Seismic Hazard

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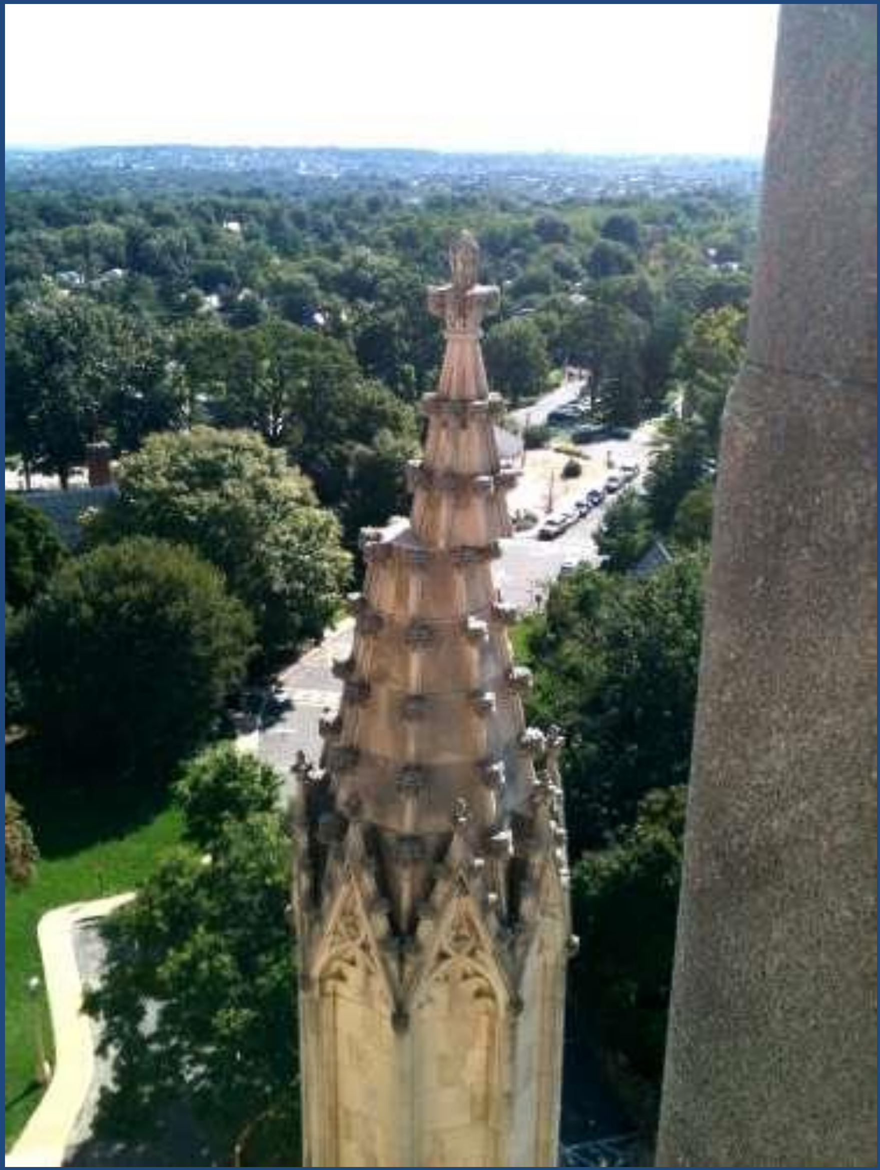
Pictures and slides:
NESEC
USGS
FEMA
Weston Observatory
Kean University



National Cathedral, 5.8

Plate tectonics and earthquakes – how and where but not when…..

