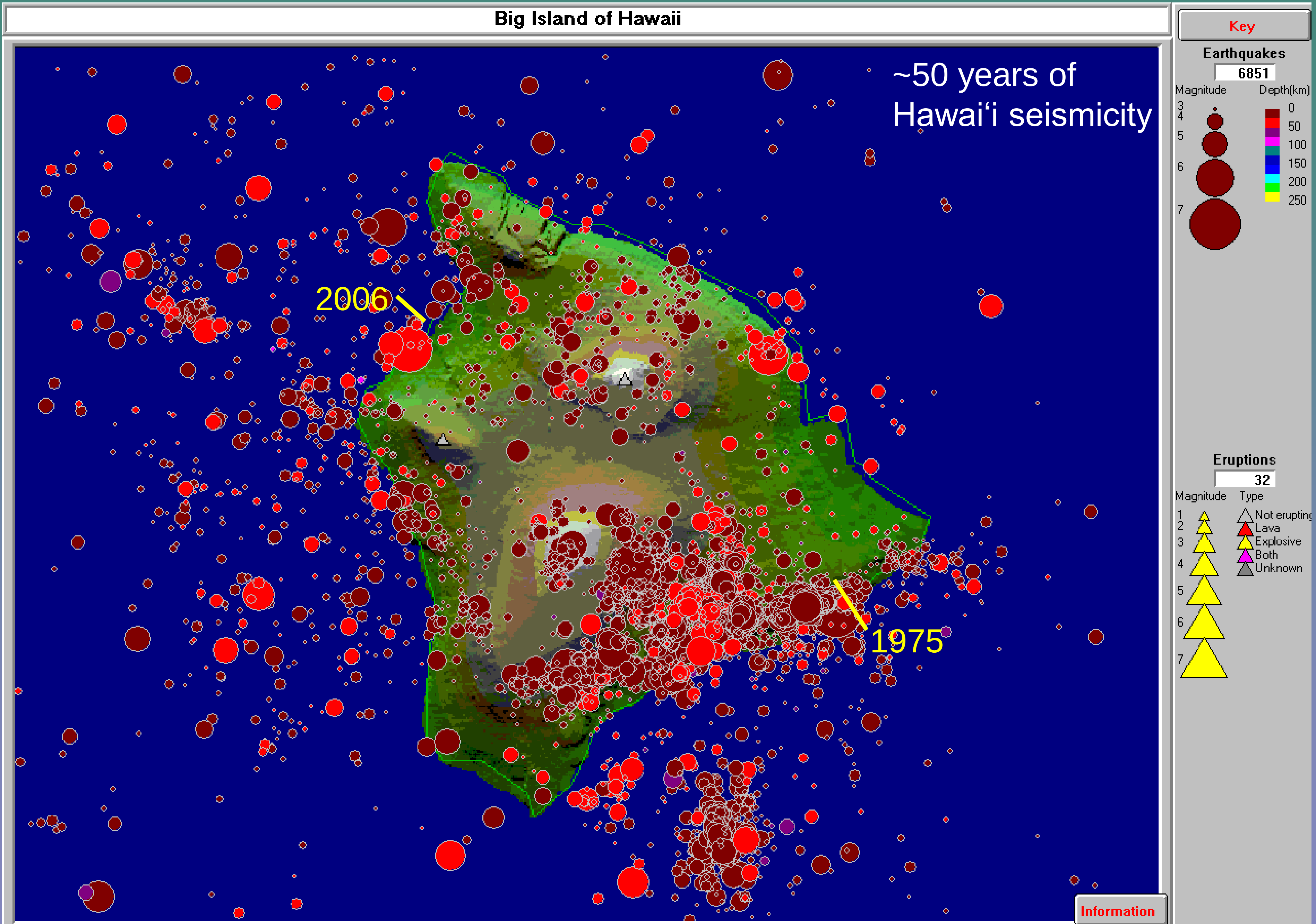
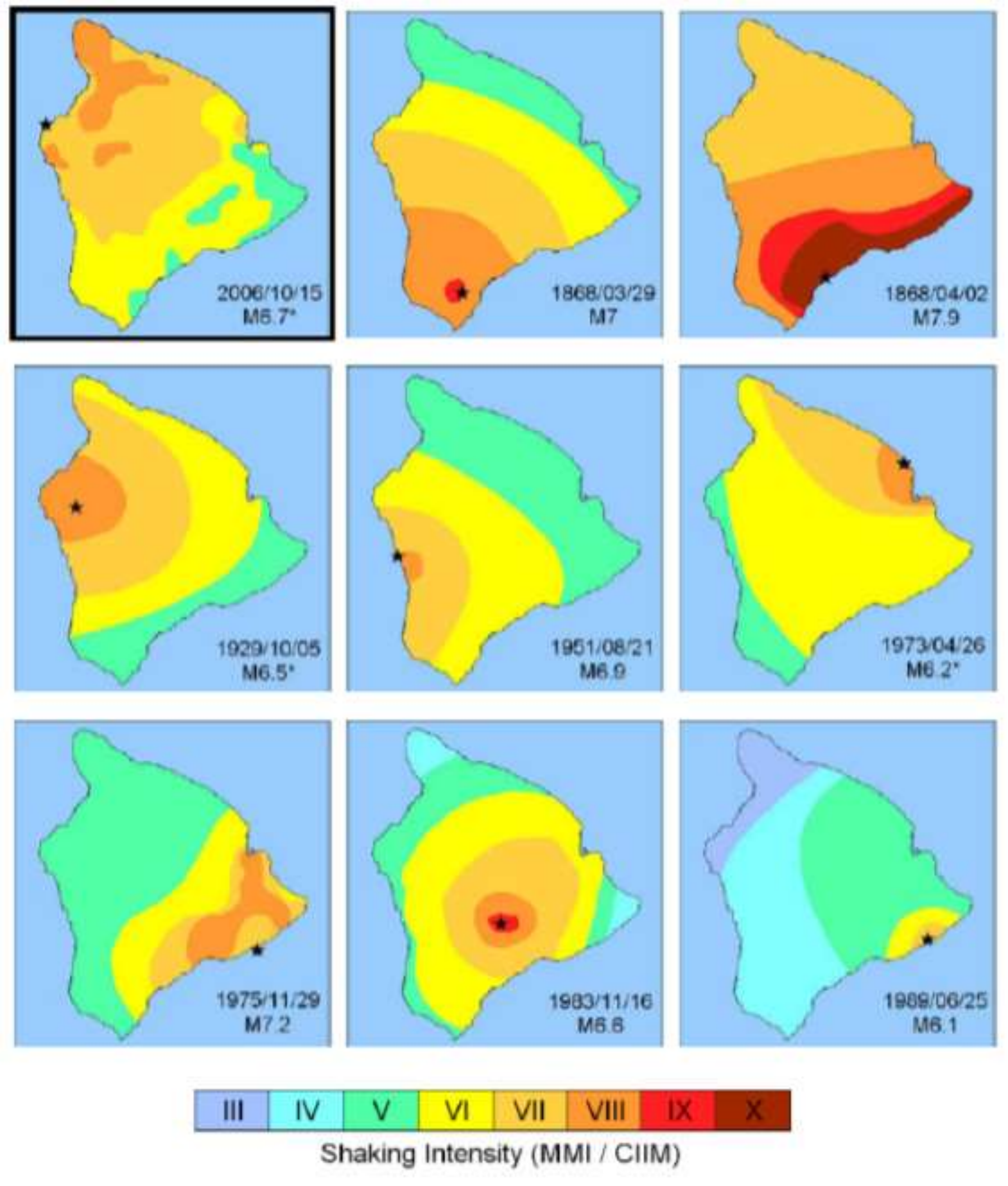
