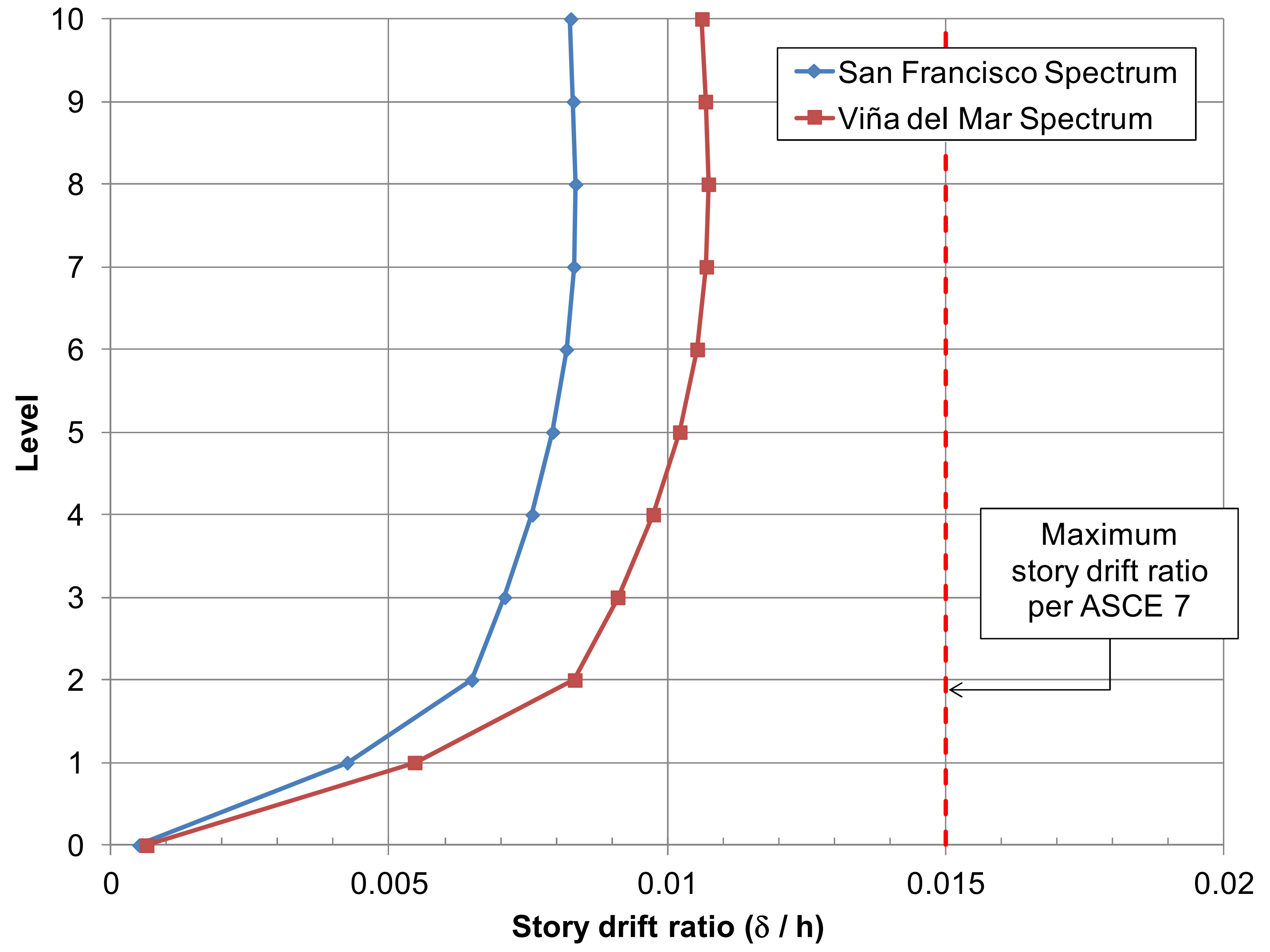


Figure 5-18 Maximum story drift ratios in the transverse direction at the center of mass, calculated per ASCE/SEI 7-05.