Measurement scales

Earthquake aftershocks

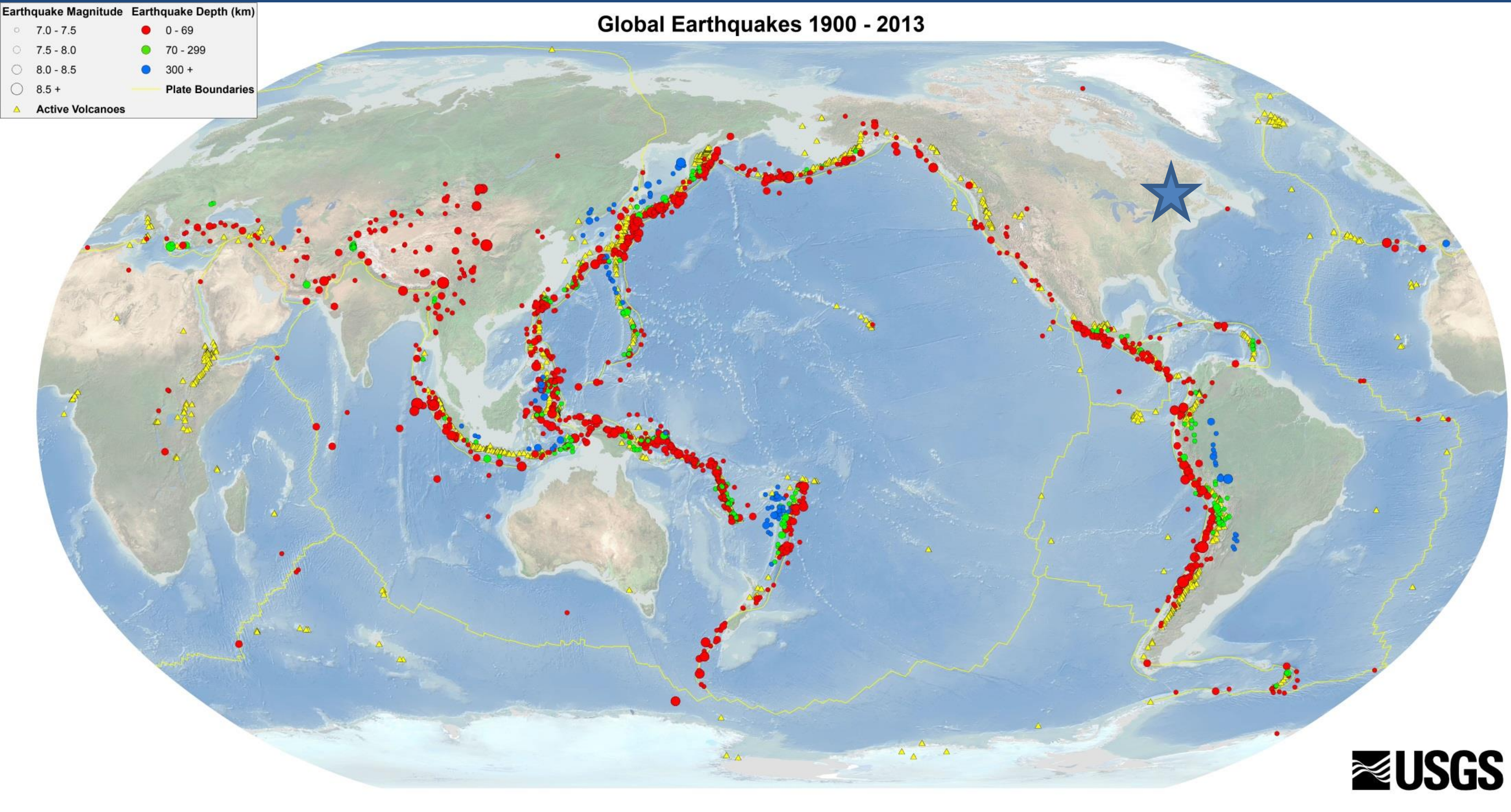
Earthquake Swarms

What to expect; what to do in an earthquake

Hazard Maps

Vermont's geology and earthquake history

Examples of Damage

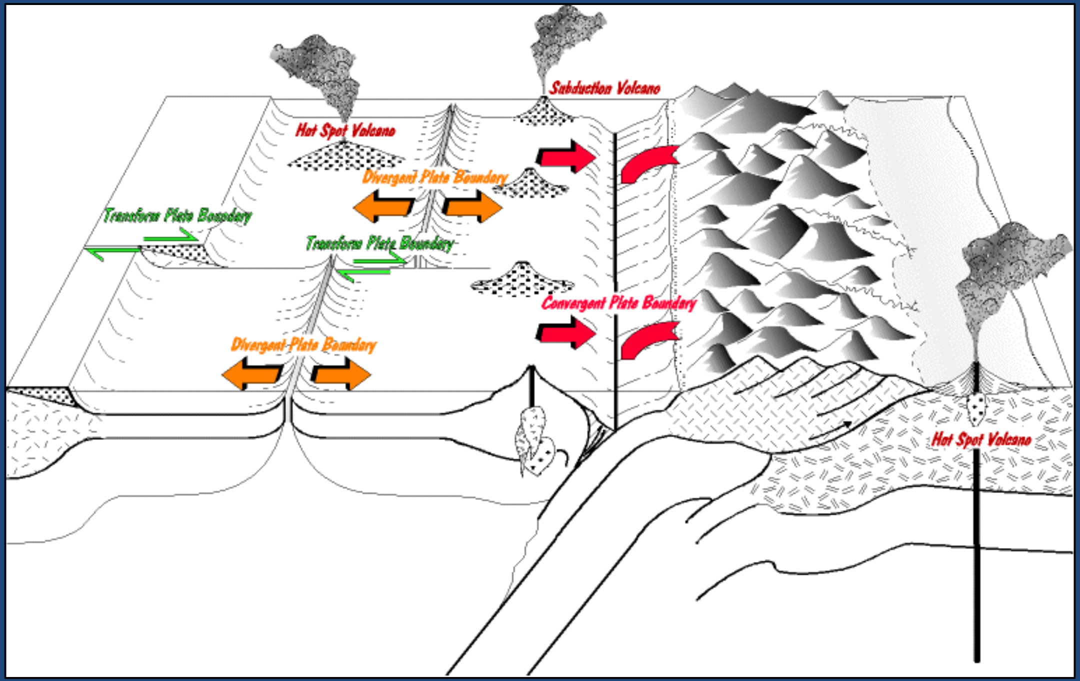


Most earthquakes occur along collisional plate boundaries

Map shows 7.0 or greater from 1900 to 2013

Tectonic environments-

Plate boundaries - rift, subduction zone, volcanic arc
Intraplate – within plate



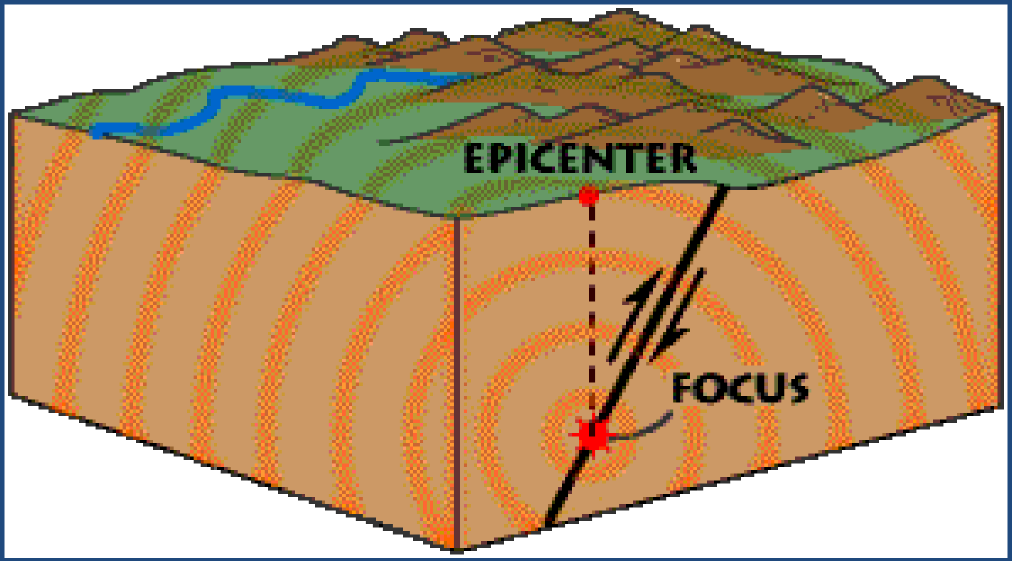
Earthquakes-

Last from seconds to minutes; Occur anytime, day or night

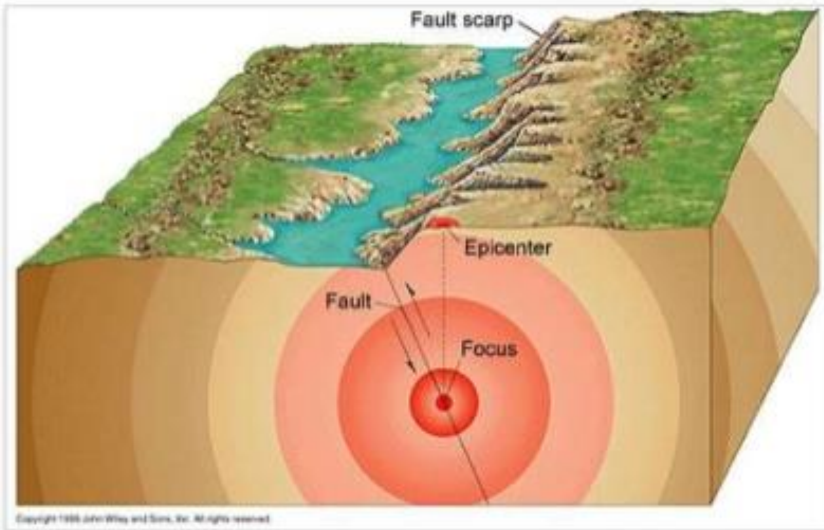
Pressure builds and energy is released when rocks crack and slide past each other along a fault

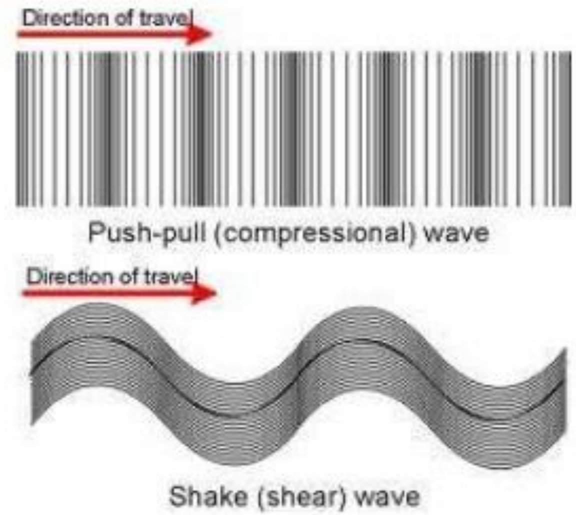
Energy radiates out in all directions

Epicenter – directly above the focus where the earthquake originates



EARTHQUAKE CHARACTERISTICS: FOCUS, EPICENTER, DEPTH, SHOCKWAVES





Shallow focus = ~100 km depth or less
Deep focus = 100-700 km depth

P-waves (primary / push-pull) = felt first (5-8 km/s): feels like a shock wave rattling windows
S-waves (secondary / shake) = felt a few seconds later (3-5 km/s): can be very destructive

Ex 1: Loma Prieta (California 1989): 6.7 magnitude at 18 km depth (inland)
Ex 2: Sendai (Japan 2011): 9.0 magnitude at 32 km depth (70 km the coast)

Magnitude – each quake has a single magnitude expressed as a number

Shaking intensity varies from place to place

Shaking may be amplified by soft soils

Measurement of Earthquakes

- Modified Mercalli scale

measures intensity (I-X);
Describes the effects of earthquakes. Values vary with distance from epicenter, building materials used, and population density.

- Richter scale

measures magnitude (1.0- ?) using the amplitude (height) of the S wave recorded on a seismogram.

Each division is a 10-fold increase in amplitude and an approximate 30-times increase in energy released.

Modified Mercalli Scale (MMI-MMX)

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Richter Scale - Magnitude Scale

Magnitude	Earthquake Effects	Estimated Number Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years

The Great Alaskan earthquake and tsunami of 1964 – magnitude 9.2

Foreshock, mainshock, and aftershock

Large earthquakes rarely occur alone; several felt aftershocks within an hour.

Mainshock - Largest magnitude quake of the set

Change in stress on fault in the mainshock may be great enough to trigger aftershocks on nearby faults.

The stress change dies off quickly with distance from the fault; rarely see aftershocks more than a few km from the main fault.

Bigger quake = more and larger aftershocks.

How many aftershocks will there be?
for each magnitude 5 aftershock in a sequence, there are
10 magnitude 4 aftershocks, 100 magnitude 3 aftershocks,
1000 magnitude 2 aftershocks, etc.

What is an earthquake swarm?

It’s not an aftershock.

> “Typically…, you have a large earthquake followed by a bunch of aftershocks, … earthquakes in the same spot,” Don Blakeman, geophysicist.
>
> “That’s not a swarm. A swarm usually doesn’t have the large earthquake beginning, but is instead a series of earthquakes of similar low magnitudes that occur in the same region.” (ex. 50 earthquakes an hour)

Swarm sequences generally last a few days or weeks.

Swarms will have many earthquakes within a day or a week.

Typically, magnitude 2-3 which result in no damage to minor damage (books falling off shelves etc)

They DO NOT foreshadow a large earthquake.

Before a quake

Identify safe places such as under a sturdy piece of furniture or against an interior wall

Practice how to "**Drop, Cover, and Hold On!**"

Before an earthquake occurs, secure or move items that could fall and cause injuries (e.g., bookshelves, mirrors, light fixtures).