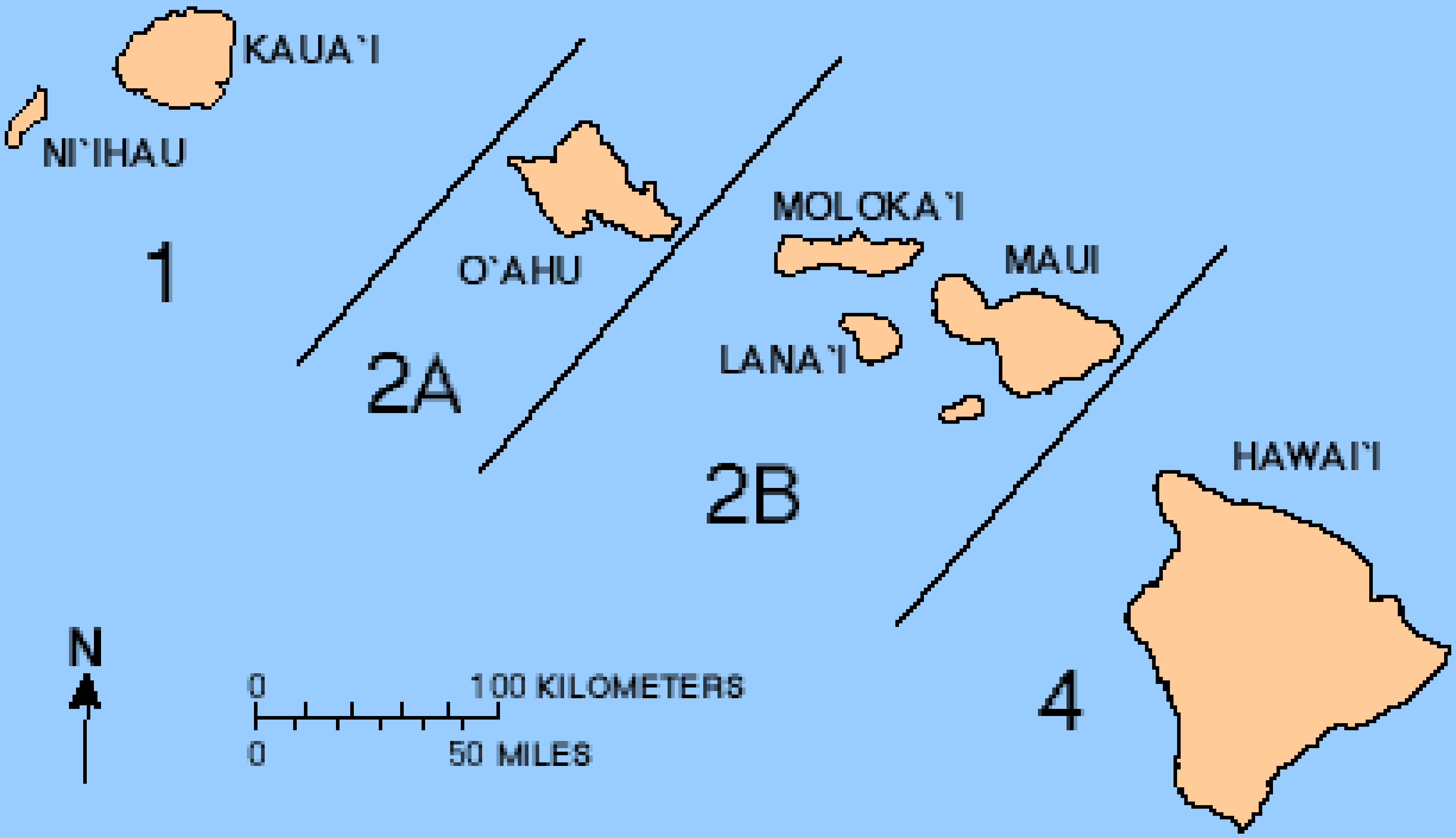
EARTHQUAKES AND TSUNAMI IN HAWAI‘I (GG103)



