

EARTHQUAKE CASE HISTORIES II (08)

- I Main Topics for next two lectures
 - A Recognition of earthquake hazards from case histories
 - B Key Lessons
 - C Key questions regarding characterization of earthquakes and faulting

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II Case Histories

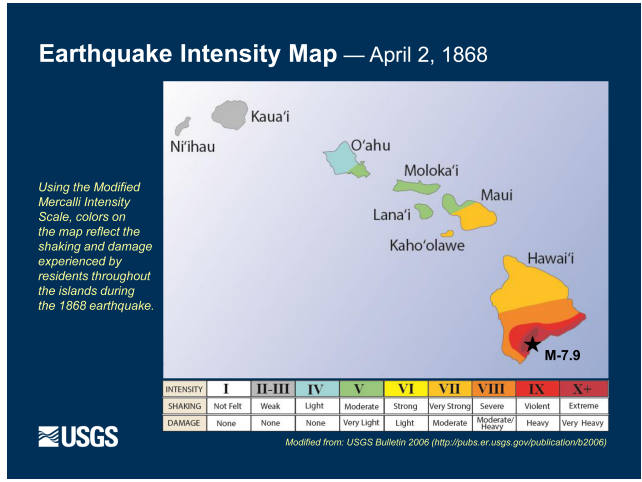
- A Kau, HI, 1868
- B Alaska, 1946
- C Chile, 1960
- D Kalapana, HI, 1975
- E Kiholo Bay, HI, 2006
- F Tohoku, Japan, 2011

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A Kau Earthquake 4/2/1868, M ≈ 7.9



http://hvo.wr.usgs.gov/products/PPT_EQ%20in%20Hawaii_2014.pdf

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A Kau Earthquake 4/2/1868, M ≈ 7.9

The April 2, 1868, earthquake...

- ◆ destroyed houses, toppled stone walls, opened ground cracks, and threw people off their feet.
- ◆ killed at least 77 people.
- ◆ generated a **tsunami**. A wave up to 18 m (60 ft) high along the Ka'ū-Puna coast resulted in 46 deaths.
- ◆ triggered multiple **landslides**, including one in Ka'ū's Wood Valley, where 31 people died.
- ◆ induced short-lived **eruptions** on Kīlauea and Mauna Loa.

Source: Titus Coan, Scribner's Monthly, 1871

If this earthquake occurred today, damages could cost as much as:
\$ 500 million

Source: PDC's Hawaii HAZUS Atlas
<http://apps.pdc.org/hawaii/hazsumsummary.jsp>

USGS

http://hvo.wr.usgs.gov/products/PPT_EQ%20in%20Hawaii_2014.pdf

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B Alaska, 1946 (April 1)

$M_w = 8.1$; 165 killed; 159 killed in Hawaii



http://en.wikipedia.org/wiki/1946_Aleutian_Islands_earthquake

<https://www.youtube.com/watch?v=gcaR7tDKlq8>

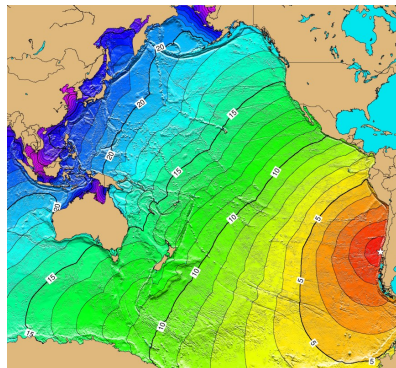
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C Chile, 1960

$M_w = 9.5$; 61 killed in Hilo by tsunami



http://en.wikipedia.org/wiki/1960_Valdivia_earthquake#Tsunami

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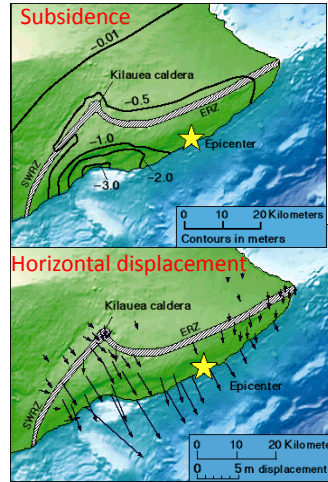
C Kalapana, Hawaii

4:48 AM, November 29, 1975; M=7.7

- 1 Maximum subsidence along coast: 3.5 m
- 2 Earthquake caused by deep-seated failure of SE flank of Kilauea
- 3 Triggered eruption at Kilauea at 5:32 AM