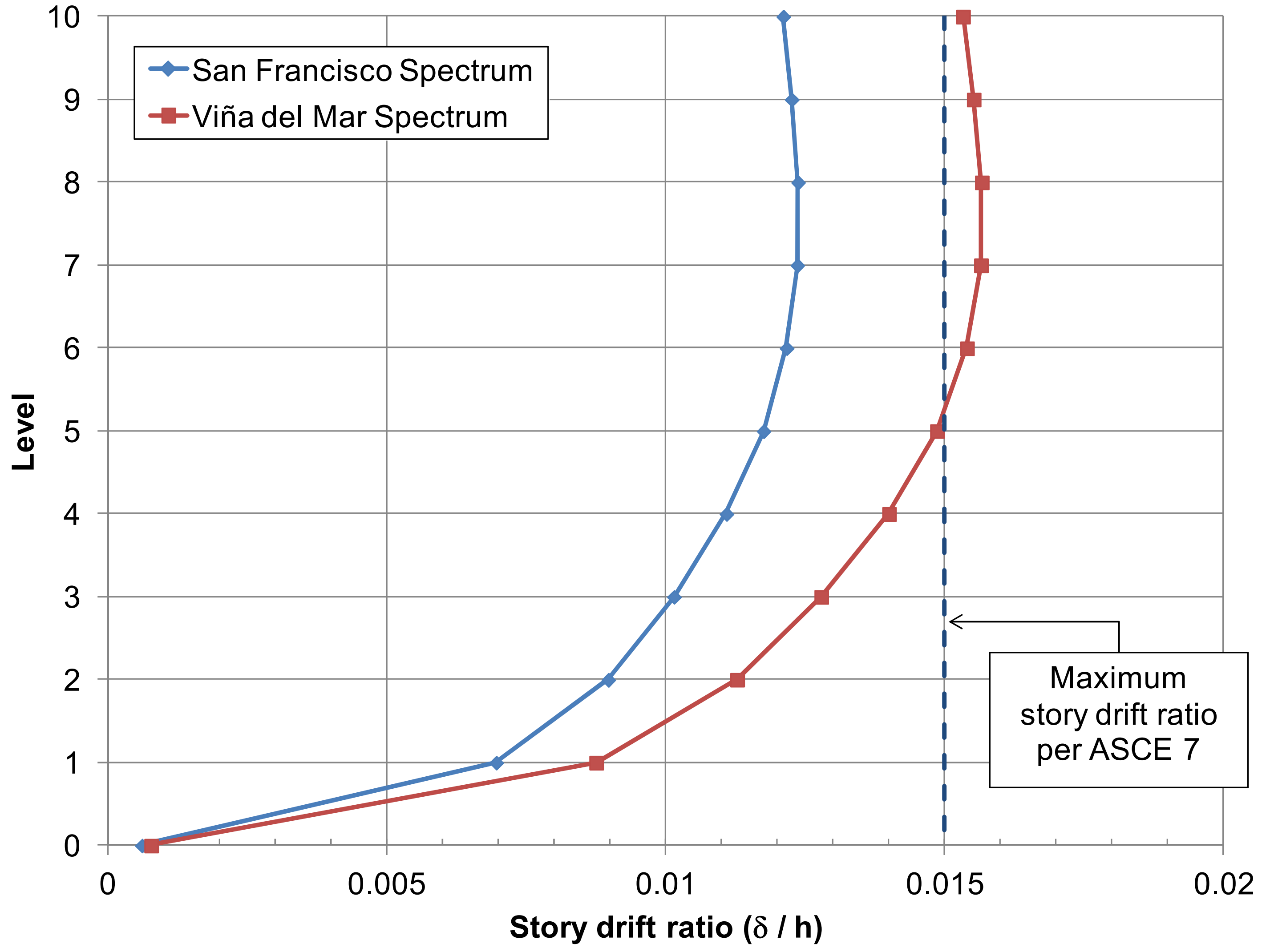


Figure 5-19 Maximum story drift ratios in the transverse direction at an extreme corner, calculated per ASCE/SEI 7-05.