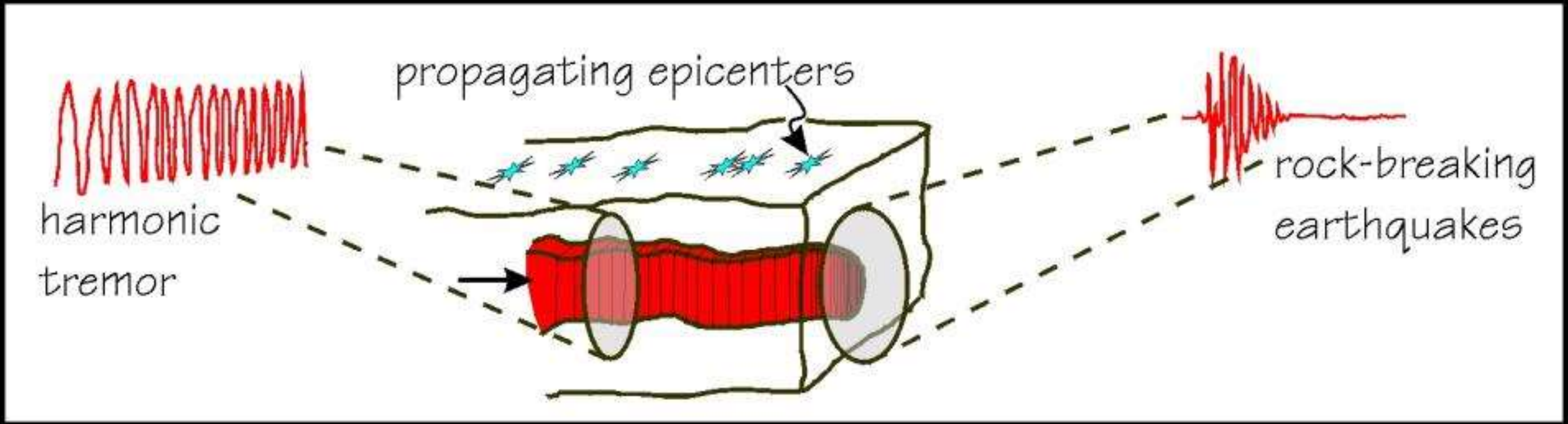


From: 2006 Kiholo Bay, Hawaii Earthquake, RMS Event Report

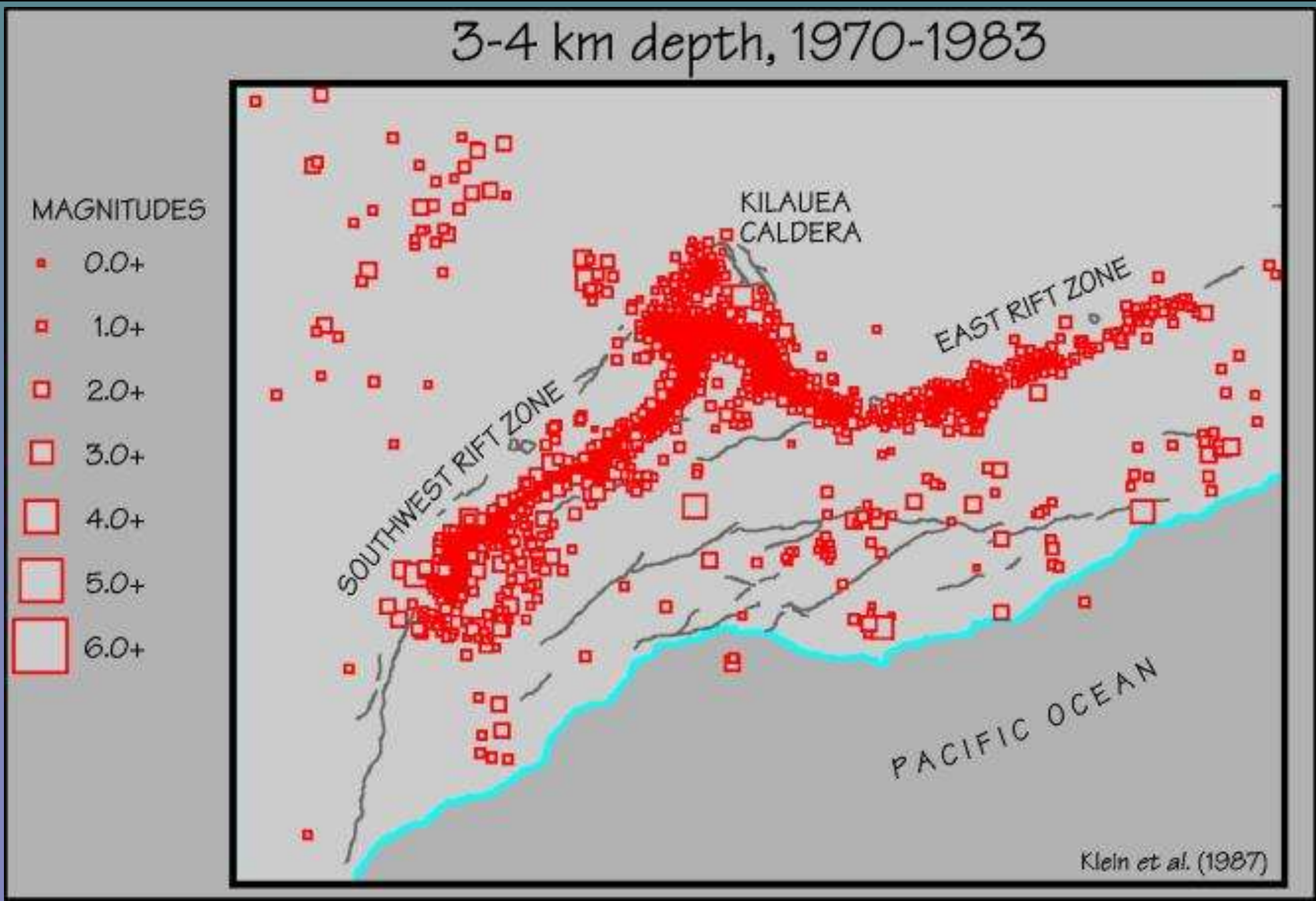
Earthquake hazard zones, used mainly for building codes