Examples of potential hazards from earthquake shaking

If you are inside a building:

Stay where you are until the shaking stops.

Do not run outside. Do not get in a doorway or near glass.

If in bed, stay there. Otherwise: Drop, Cover, and Hold on to any sturdy covering.

People who use wheelchairs or other mobility devices should:
lock their wheels, remain seated until the shaking stops, use a pillow or arms to protect their your head.

If outside:

Move away from buildings, streetlights, and utility wires.

In a city, you may need to go inside to avoid falling debris.

Then…DROP, COVER and HOLD ON

If you are in a car:

stop and stay inside

Stay away from bridges and utility lines

Afterwards, avoid bridges, ramps and roads which may have been damaged.

When the shaking stops

If there is a clear path to safety, leave the building and go to an open space away from damaged areas.

If you are trapped, do not move about or kick up dust.

If you have a cell phone, call or text for help.

Tap on a pipe or wall or use a whistle, so that rescuers can locate you.

Be prepared to "Drop, Cover, and Hold on" in the likely event of aftershocks.

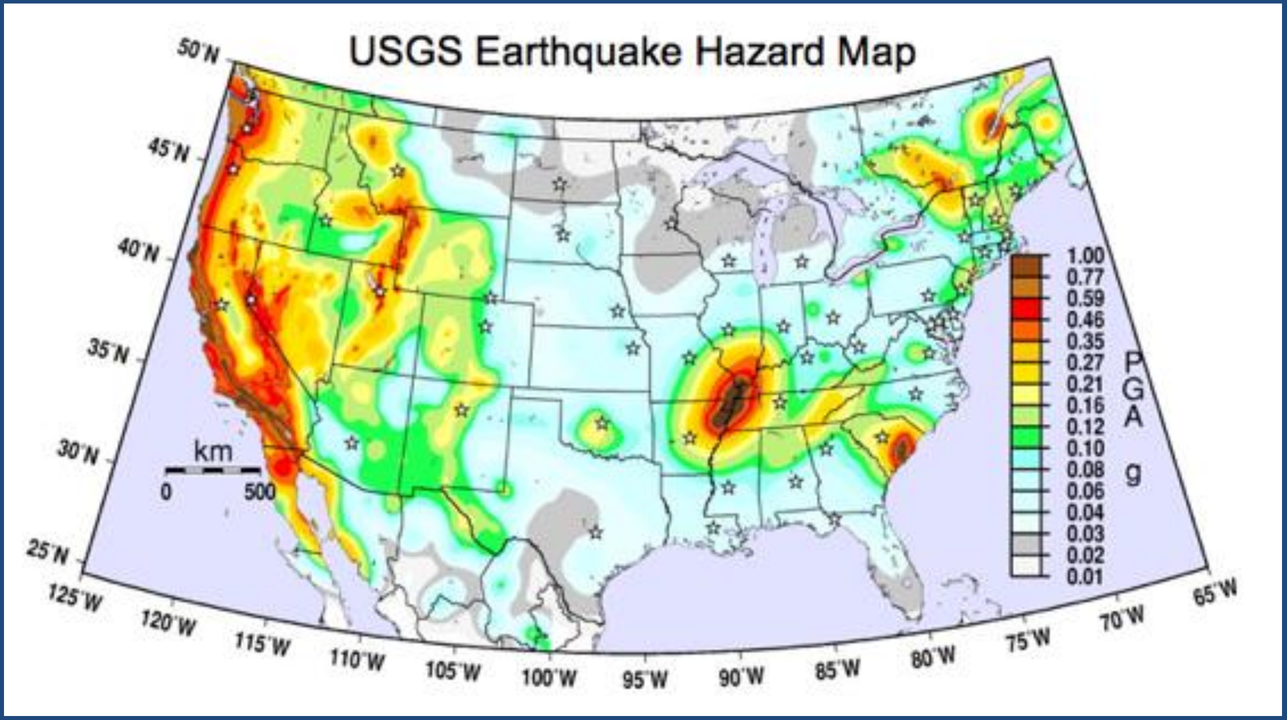
Hazards Maps

Ground shaking varies from place to place; hazard mapping shows this variability.

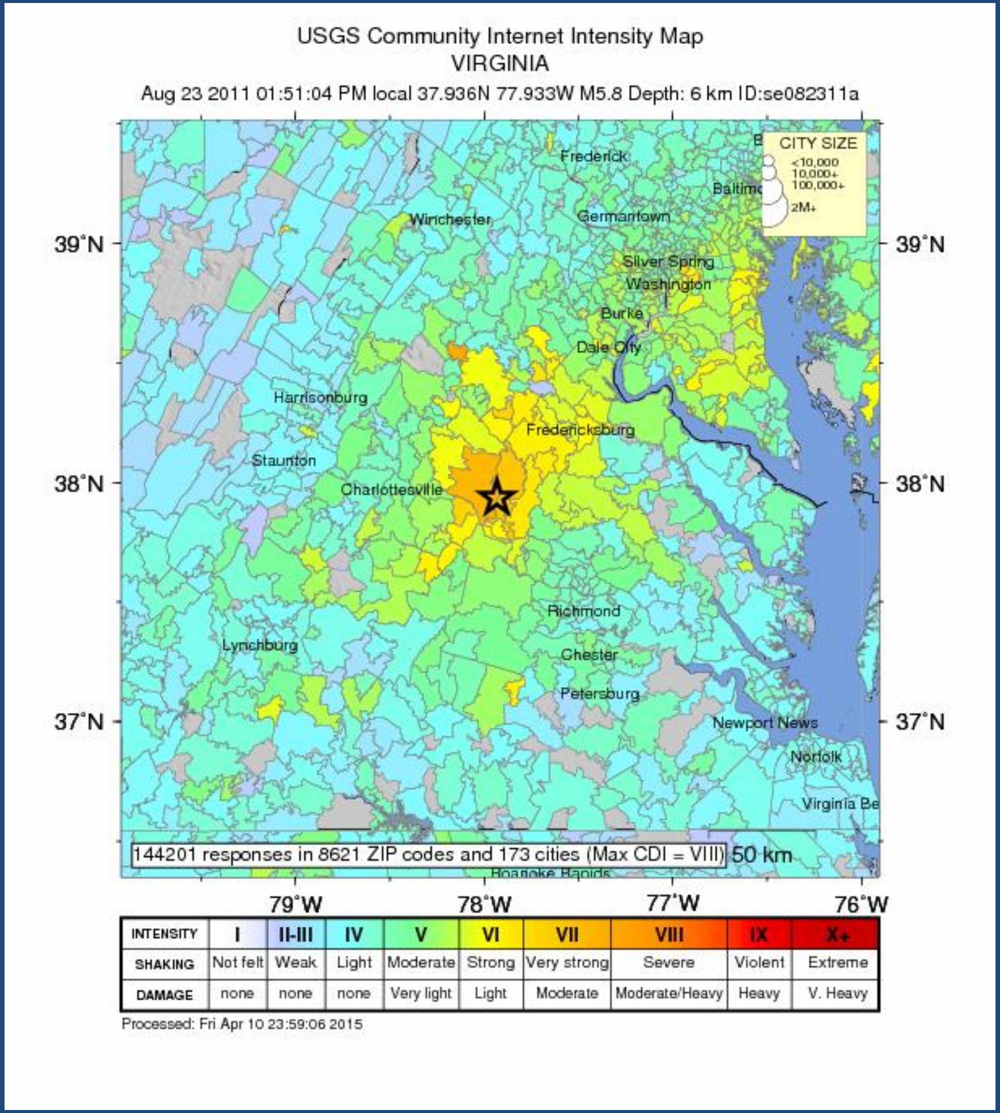
The mapped hazard refers to an estimate of the probability of exceeding a certain amount of ground shaking, or ground motion, in 50 years.

The hazard depends on the magnitudes and locations of likely earthquakes, how often they occur, and the properties of the rocks and sediments that earthquake waves travel through.

National Seismic Hazard Map developed by the U.S. Geological Survey in 2008. This map shows contours of the percentage of the force of gravity that is predicted to have a 2% chance of being exceeded in 50 years.