Because the San Francisco spectrum includes a short period plateau, the Viña del Mar spectrum produced higher drifts in all cases. Although NCh433.Of96 specifies the use of gross section properties, drift demands exceeded ASCE/SEI 7-05 drift demands calculated using effective section properties and a displacement

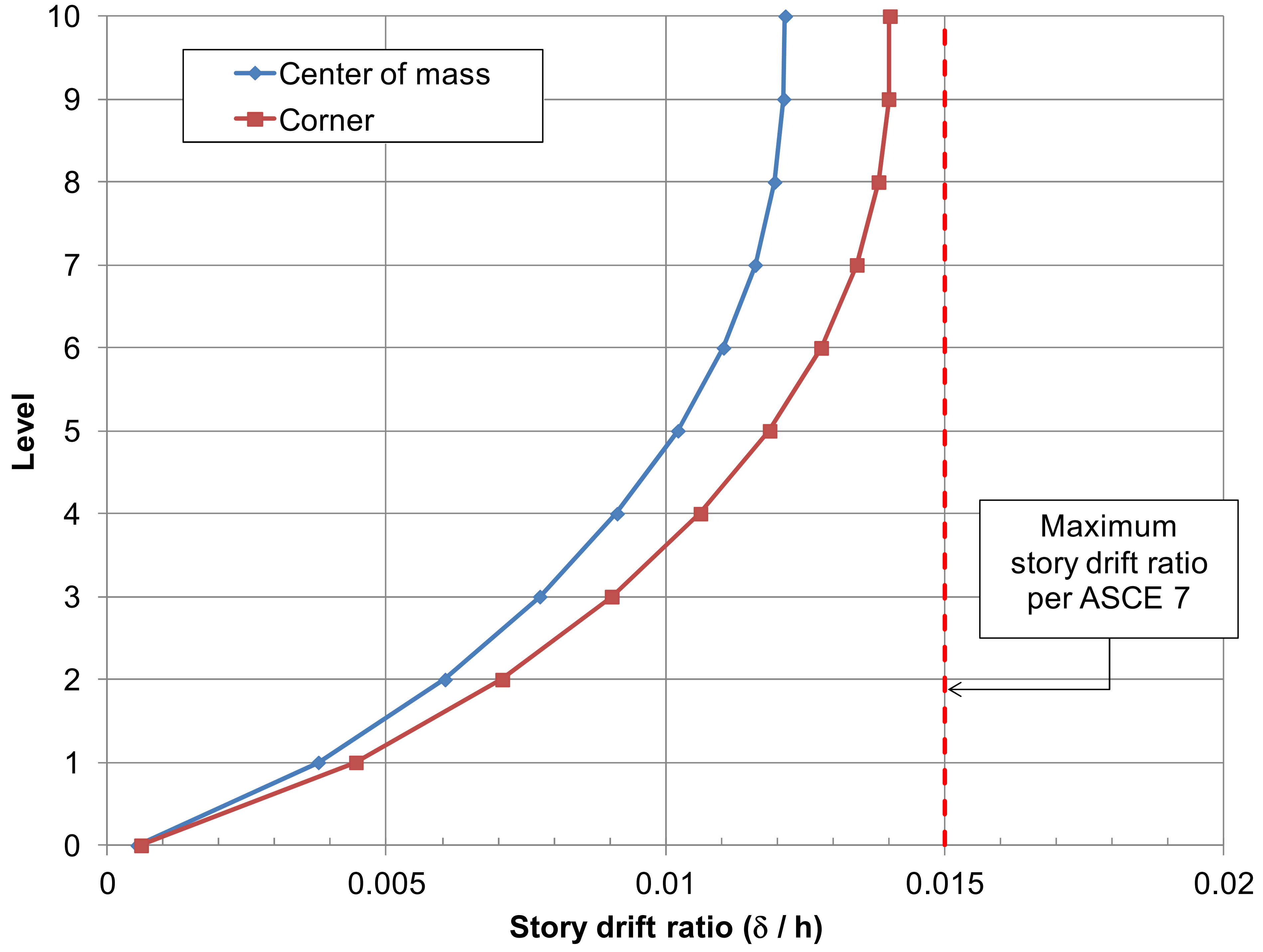


Figure 5-27 Maximum story drift ratios in the transverse direction for the U.S. building configuration, calculated per ASCE/SEI 7-05.