EOSC 256 Earthquakes

- course outline and policies
- pre-course questionnaire
- What makes a quake a disaster: intensity vs. magnitude

earthquake (noun)

A series of vibrations induced in the earth's crust by the abrupt rupture and rebound of rocks in which elastic strain has been slowly accumulating.

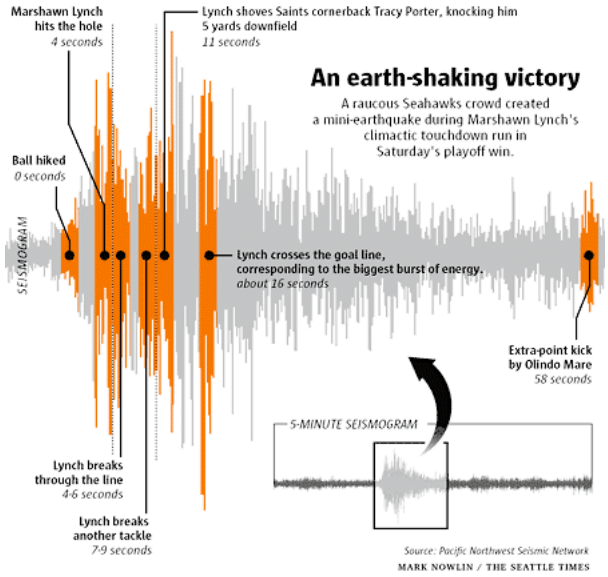
Shaking and vibration at the surface of the earth resulting from underground movement along a fault plane of from volcanic activity.

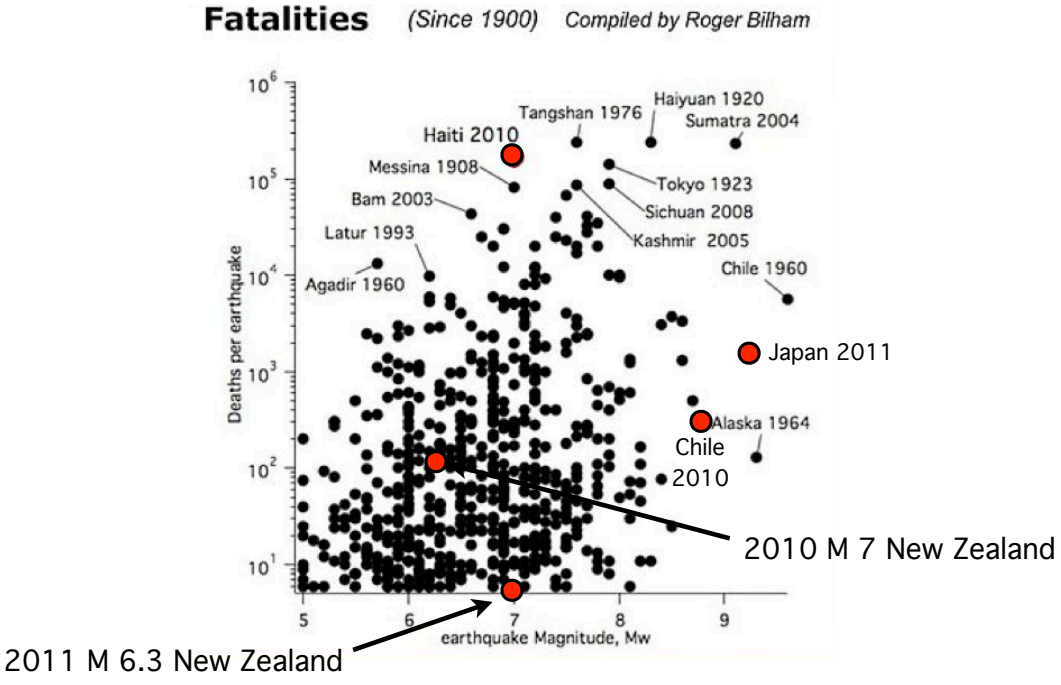
A sudden movement of the earth's crust caused by the release of stress accumulated along geologic faults or by volcanic activity.

A sudden movement of the Earth's lithosphere (its crust and upper mantle). Earthquakes are caused by the release of built-up stress within rocks along geologic faults or by the movement of magma in volcanic areas.