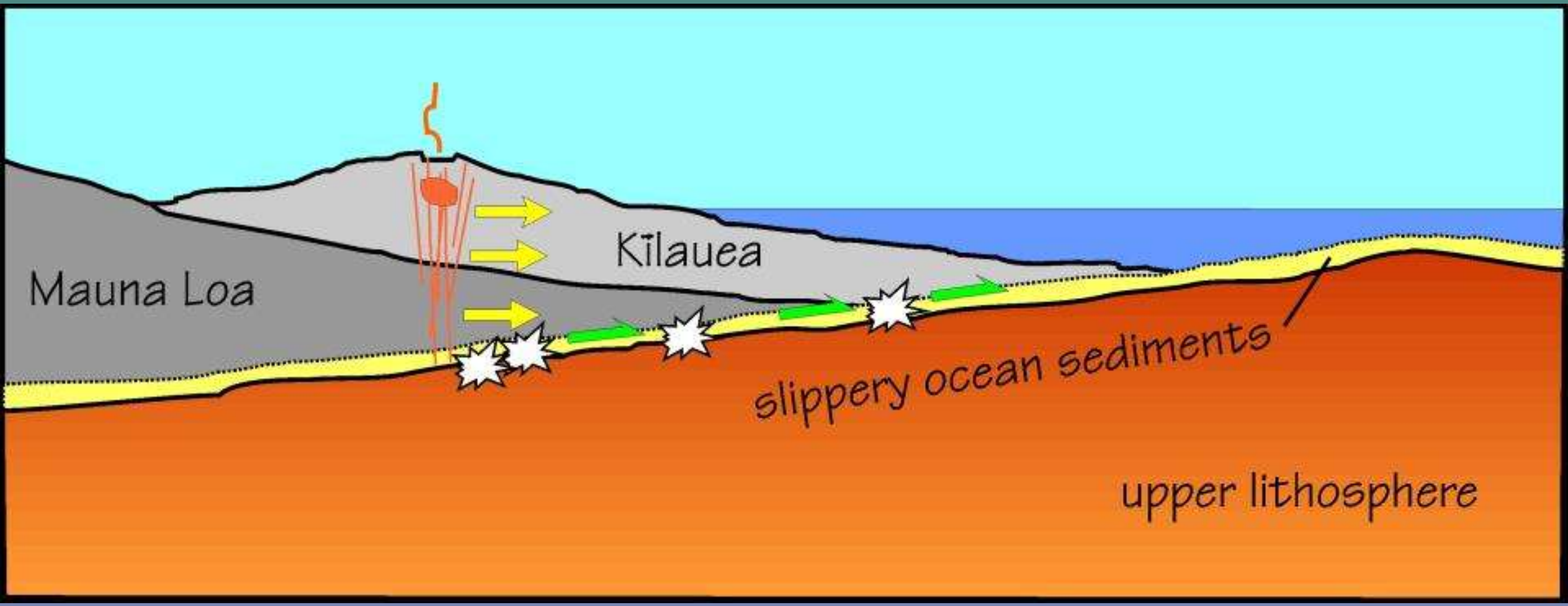
http://hvo.wr.usgs.gov/earthquakes/hazards/hazardmap.gif



The most numerous Hawai‘i earthquakes are caused by propagating dikes in rift zones. But they are very small.



Bigger, more serious Hawaiʻi earthquakes occur when the