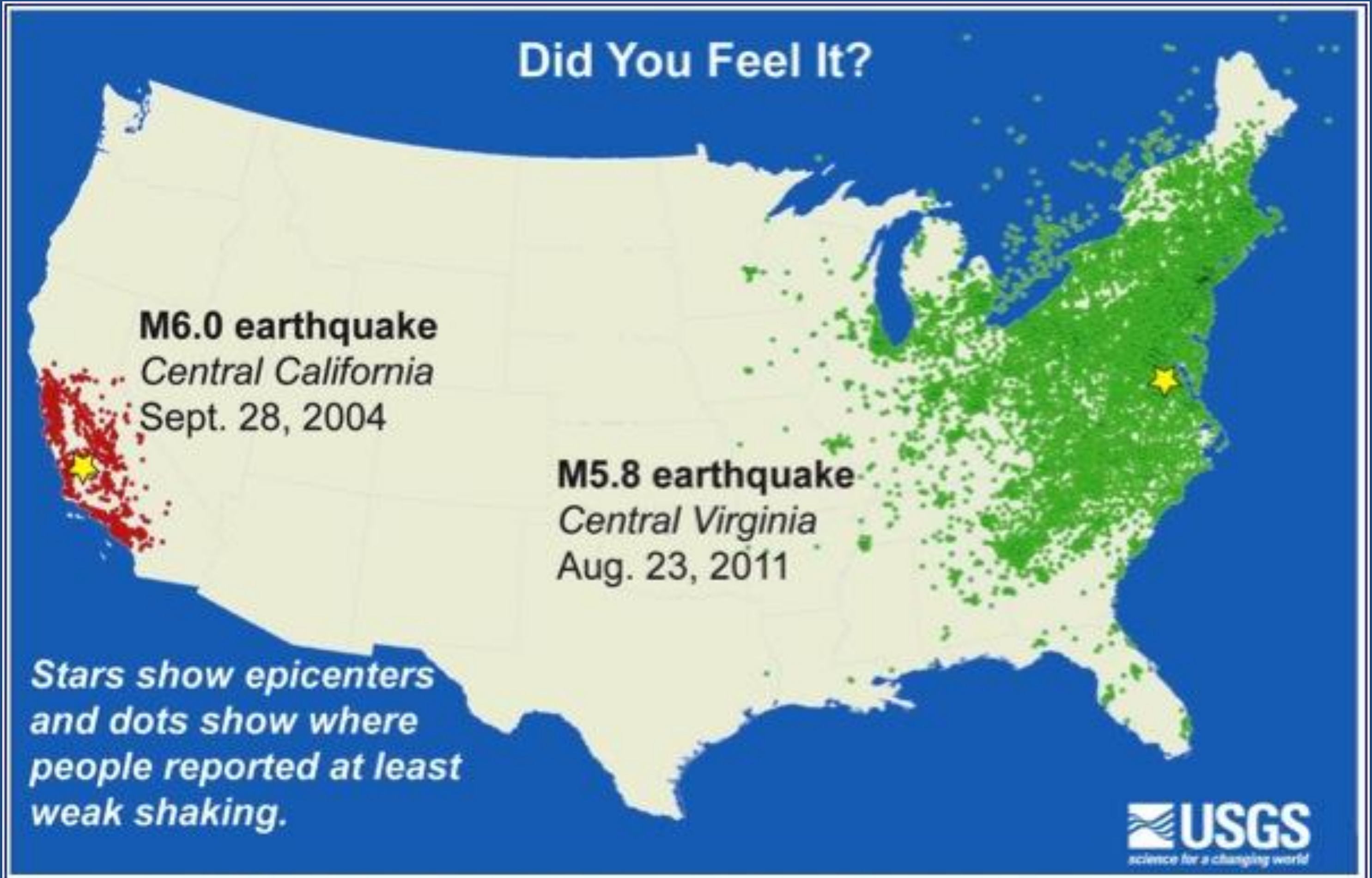


Shake Map – shows intensity and damage
Mineral, VA 5.8 quake, August 23, 2011

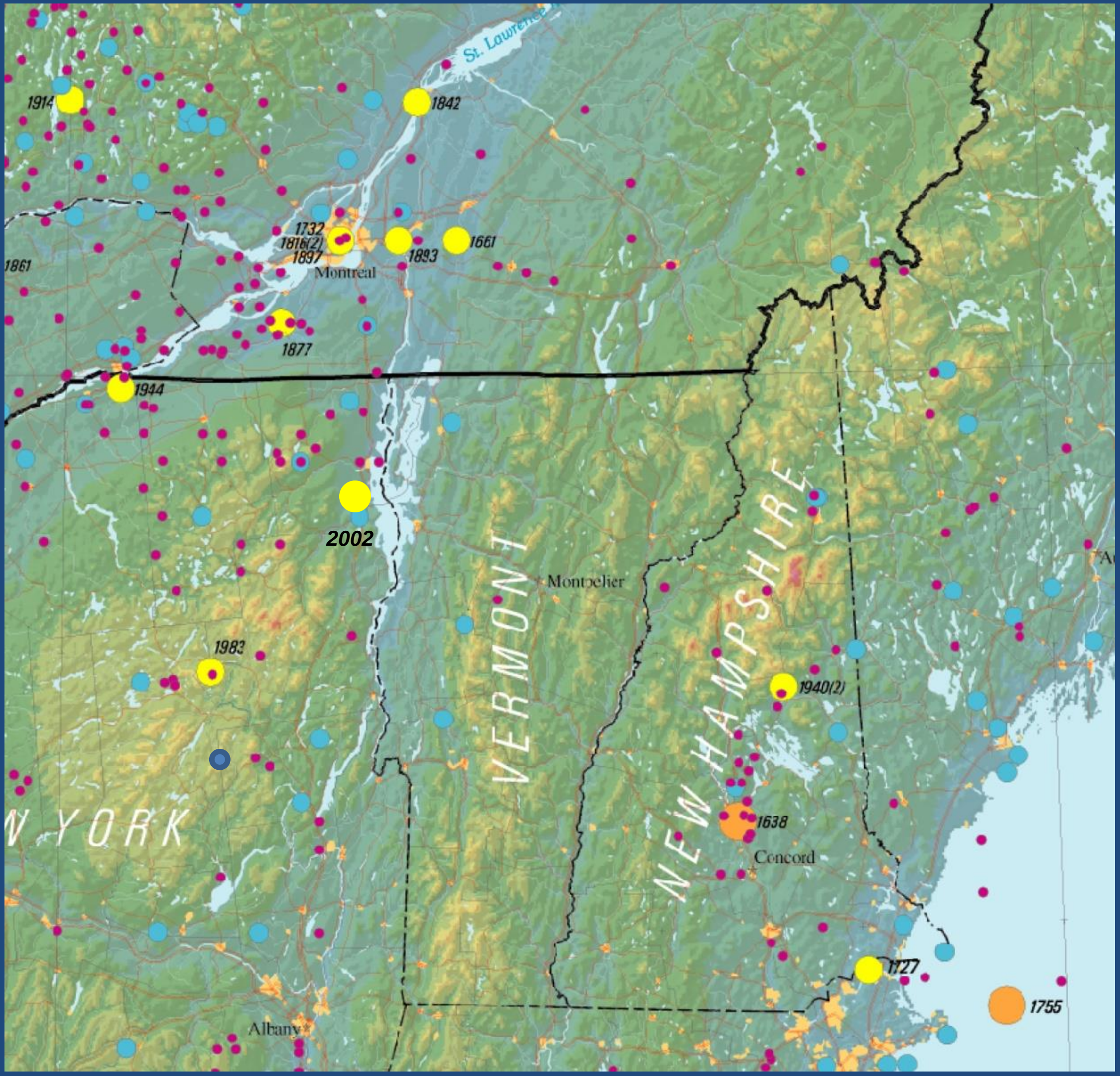


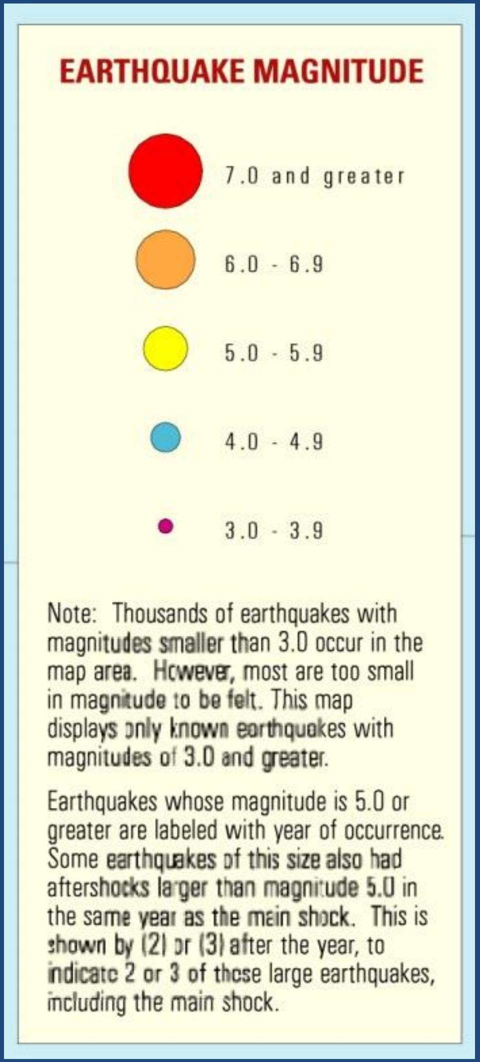
Light to moderate damage near epicenter – ex. Washington Monument

No damage at distance of ~50 miles



Did You Feel It? East vs West: This image illustrates how earthquakes are felt over much larger areas in the eastern U.S. than those west of the Rocky Mountains. The map compares USGS "Did You Feel It?" data from the magnitude 5.8 earthquake on August 23, 2011 in central Virginia (green) to data from an earthquake of similar magnitude and depth in California (red).