“tectonic earthquake”

Seattle 12th man “earthquake”





January 12, 2010
M 7 Haiti Earthquake

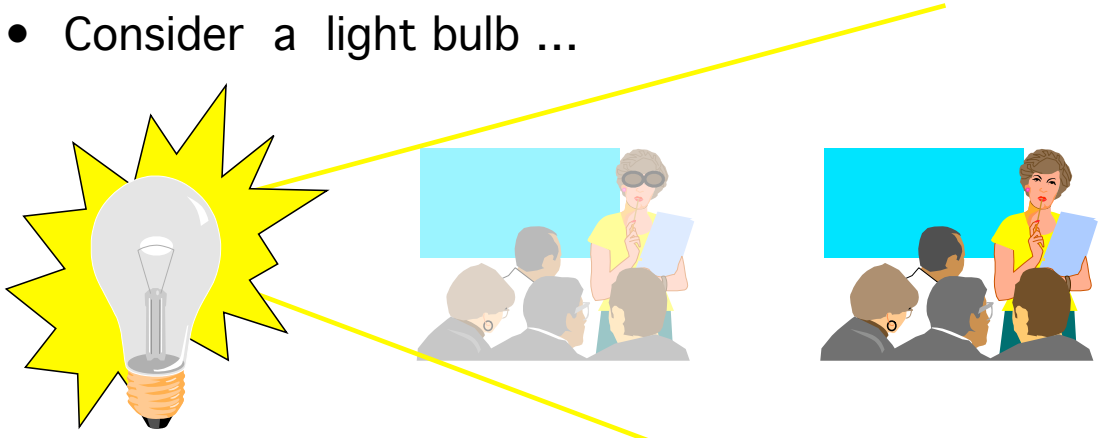
Built to withstand hurricanes, not earthquakes
People ran indoors (hurricane procedure)
Extremely high intensity in populated areas

March 11, 2011
M 9 Japan Earthquake

How do we express the size of an earthquake? (Two ways)

What does an earthquake of a given size feel like, and how much damage does it cause?
vs.
How much energy was released?

- We must distinguish between magnitude and intensity
  - magnitude indicates how much energy was released.
  - intensity is how strong the ground motion is at the felt location.
- Consider a light bulb ...



Fixed *magnitude* **Local *intensity*** **Local *intensity***

Earthquake Intensity: four factors

1. Earthquake magnitude
2. Distance from epicentre
3. Ground type
4. Duration

Mercalli intensity is a subjective description of violence and duration of shaking, and damage. Not based on quantitative measures of ground displacement, velocity or acceleration.

The Mercalli Intensity Scale was devised before accurate seismometers were widespread!

Instrumental intensity: use seismograms to estimate what the Mercalli intensity was.

Modified Mercalli Intensity Scale: I to XII

Example: VII "Strong"

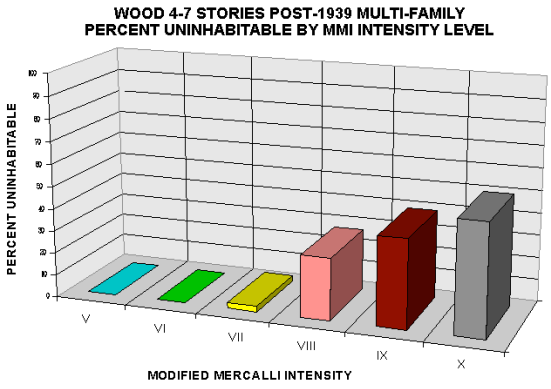
Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

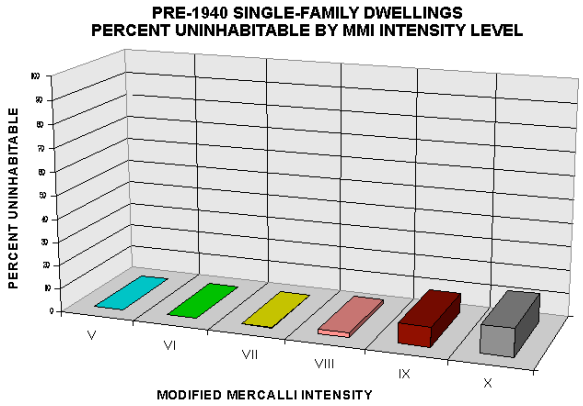
Masonry A: Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.
Masonry B: Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C: Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.
Masonry D: Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

Mercalli scale was originally devised (and refined) 1883-1902, modified 1931 and 1958

Full descriptions is from: Richter, C.F., 1958. ***Elementary Seismology.*** W.H. Freeman and Company, San Francisco, pp. 135-149; 650-653.

Why bother with intensity?





- emergency response planning, insurance, loss estimating
- inferring magnitude from subjective historical accounts (such as the Lawson Report on the 1906 SF earthquake)

USGS PAGER program: estimates population exposure to various intensities, and damage (in dollars). Based on rapid instrumental intensity and database of building types. Estimates within 30 minutes.