<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/eruption.html>
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<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/deformation.html>
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C Kalapana, Hawaii

4:48 AM, November 29, 1975; M=7.7

- 4 Damage estimate: \$4 million (~\$13 million in 1999 dollars)

Spilled merchandise in Hilo supermarket

Damaged home about 7 km north of Hilo



<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/damages.html> http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/market_1.jpg

C Kalapana, Hawaii

4:48 AM, November 29, 1975; M=7.7

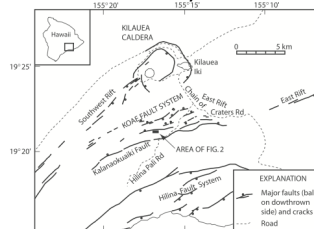
5 Surface rupture along Koae fault system and Hilina fault system

Reactivated scarp along Hilina Pali

Crack in Hilina Pali Road



Location of Koae and Hilina fault systems



From Martel and Langley, 2006



<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/damages.html>
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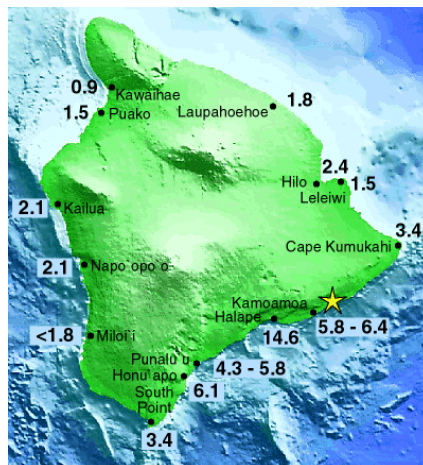
<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/deformation.html>
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C Kalapana, Hawaii

4:48 AM, November 29, 1975; M=7.7

6 Maximum tsunami height 12.2-14.6 m, at Keauhou Landing

House in Punalu'u demolished by tsunami



<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/tsunami.html>

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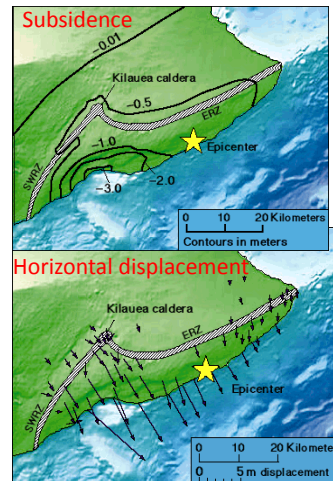
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C Kalapana, Hawaii

4:48 AM, November 29, 1975; $M=7.7$

- 7 Earthquake similar to April 2, 1868 earthquake
- 8 Two "1906" earthquakes in 90 years on Big Island



<http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/deformation.html>
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D Kiholo Bay, Hawaii

7:08 AM, November 29, 1975; $M_w=6.7$

- Date October 15, 2006
- Origin time 17:07:49 UTC
- Magnitude 6.7 M_w
- Depth 29 kilometers (18 mi)
- Epicenter [Coordinates: 19.89°N 156.07°W](#)
- Areas affected [Hawaii, United States](#)
- Max. intensity VIII (*Severe*)
- Tsunami Yes
- Aftershocks 6.1 M_w Oct 15 at 17:14 UTC
- Casualties: None

http://en.wikipedia.org/wiki/2006_Hawaii_earthquake

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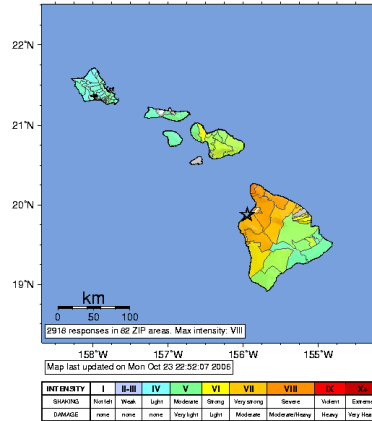
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D Kiholo Bay, Hawaii

7:08 AM, November 29, 1975; Mw=6.7

1 Earthquake attributed flexure of oceanic crust from load of Big Island

USGS Community Internet Intensity Map (10 miles NNW of Kailua Kona, Hawaii, Hawaii)
ID:twbh_05_07:07:48 HST OCT 15 2006 Mag=6.7 Latitude=N19.68 Longitude=W155.94