What about Vermont?

Earthquakes >3.0 In/ Near the NE USA, 1638 - 2001

Some Earthquakes Felt in Vermont

Location	Mag.	Mercalli Int.
Montreal, Que. 1732	5.8	IV - VI
La Malbie, Que. 1925	6.5	III - IV
Timiskaming, Que. 1935	6.1	III - IV
Ossipee, N.H. 1940	5.5	IV - VI
Ossipee, N.H. 1940	5.5	IV - VI
Massena, N.Y. 1944	5.2	IV - V
ME-NH-Que Bord 1973	4.8	III - V
Gaza, N.H. 1982	4.7	III - IV
Goodnow, N.Y.	5.1	III - IV
Saguenay, Que. 1988	6.2	IV - V

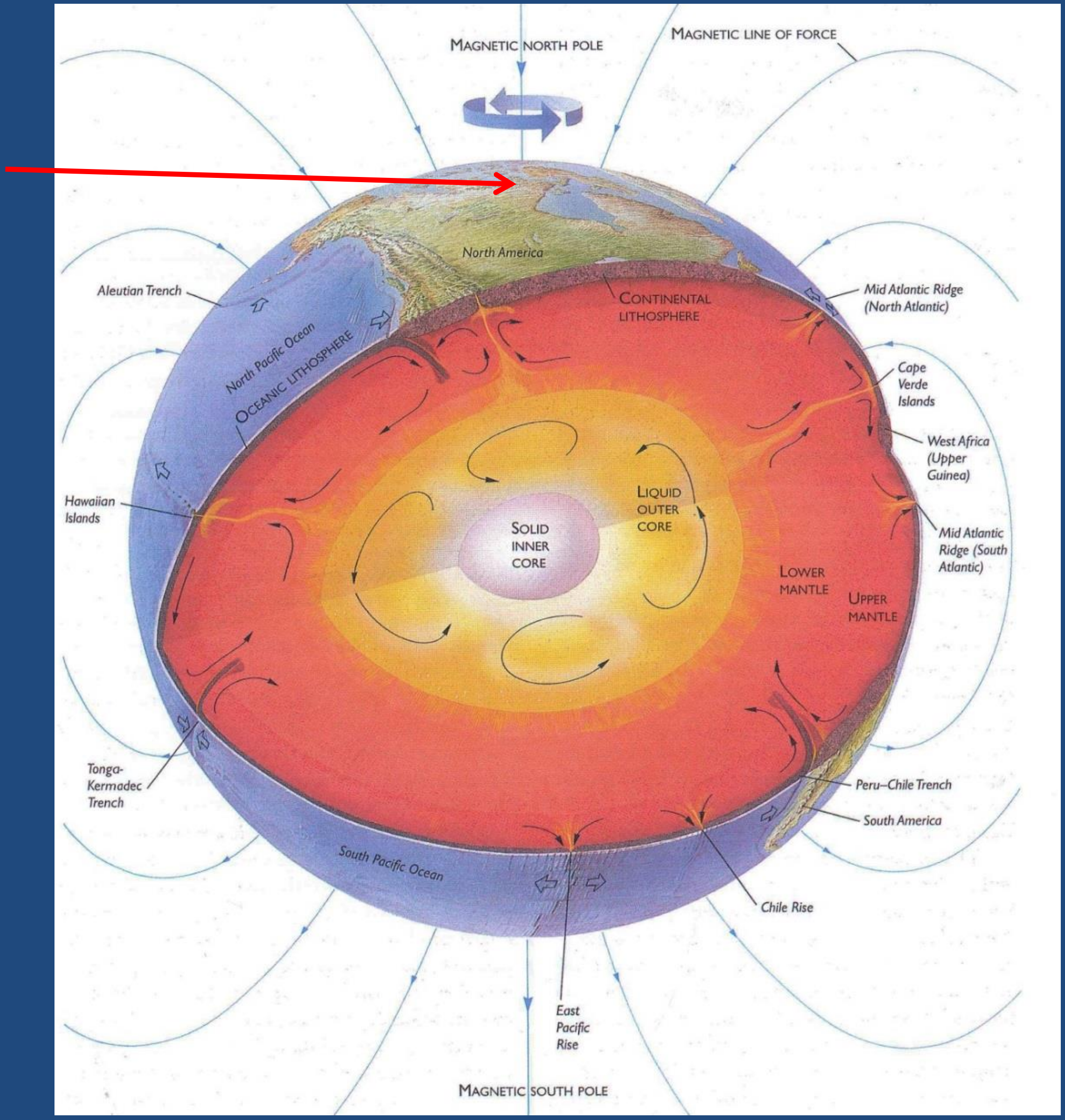
LARGEST EARTHQUAKES WITH EPICENTERS IN VERMONT THROUGH 1993

Date	Time	Lat (N)	Long (W)	Mag.	MMI	Epicenter
04/10/62	09:30am	44.11	72.97	4.1	V	Middlebury, VT
07/06/43	05:10pm	44.84	73.03	4.1	IV	Swanton, VT
03/31/53	07:59am	43.07	73.00	4.0	V	Brandon, VT

Vermont is in the more stable interior of the North American plate, not at a plate boundary, but there is still stress.

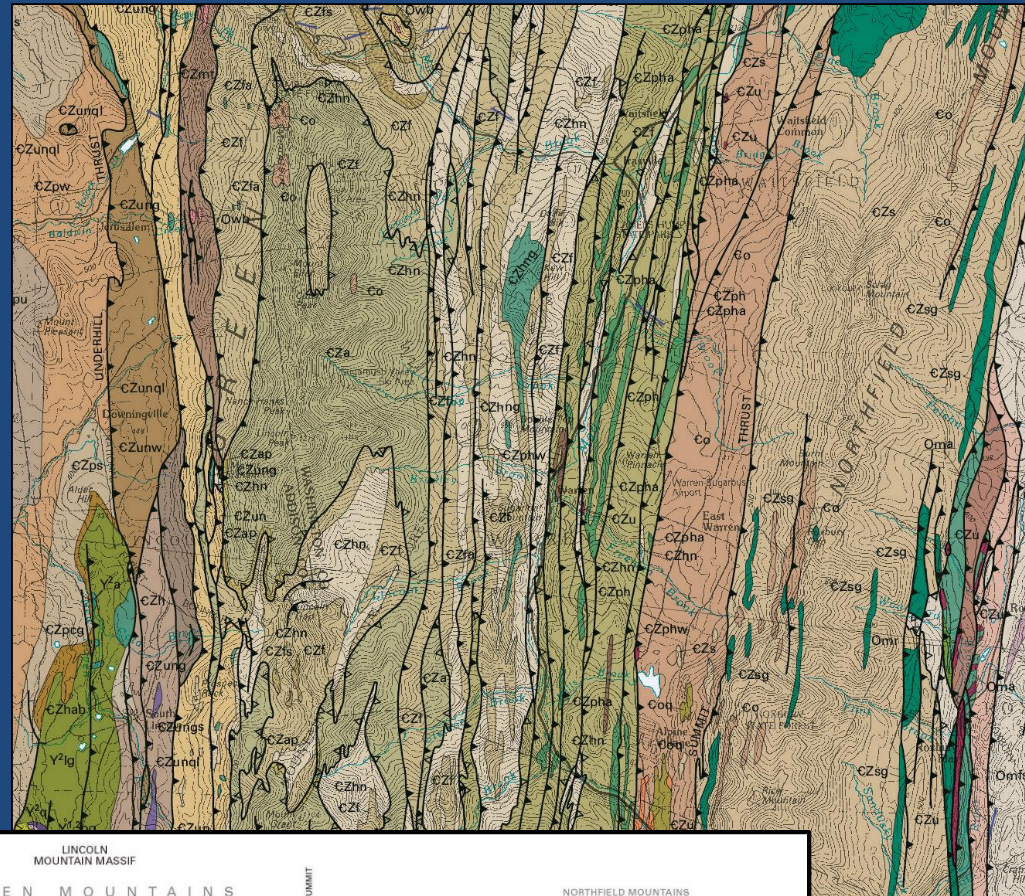
Waves travel further and faster and have less attenuation in old, cold crust (northeast US)

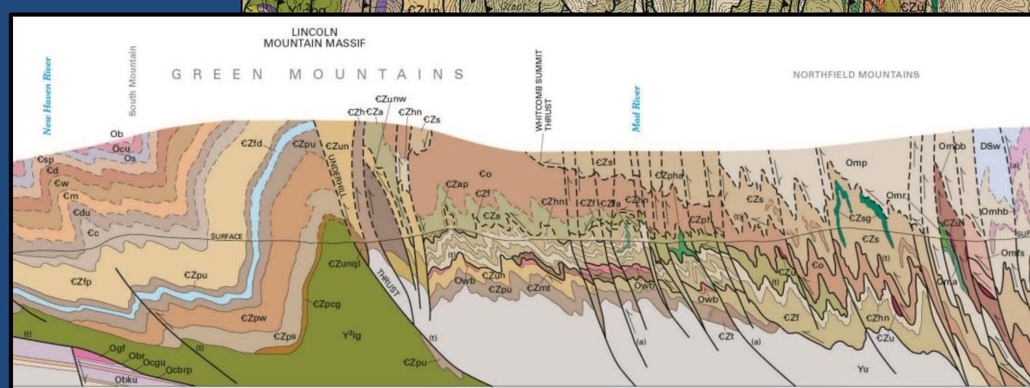
Depth of New England quakes are shallow – usually less than 15 km or 9 miles (shallow is 0-70 km)



Are there faults in Vermont?