Generally, maximum intensity correlates with magnitude

Magnitude / Intensity Comparison

Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 - 3.0	I
3.0 - 3.9	II - III
4.0 - 4.9	IV - V
5.0 - 5.9	VI - VII
6.0 - 6.9	VII - IX
7.0 and higher	VIII or higher

Table 3.6 Magnitude versus Length of Shaking

Magnitude	Duration of Strong Ground Shaking in Seconds
8–8.9	30 to 90
7–7.9	20 to 50
6–6.9	10 to 30
5–5.9	2 to 15
4–4.9	0 to 5

But proximity to the *epicenter*, local amplification of shaking, and other effects can make violence and duration of shaking worse than expected

Earthquakes can be unusually devastating due to either
(1) high intensities in areas with high populations
or
(2) other events caused by the earthquake (landslides, fires, tsunamis, etc.) also poor construction.

Bam, IRAN 2003

Kobe Japan, 1995

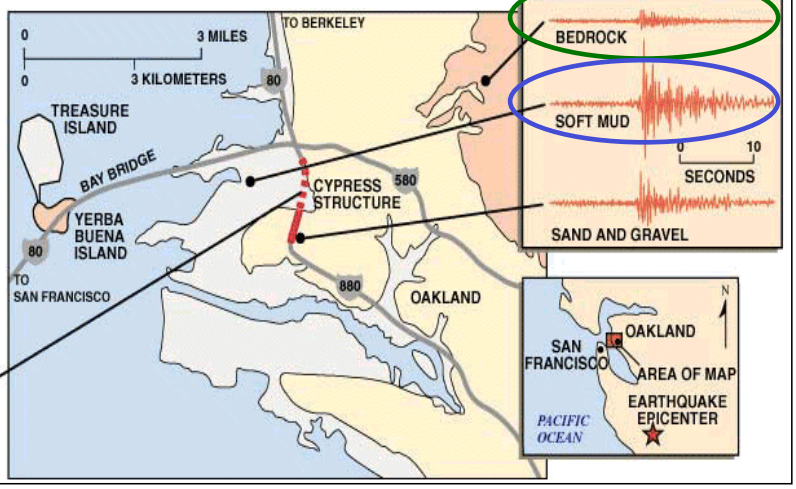
1995 Kobe earthquake

Both:
Magnitude only 6.7 to 6.9 but Mercalli intensity of IX or more in very populous areas
extreme damage and thousands of deaths

Earthquake Intensity: Effect of ground type

- Harder rocks
  - no amplification
  - a mixture of frequencies
- Softer rocks
  - shaking is amplified
  - low-frequencies may reverberate in basins, plus soft rocks absorb high frequencies

http://wrgis.wr.usgs.gov/fact-sheet/fs151-99/

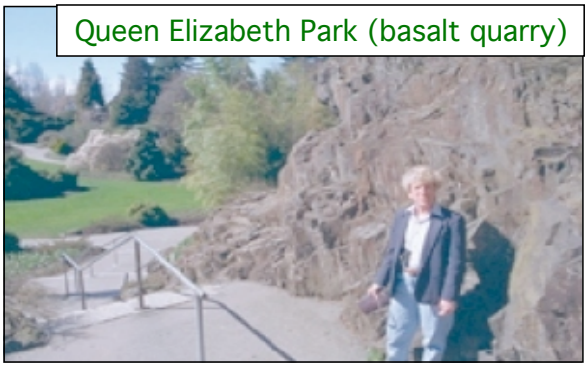


Ground type in Vancouver

- Harder rocks (bedrock - North Vancouver)
  - no amplification
  - all (high and low) frequencies present
- Softer rocks (sediments - Richmond)
  - much amplification
  - loss of high frequency wave energy
  - reverberating low frequency waves

Which area might shake more in an earthquake?

Tidal mud, Richmond



Queen Elizabeth Park (basalt quarry)

Photos by J. Clague

Buildings in central Kobe, Japan.

Foreground: The complete collapse of a two- or three-story traditional Japanese wood-frame building with a heavy tile roof.

Background: A six- or seven-story office building of 1960s' or 1970s' vintage. This reinforced concrete building is a typical example of a mid-height story collapse.

Left: The high rise is post-1981 office building that has no apparent damage. Ground settlement in the vicinity of these buildings was between 30 and 60 centimeters.