south flank of Kīlauea and the southeast or southwest flanks of Mauna Loa slide seaward due to accumulated strain caused by dikes intruding down rift zones.



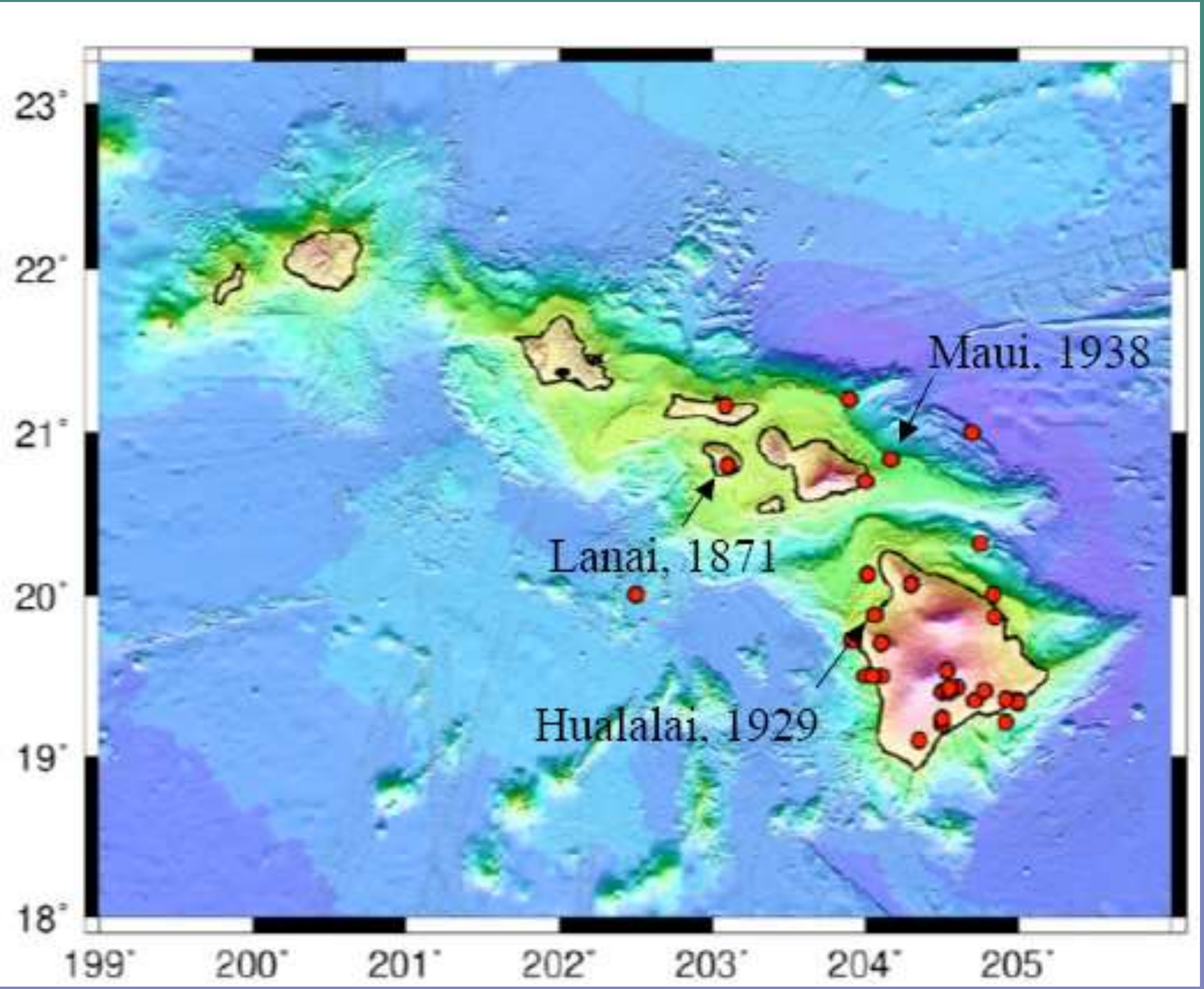
Examples:
1868 Kaʻū (M > 8?)
1951 Kona (M = 6.9)
1975 Kalapana (M = 7.2)