Inactive faults are commonplace….. Because we WERE at an active plate collision boundary 500 – 350 mya





Faults in Vermont

Most are 350 my to 500 million years old; some are younger.

Generally not indicative of where an earthquake would occur.

There are no identified surface expressions of fault movement.

Faults are inactive although some may be zones of weakness.

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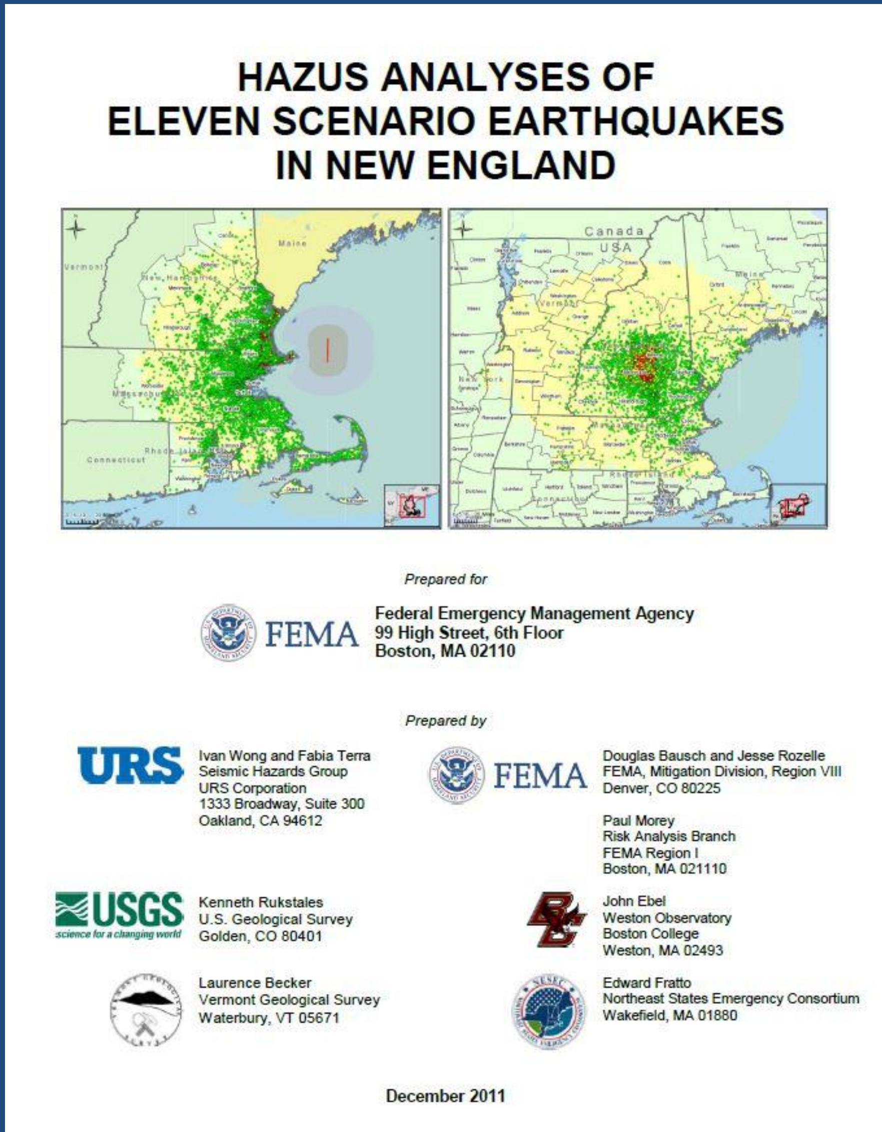
Champlain Thrust Fault at Lone Rock Point, Burlington
Moved 35-50 miles and up ~8800 ft

We can estimate how severe the damage may be in a given event, but there is not an early warning system.

Predict impact but not the time of the earthquake.

Most injuries are due to collapsing walls, falling glass, flying objects. What does your workplace look like?



HAZUS ANALYSES OF ELEVEN SCENARIO EARTHQUAKES IN NEW ENGLAND

Prepared for

FEMA

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Prepared by

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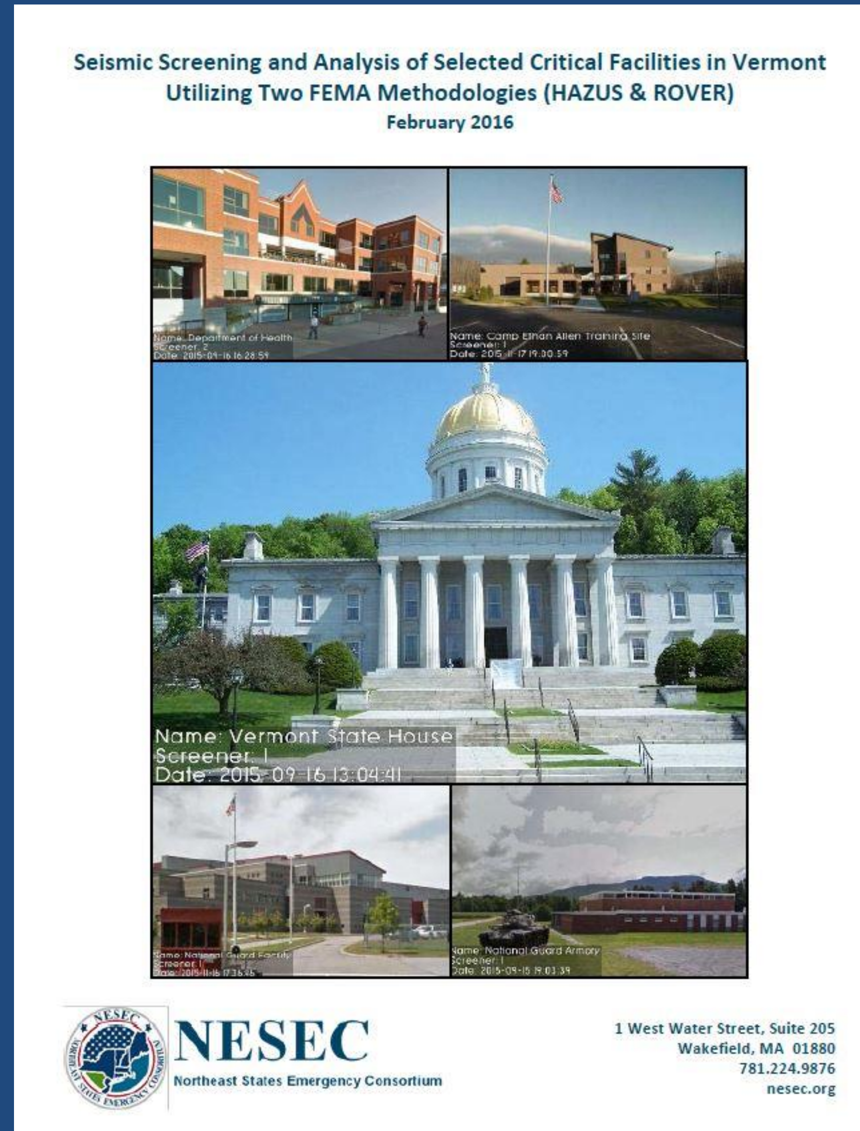
December 2011