The January 17, 1995 Kobe Earthquake. An EQE Summary Report, April 1995 at http://www.eqe.com/publications/kobe/building.htm

Student interests

- Why / how earthquakes occur (4)
- Predicting earthquakes (3)
- One each: Local hazard in Vancouver, effects worldwide, tsunami creation, current events, preparation and reaction, how earthquakes change the Earth

Intensity estimates come from

- felt reports from people (e.g., USGS "Did You Feel It" online questionnaires, generates "community internet intensity map")
- felt reports from seismometers (e.g., USGS ShakeMap, generates "rapid instrumental intensity map" from seismograms)

Part of the USGS "Did You Feel It" questionnaire

While answering all these questions is optional, we encourage you to fill out as many as possible so we can provide a more accurate intensity estimate.

What was your situation during the earthquake? No answer

If you were inside please select the type of building or structure:

No building

If other, please describe:

Were you asleep during the earthquake?

No

Did you feel the earthquake? (If you were asleep, did the earthquake wake you up?)

☐ No ☐ Yes

Did others nearby feel the earthquake?

No answer/Don't know /Nobody else nearby

Your experience of the earthquake:

How would you best describe the ground shaking? No description

About how many seconds did the shaking last?

How would you best describe your reaction? No answer/Don't remember

How did you respond? (Select one.) No answer/Don't remember

If other, please describe:

Was it difficult to stand or walk? No answer/Did not try

Earthquake effects:

Did you notice the swinging/swaying of doors or hanging objects? No answer/Did not look

Did you notice creaking or other noises? No answer/Did not pay attention

Did objects rattle, topple over, or fall off shelves? No answer/No shelves

Did pictures on walls move or get knocked askew? No answer/No pictures

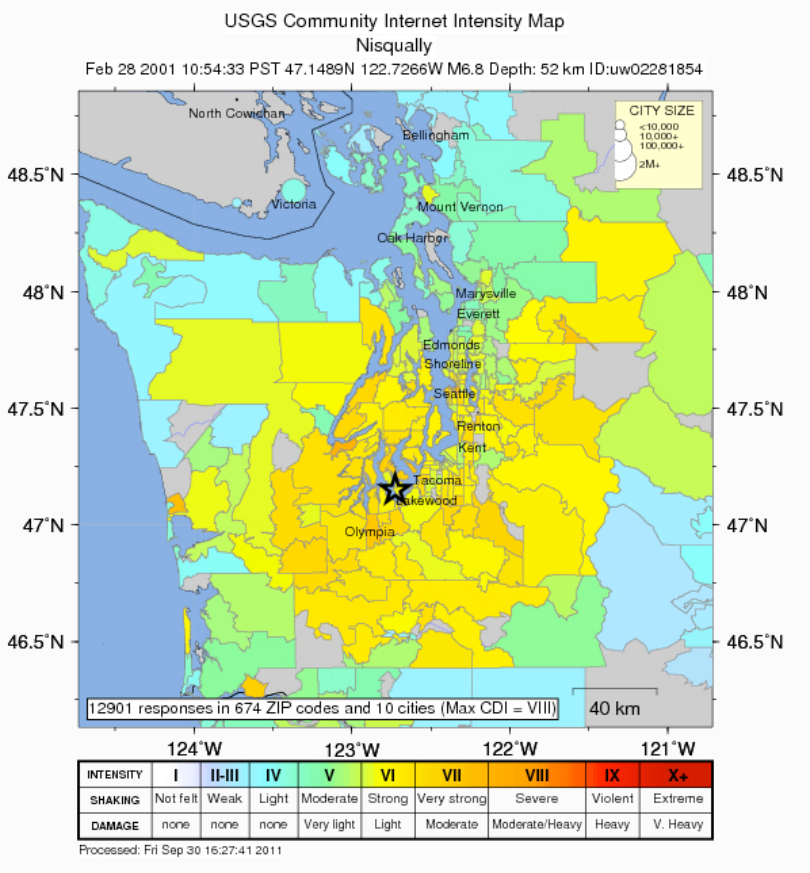
Did any furniture or appliances slide, tip over, or become displaced? No answer/No furniture

Was a heavy appliance (refrigerator or range) affected? No answer/No heavy appliance

Were free-standing walls or fences damaged? No answer/No walls

If you were inside, was there any damage to the building? Check all that apply.