An account of the 1868 Kaʻū earthquake

"About ten o'clock A.M. on the 28th (Saturday), a series of earthquakes began…From this time until the 10th of April the earth was in an almost constant tremor. In the district of Kona as many as fifty or sixty distinct shocks were counted in one day; in Kau over three hundred in the same time; while near Kilauea and about Kapapala it was difficult to count them…The culminating shock came on Thursday, April 2nd, at twenty minutes before four in the afternoon. Every stone wall, almost every house, in Kau was overturned, and the whole was done in an instant. A gentleman riding found his horse lying flat underhim before he could think of the cause, and persons were thrown to the ground in an equally unexpected manner…

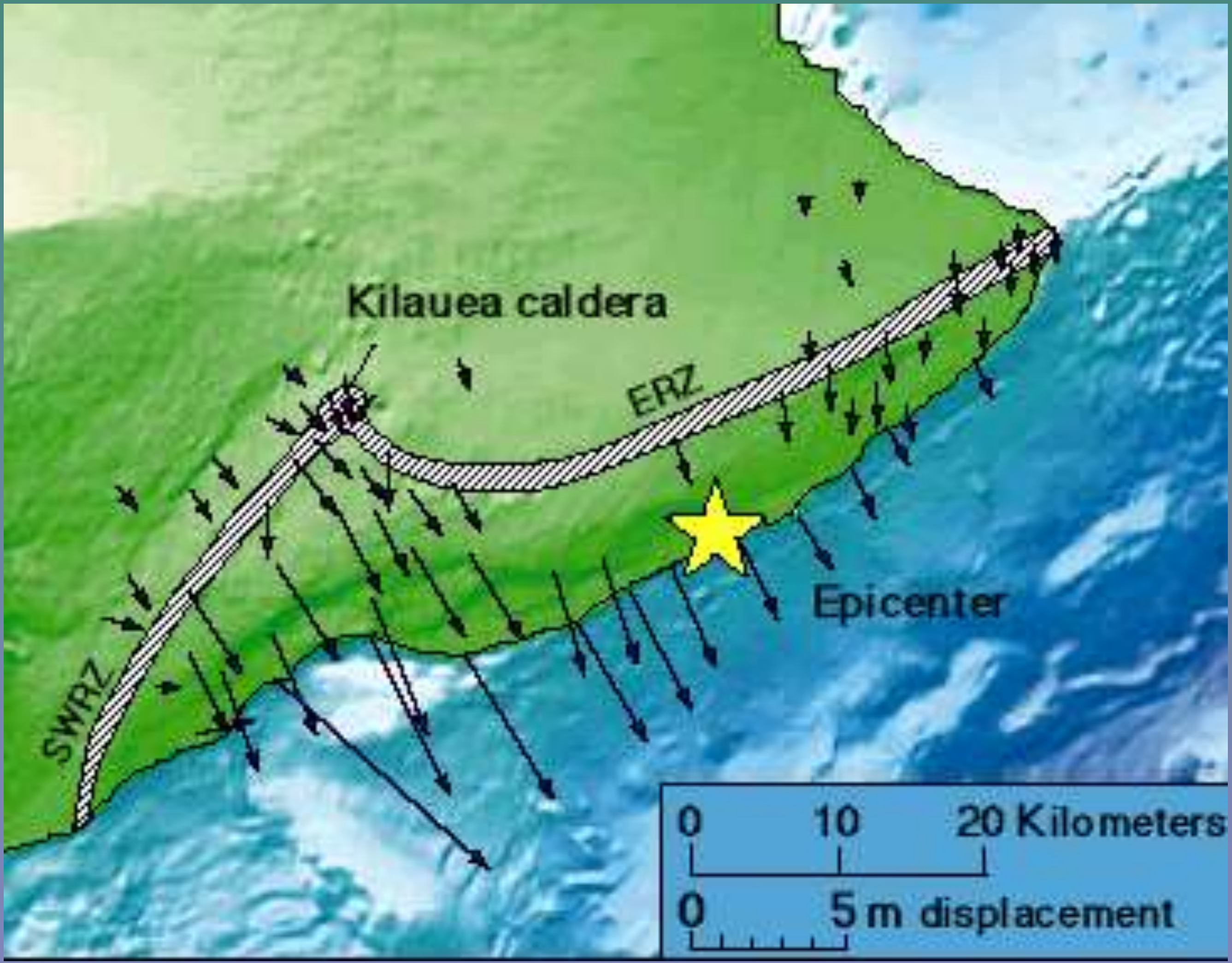
-Brigham (1909) The Volcanoes of Kilauea and Mauna Loa on the Island of Hawaii, Bishop Museum Press.