D Kiholo Bay, Hawaii

7:08 AM, November 29, 1975; Mw=6.7

2 >\$200 million in damage

Road damage, Pololu Valley (Kahala)



Kalahikiola Congregational Church (Kohala)



<http://www.geotimes.org/feb07/geophen.html>

D Kiholo Bay, Hawaii

7:08 AM, November 29, 1975; Mw=6.7

- 3 Power outages on Oahu, Big Island, and Maui
- 4 Honolulu Airport temporarily closed

Power outage, Manoa Valley Safeway



<http://archives.starbulletin.com/2006/10/16/news/art2bx.jpg>
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Delays at Honolulu Airport



<http://archives.starbulletin.com/2006/10/16/news/art3x.jpg>
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D Kiholo Bay, Hawaii

7:08 AM, November 29, 1975; Mw=6.7

- 4 Many rock falls on Hawaii

Rock fall between Ka`aha and Halape



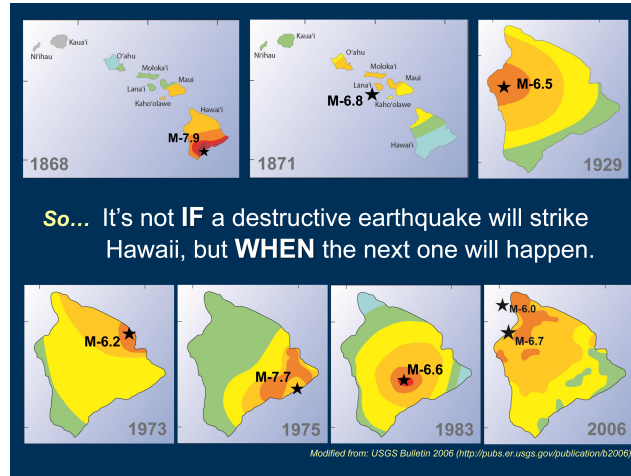
http://hvo.wr.usgs.gov/volcanowatch/archive/2008/08_12_24.html
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Rock fall at Waipio Valley



http://en.wikipedia.org/wiki/2006_Hawaii_earthquake
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Major Earthquakes in Hawaii since 1868



http://hvo.wr.usgs.gov/products/PPT_EQ%20in%20Hawaii_2014.pdf

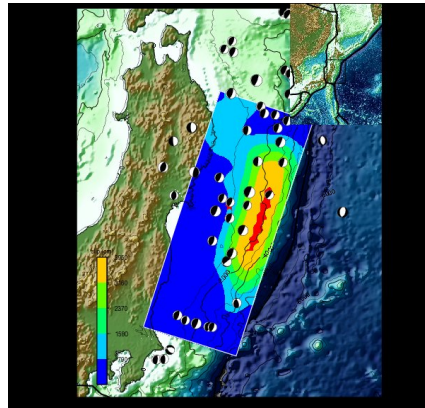
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E Tohoku, Japan

- Date 11 March 2011
- Origin time 14:46:24 [JST \(UTC+09:00\)](#)
- Duration 6 minutes
- Magnitude 9.0 ([M_w](#))
- Depth 30 km (19 mi)
- Epicenter [Coordinates: 38.322°N 142.369°E](#)
- Type [Megathrust earthquake](#)
- Total damage Tsunami wave, flooding, landslides, fires, building and infrastructure damage, nuclear incidents including radiation releases
- Max. intensity [IX - Violent](#)
- Peak acceleration 2.99 [g](#)
- Tsunami Up to 40.5 m (133 ft) in [Miyako, Iwate, Tōhoku](#)
- Foreshocks 7
- Aftershocks 11,106 (as of 7 September 2014)
- Casualties 15,889 deaths, 6,152 injured, 2,601 people missing



<http://www.newscientist.com/blogs/shortsharpscience/2011/03/giant-quake-was-small-for-its.html>

http://en.wikipedia.org/wiki/2011_Tōhoku_earthquake_and_tsunami#cite_note-Asahi-ERI-Takashi-1

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E Tohoku, Japan Severe shaking for 2-3 minutes