- ☐ No damage
- ☐ Hairline cracks in walls
- ☐ A few large cracks in walls
- ☐ Many large cracks in walls
- ☐ Ceiling tiles or lighting fixtures fell
- ☐ Cracks in chimney
- ☐ One or several cracked windows
- ☐ Many windows cracked or some broken out
- ☐ Masonry fell from block or brick wall(s)
- ☐ Old chimney, major damage or fell down
- ☐ Modern chimney, major damage or fell down
- ☐ Outside wall(s) tilted over or collapsed completely



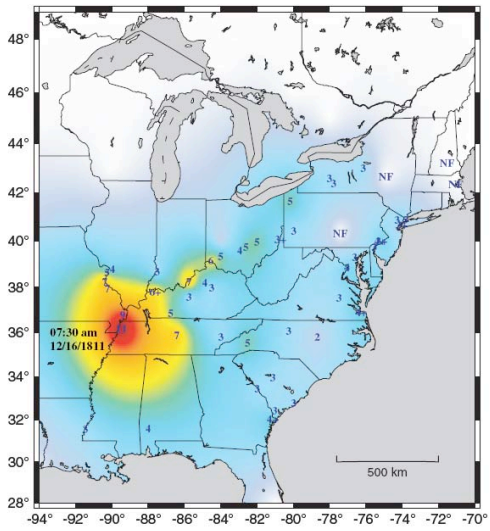
28 February 2001
M 6.8 Nisqually
Earthquake

Five of you
felt this
earthquake here
in Vancouver

KPLU

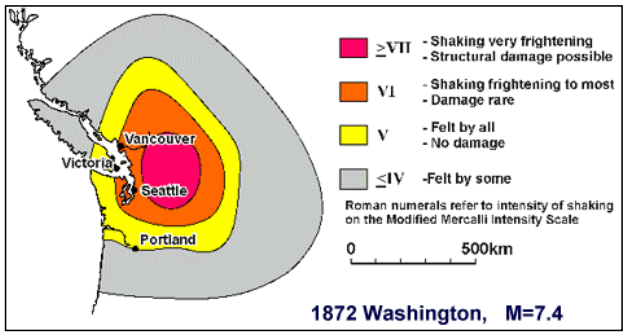
Joe Hull

Mercalli intensity for 1811-1812 New Madrid and 1872 Washington-BC earthquakes, based on historical accounts



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

▲ **Figure 3.** Shaking intensity map for event NM1-A.

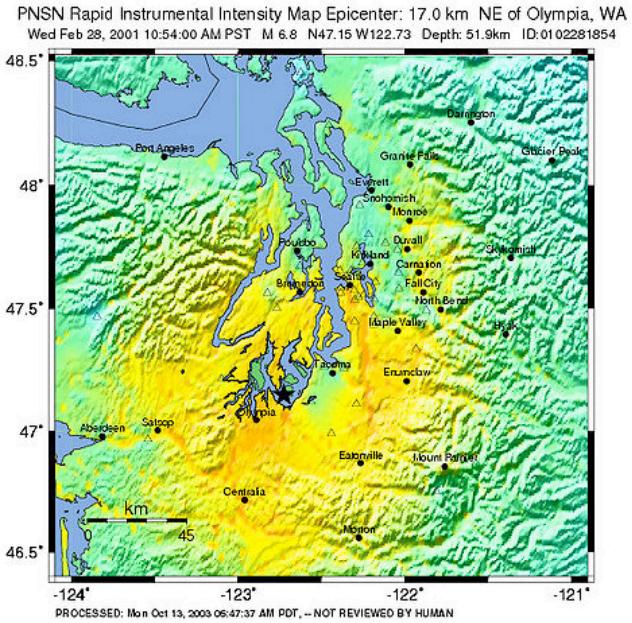


USGS ShakeMap: instrumental intensity

uses records from seismographs

computer automatically generates a map of inferred intensity within minutes

used for emergency response (PAGER)



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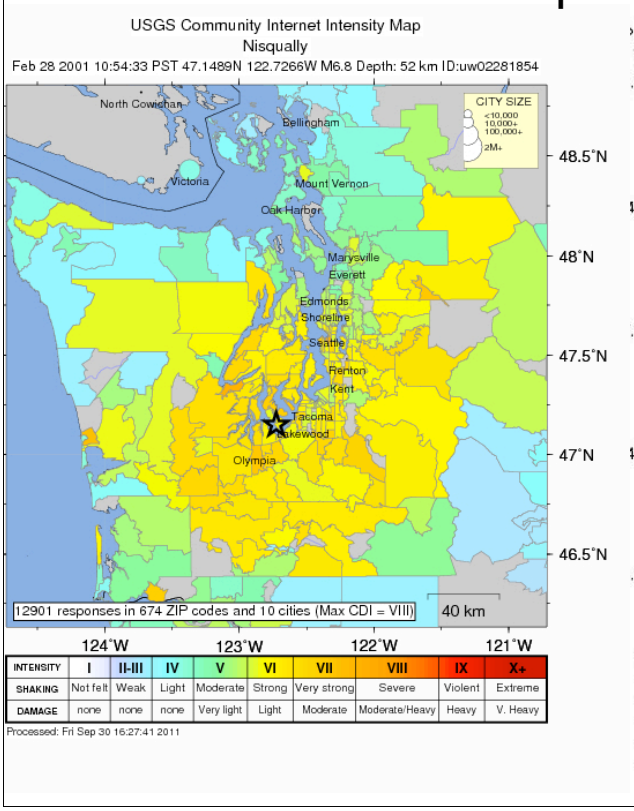
Comparison