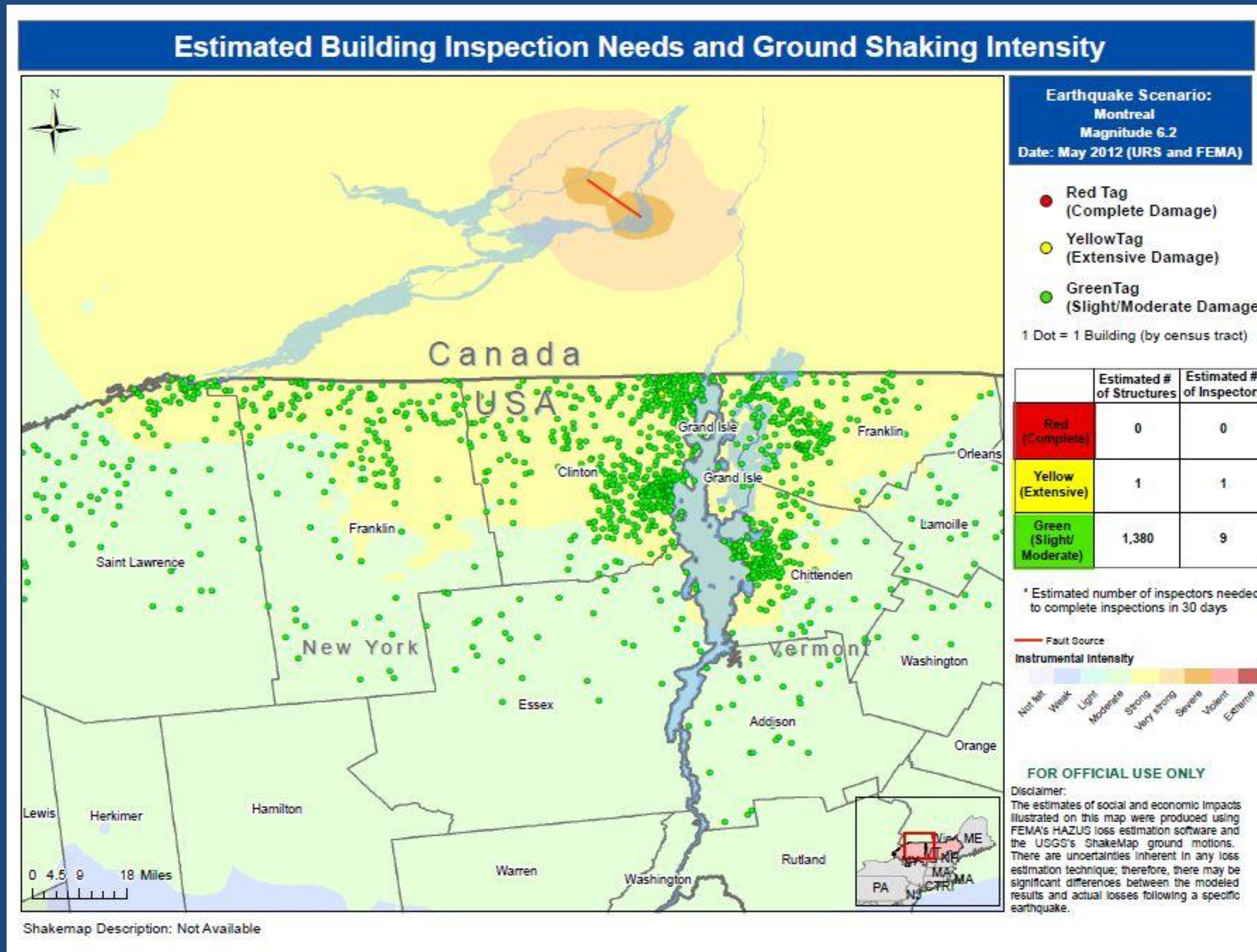
Seismic Screening and Analysis of Selected Critical Facilities in Vermont Utilizing Two FEMA Methodologies (HAZUS & ROVER)

February 2016

NESEC
Northeast States Emergency Consortium

1 West Water Street, Suite 205
Wakefield, MA 01880
781.224.9876
nesec.org

http://www.anr.state.vt.us/dec/geo/hazinx.htm

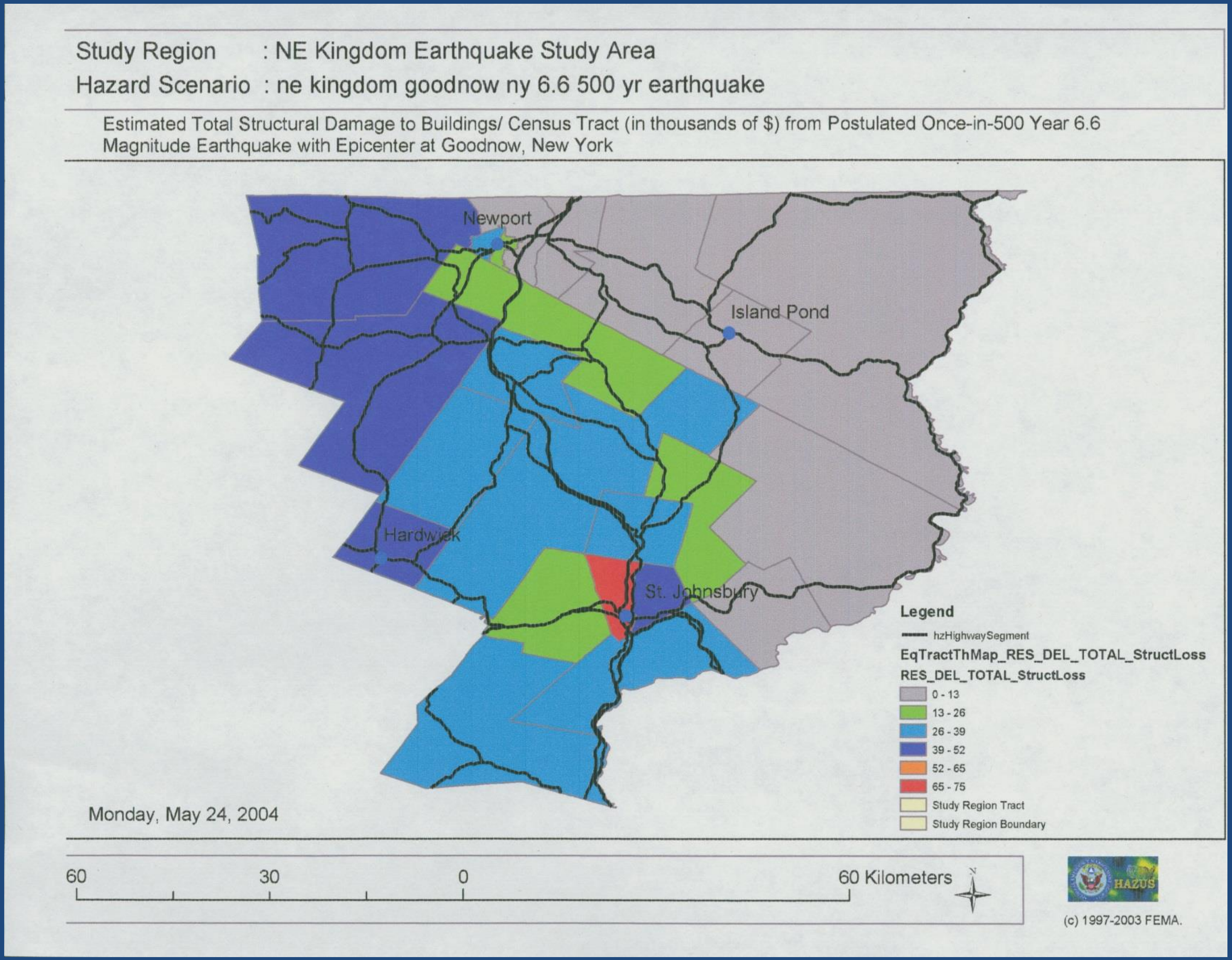

Estimated Building Inspection Needs and Ground Shaking Intensity
Earthquake Scenario:
Montreal
Magnitude 6.2
Date: May 2012 (URS and FEMA)
Red Tag (Complete Damage)
YellowTag (Extensive Damage)
GreenTag (Slight/Moderate Damage)
1 Dot = 1 Building (by census tract)
Estimated # of Structures
Estimated # of Inspectors
Red (Complete) 0 0
Yellow (Extensive) 1 1
Green (Slight/ Moderate) 1,380 9
* Estimated number of inspectors needed to complete inspections in 30 days
Fault Source
Instrumental Intensity
Not felt
Weak
Light
Moderate
Strong
Very strong
Severe
Violent
Extreme
FOR OFFICIAL USE ONLY
Disclaimer:
The estimates of social and economic impacts illustrated on this map were produced using FEMA's HAZUS loss estimation software and the USGS's ShakeMap ground motions. There are uncertainties inherent in any loss estimation technique; therefore, there may be significant differences between the modeled results and actual losses following a specific earthquake.
Canada
USA
New York
Vermont
Grand Isle
Franklin
Orleans
Clinton
Lamoille
Saint Lawrence
Chittenden
Washington
Essex
Addison
Orange
Lewis
Herkimer
Hamilton
Warren
Rutland
0 4.5 9 18 Miles
ME
PA
NJ
MA
Shakemap Description: Not Available