The third major type of Hawaiʻi earthquake occurs as the lithosphere flexes under the Weight of the islands. The 2006 Kīholo Bay earthquake (M 6.9) was one of these.



Slide by Carolina Anchieta and Cecily Wolfe

Displacements associated with the 1975 M 7.2 Kalapana earthquake



http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/75eqHoriz.gif

Subsidence associated with the 1975 Kalapana earthquake

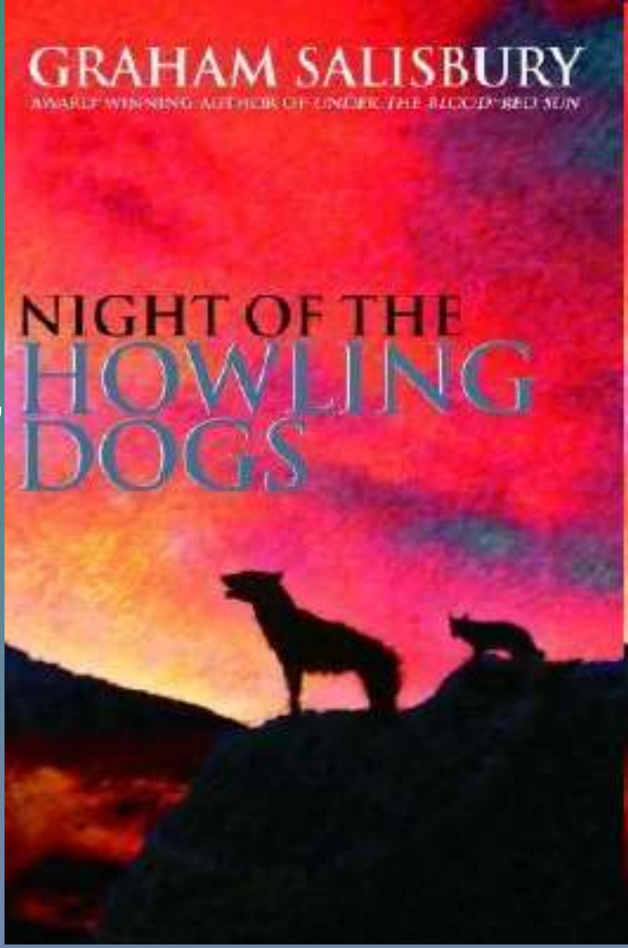
http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/75eqVert.gif

The south flank of Kīlauea, showing numerous down-dropped blocks

http://volcanoes.usgs.gov/Imgs/Jpg/Photoglossary/fault1_large.jpg

Troop 77, heading out for Halapē, November 27, 1975

http://www.tsunami.org/archives1975.html



Senior patrol leader of his Hilo, Hawaii, scout troop, eighth-grader Dylan looks forward to camping on the coast in the shadow of a volcano. But when he hears that Louie, a tough, troubled kid, will be joining the scouts on the trip, Dylan remembers when their paths crossed once before, and his anticipation turns to dread. Dylan's sense of foreboding is justified tenfold. After a difficult trek to their campsite, an earthquake jolts the ground and shakes boulders down from the cliff. Then a tsunami engulfs the area. Even in the midst of disaster, Dylan finds that support can come from unexpected directions. A strong sense of place informs the plot as well as the setting of this convincing story. In an unusually compelling author's note, Salisbury writes of camping on the site of the 1975 natural disaster at Halape with his cousin, who lived through it as a Boy Scout. Inspired by that earthquake and tsunami, this vivid adventure soon strips away every vestige of normality, leaving characters dependent on their wits, their skills, and the mysterious spirits of land and sea for their survival. Salisbury weaves Hawaiian legend into the modern-day narrative to create a haunting, unusual novel that will practically booktalk itself.--Phelan, Carolyn Copyright 2007 Booklist

http://syndetics.com/index.php?isbn=0385731221/blreview.html&client=pricp&type=rn12