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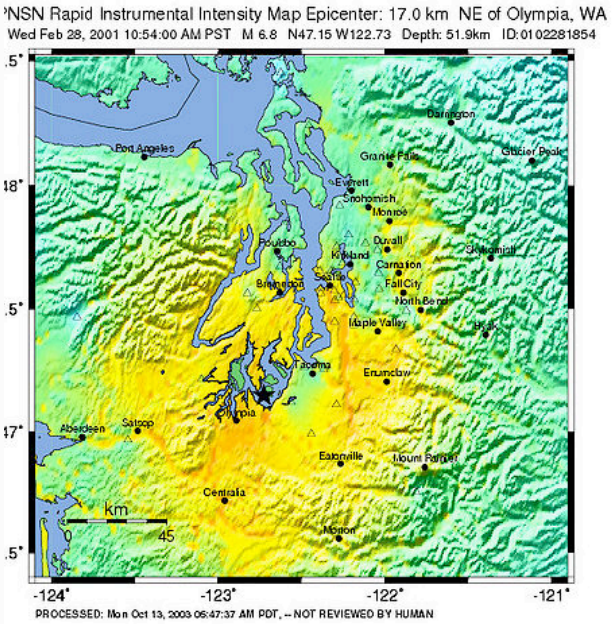

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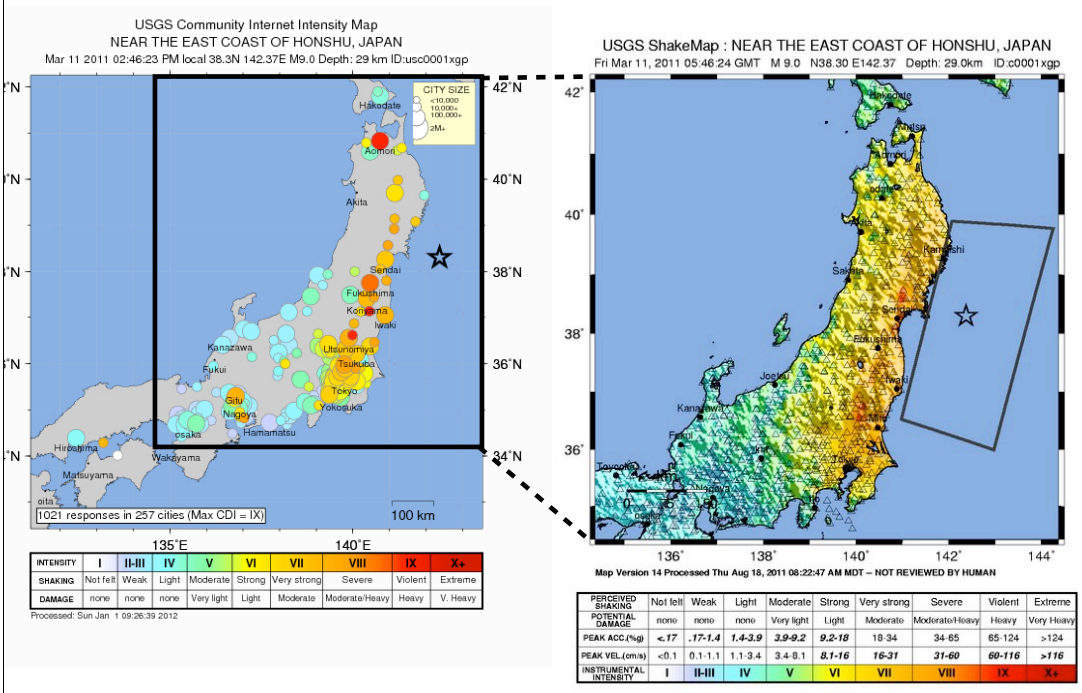
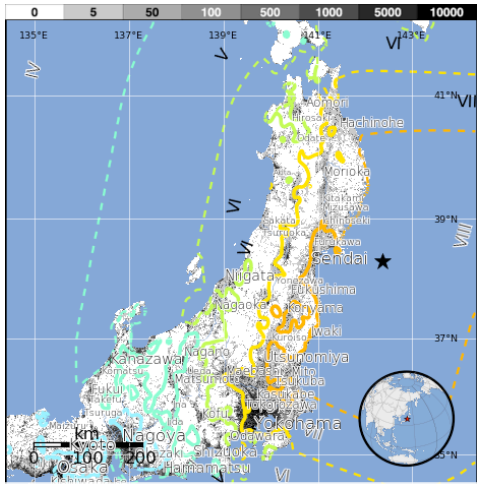
Community intensity and instrumental intensity maps: Tohoku earthquake