Montreal 6.2

Postulated Strong Earthquakes Which Can Affect Vermont (500 Year) from Ebel and others, 1995

Location	Magnitude
• Montreal, Quebec	6.8
• Goodnow, N.Y.	6.6
• Charlevoix, Quebec	6.6
• Tamworth, N.H.	6.2
• Middlebury, Vt.	5.7
• Swanton, Vt.	5.7

Damage to residences in NE Kingdom from 6.6 event in Goodnow, NY



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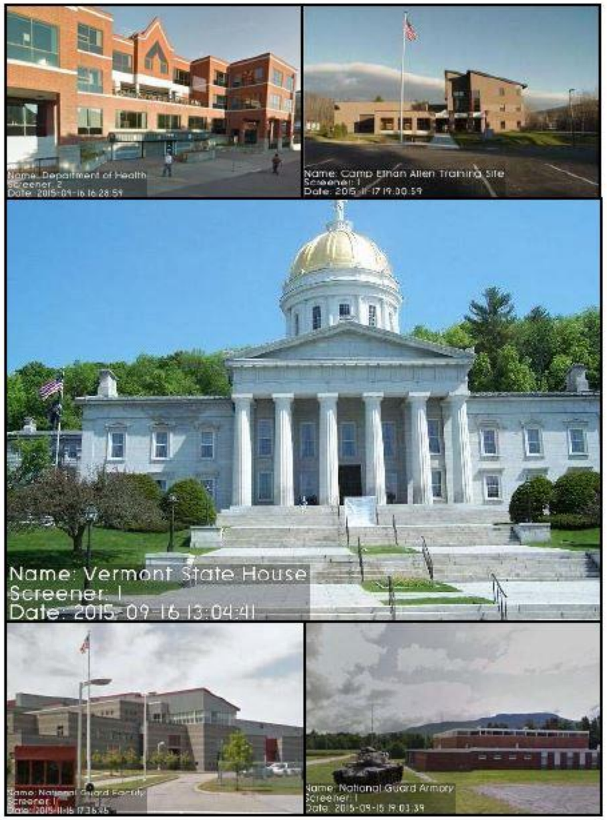

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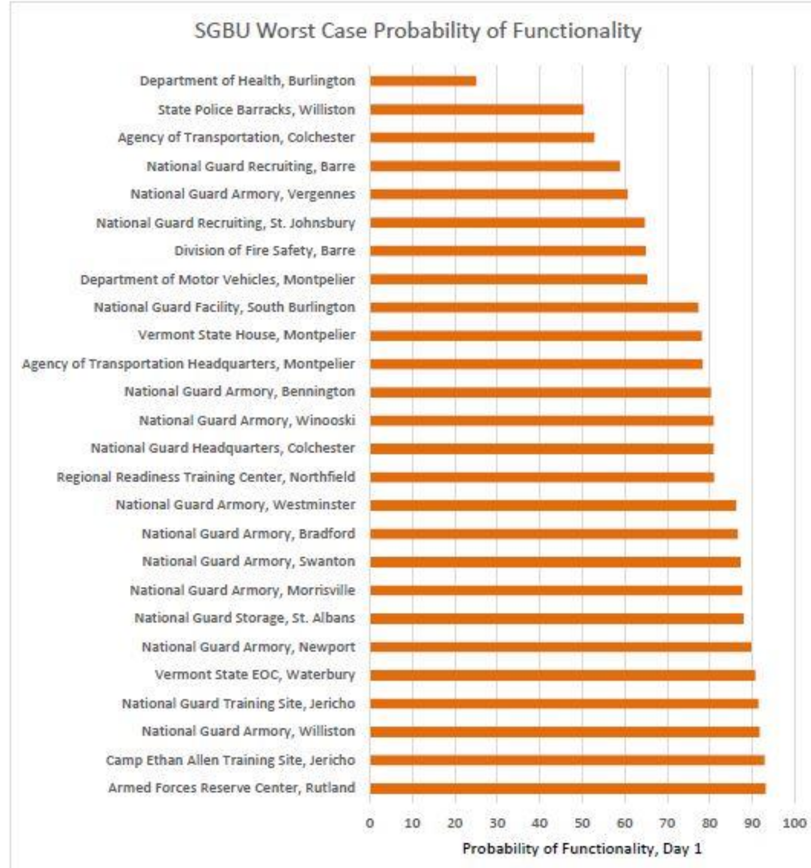


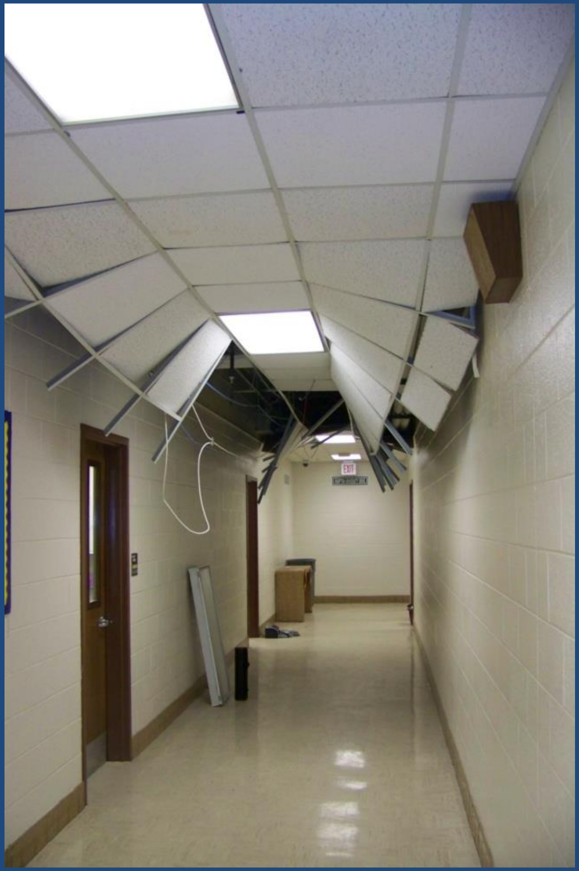
Figure 14. Worst Case Functionality for the 26 Screened Vermont Critical Facilities with Updated Soil Class and Building Type

As Figure 14 illustrates, the worst-case probability of functionality across the three events studied ranges from a low of 25% to a high of 93%. No facilities have a 100% probability of functionality.

3.2 in Concord, CA

Au Sable Forks, New York – 5.1 (2002)

Mineral, VA 5.8 Earthquake



Images courtesy of FEMA E-74 Nonstructural Hazard Mitigation Presentation

Wells, Nevada – 6.0 (2008)

Hawaii 6.2

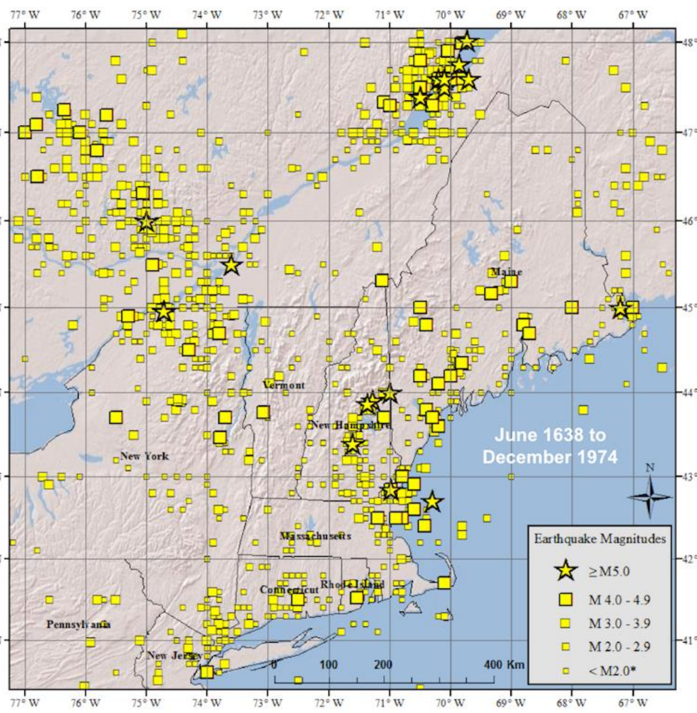
Japan 6.6

Charleston, SC - Great Quake of 1886
~7.0

7.9 in Sichuan, China in 2008 – school collapse trapped 900 students, collapse of two chemical plants and release of 80 tons of liquid ammonia

7.9 near Denali, Alaska in 2003 - Road damage, fuel tanks, rail damage

Weston Observatory Historical Seismicity



Weston Observatory Network Seismicity