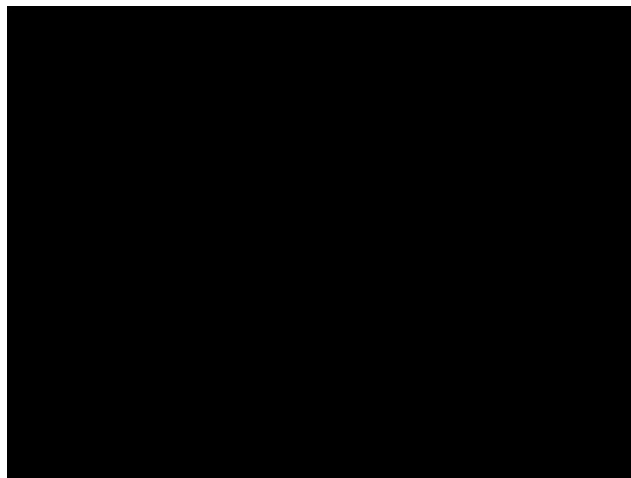
https://www.youtube.com/watch?v=PZvjJs_qkA&list=PLD216A99B9F7583D9

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E Tohoku, Japan Tsunami



<https://www.youtube.com/watch?v=w3AdFjIR50&spfreload=10>

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E Tohoku, Japan Tsunami overwhelms seawall at Miyako



<https://www.youtube.com/watch?v=5-zfCBCq-8I>

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E Tohoku, Japan Tsunami overwhelms seawall



<https://www.youtube.com/watch?v=m13A17b2Q4&index=21&list=PLD216A9989F7583D9&spfreload=10>

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E Tohoku, Japan

- 1 Collateral damage in Japan
 - a Tsunami
 - b Nuclear power plants
 - i Fukushima disaster (Level 7 event)
 - ii Fire and small coolant loss at Inagawa plant
 - iii Partial power loss at Tokai plant
 - c Multiple power plants damaged
 - d Oil refinery burned for 10 days
 - e Sendai liquefied natural gas (LPG) plant in severely damaged
 - f Severe disruption to transportation systems
 - 1 Sendai airport
 - 2 Tohoku expressway
 - 3 Various train services
 - g All Japanese ports temporarily closed
 - h Fujinuma irrigation dam failed
 - i Telecommunications failed
 - j National defense- Matsushima Air field flooded
 - k Many fires
 - l Debris: ~25 million tons

http://en.wikipedia.org/wiki/2011_Tōhoku_earthquake_and_tsunami#Japan

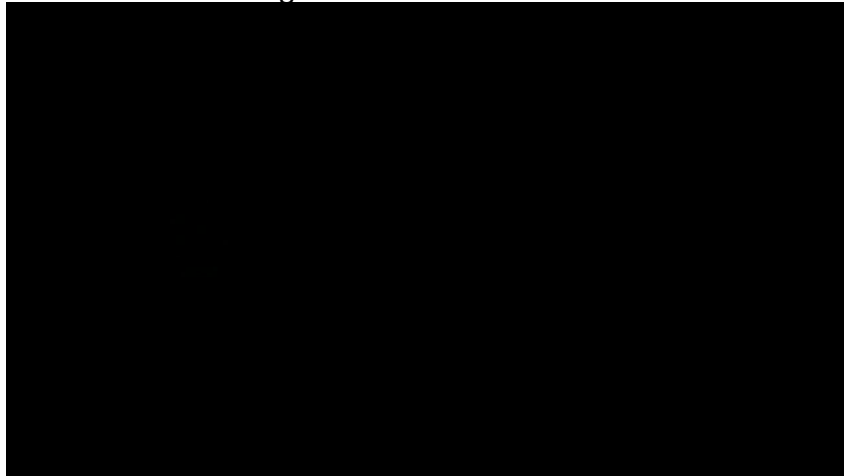
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E Tohoku, Japan

2 Collateral damage in Hawaii



<https://www.youtube.com/watch?v=IOSulxinFkQ>

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III Key Lessons

A Recognition

- 1 Major earthquakes in Hawaii not recognized until 1868
- 2 Hawaiian tsunami hazard not recognized until 1946
- 3 Japan earthquake and tsunami hazards long recognized
- 4 Hawaii faces major and varied seismic hazards

B Characterization failures

- 1 1960 Hilo tsunami
- 2 2011 tsunami
- 3 Adequate characterization, required to adequately evaluate seismic hazard and to assess whether the risk is acceptable

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IV Some key characterization questions

- A What controls earthquake size?
- B What dictates ground response to seismic waves?
- C What controls buildings respond to seismic waves?
- D How can we predict when and where an earthquake is likely to occur?
- E What is the uncertainty associated with the predictions?

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