USGS PAGER results: Tohoku

PAGER - Prompt Assessment of Global Earthquakes for Response

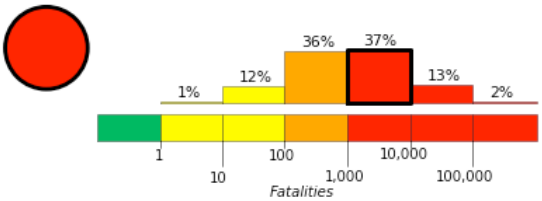


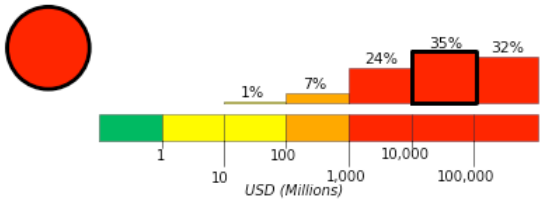
Selected Cities Exposed

from GeoNames Database of Cities with 1,000 or more residents.

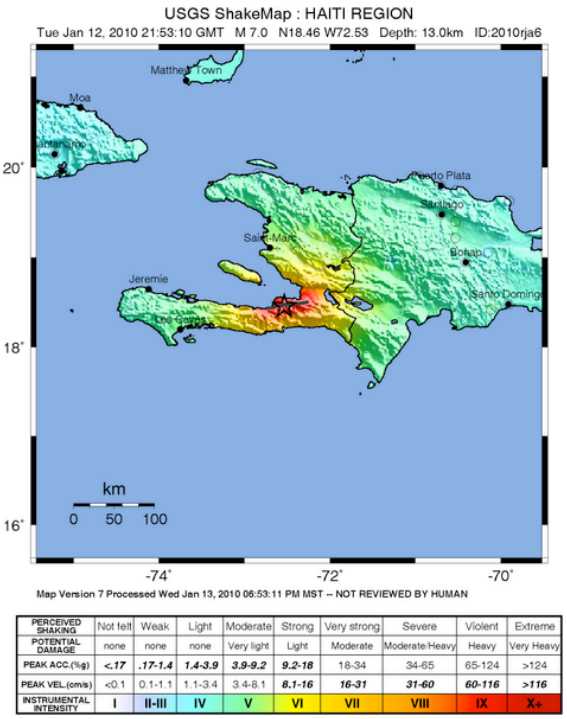
MMI	City	Population
IX	Iwanuma	42k
IX	Furukawa	76k
IX	Hitachi	186k
IX	Takahagi	34k
VIII	Karasuyama	18k
VIII	Shiogama	60k
VIII	Sendai	1,038k
VIII	Chiba	920k
VIII	Mito	247k
VII	Yokohama	3,574k
VII	Utsunomiya	450k

(k = x1,000)





2010 Haiti Earthquake Intensity



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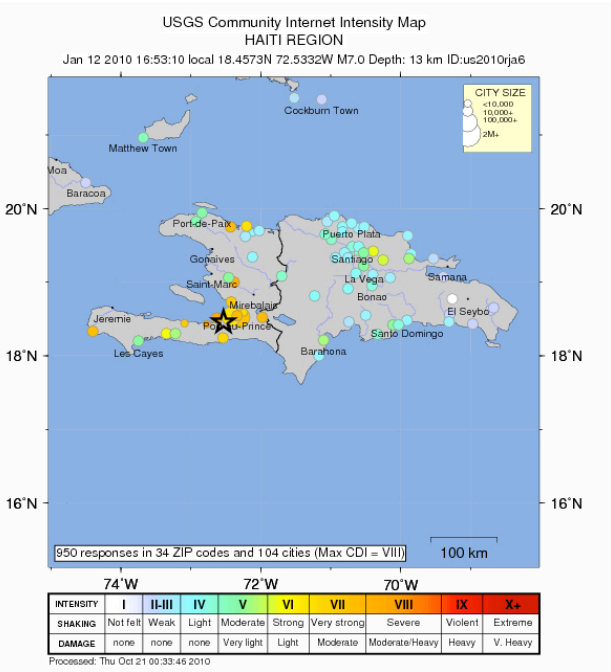

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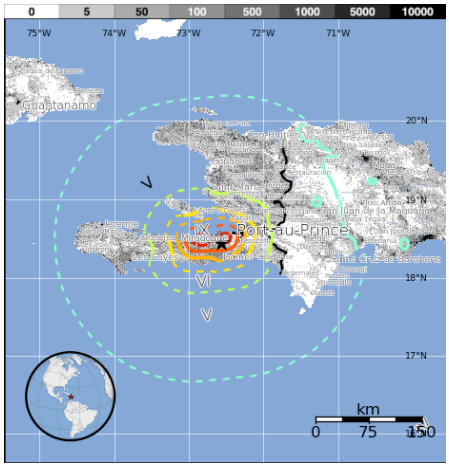
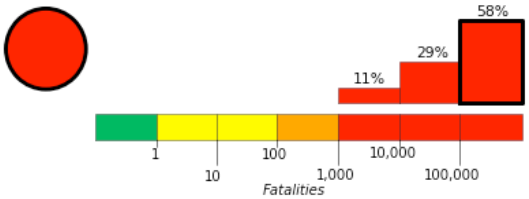
USGS PAGER results: Haiti earthquake

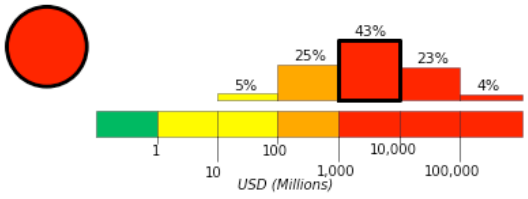


Selected Cities Exposed

from GeoNames Database of Cities with 1,000 or more residents.

MMI	City	Population
X	Petit Goave	118k
X	Grand Goave	49k
X	Gressier	26k
IX	Leogane	134k
VIII	Port-au-Prince	1,235k
VIII	Carrefour	442k
VIII	Delmas 73	383k
VIII	Miragoane	89k
V	Verrettes	49k
IV	Santo Domingo	2,202k
IV	Santiago de los Caballeros	556k





Probability of shaking at different Mercalli intensities, BC, in the next 100 years

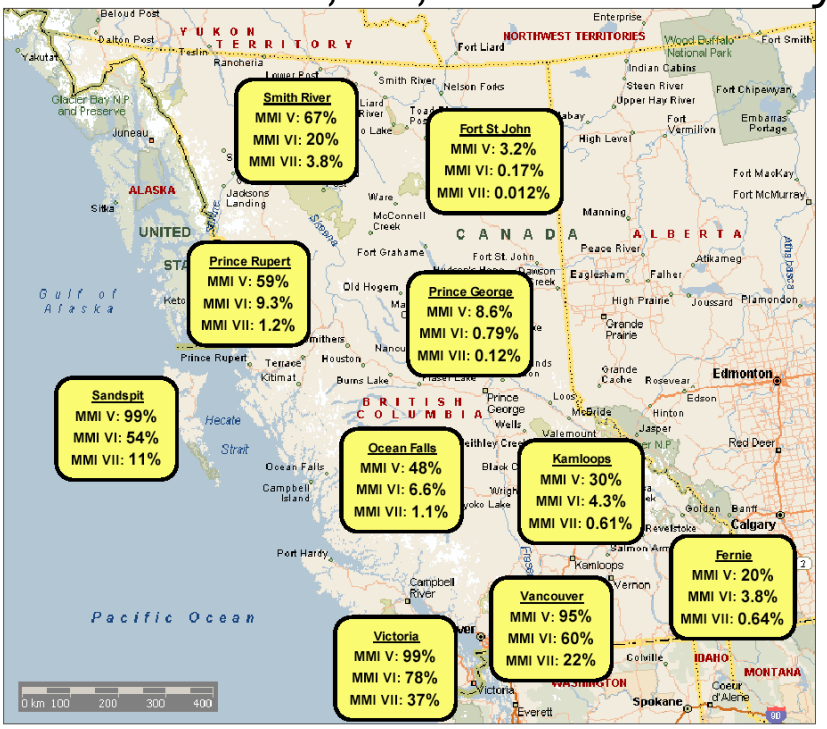


Figure 5. Distribution of earthquake shaking probabilities in BC within a 100-year period (for firm ground)

Onur and Seeman, 2004

http://www.pgc.nrcan.gc.ca/seismo/person/people/pubs/13WCEE1065.pdf

These are minimum values: numbers will be higher on softer ground