Halapē before the 1975 earthquake

http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/30424303_005_L.jpg

Halapē after the 1975 earthquake

http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/30424303_006_L.jpg

Halapē shortly after the 1975 earthquake

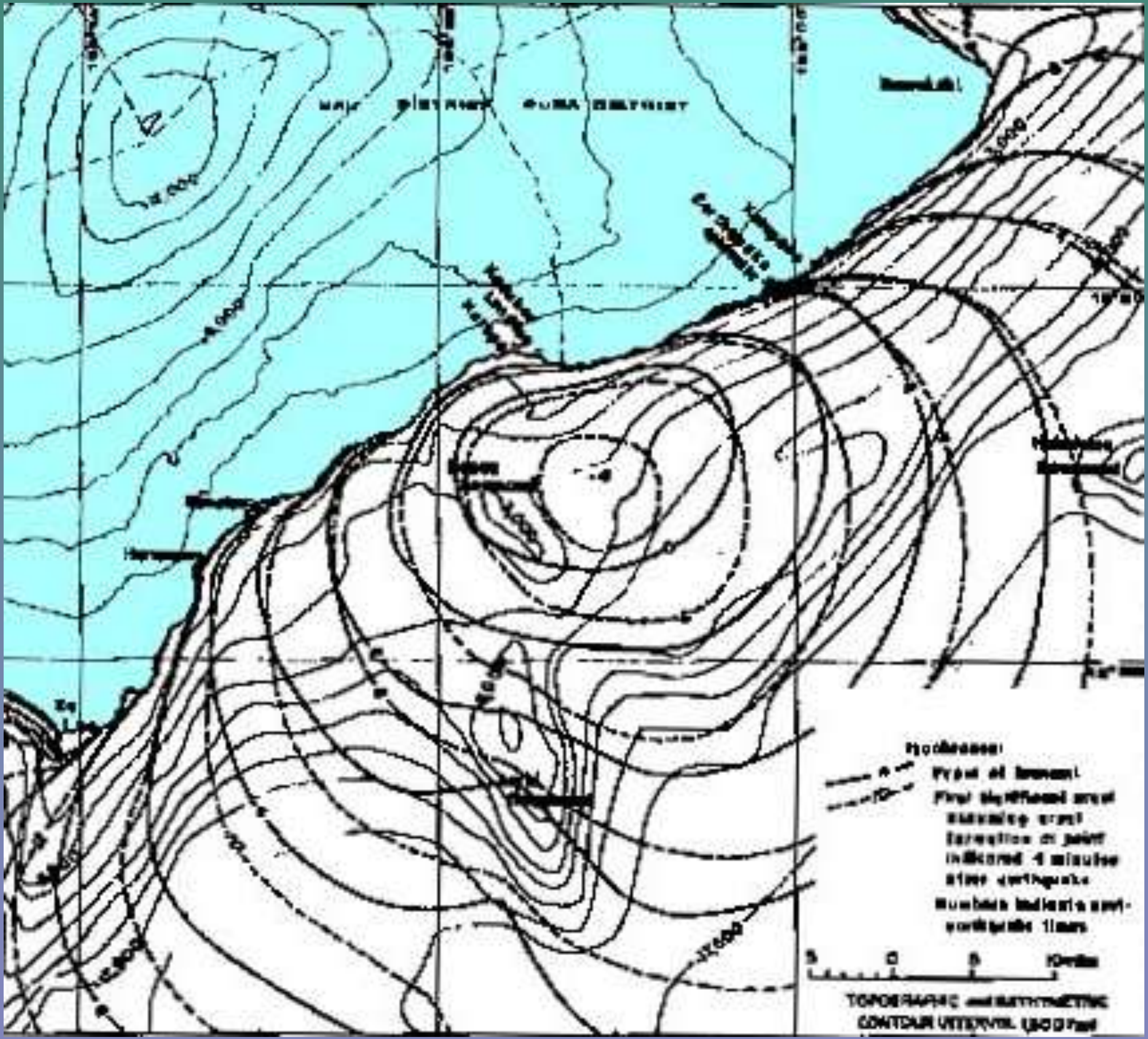
http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/30424303_008_L.jpg

Photograph by P.W. Lipman on December 2, 1975 (3 days after the earthquake)

http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/30424303_012_L.jpg

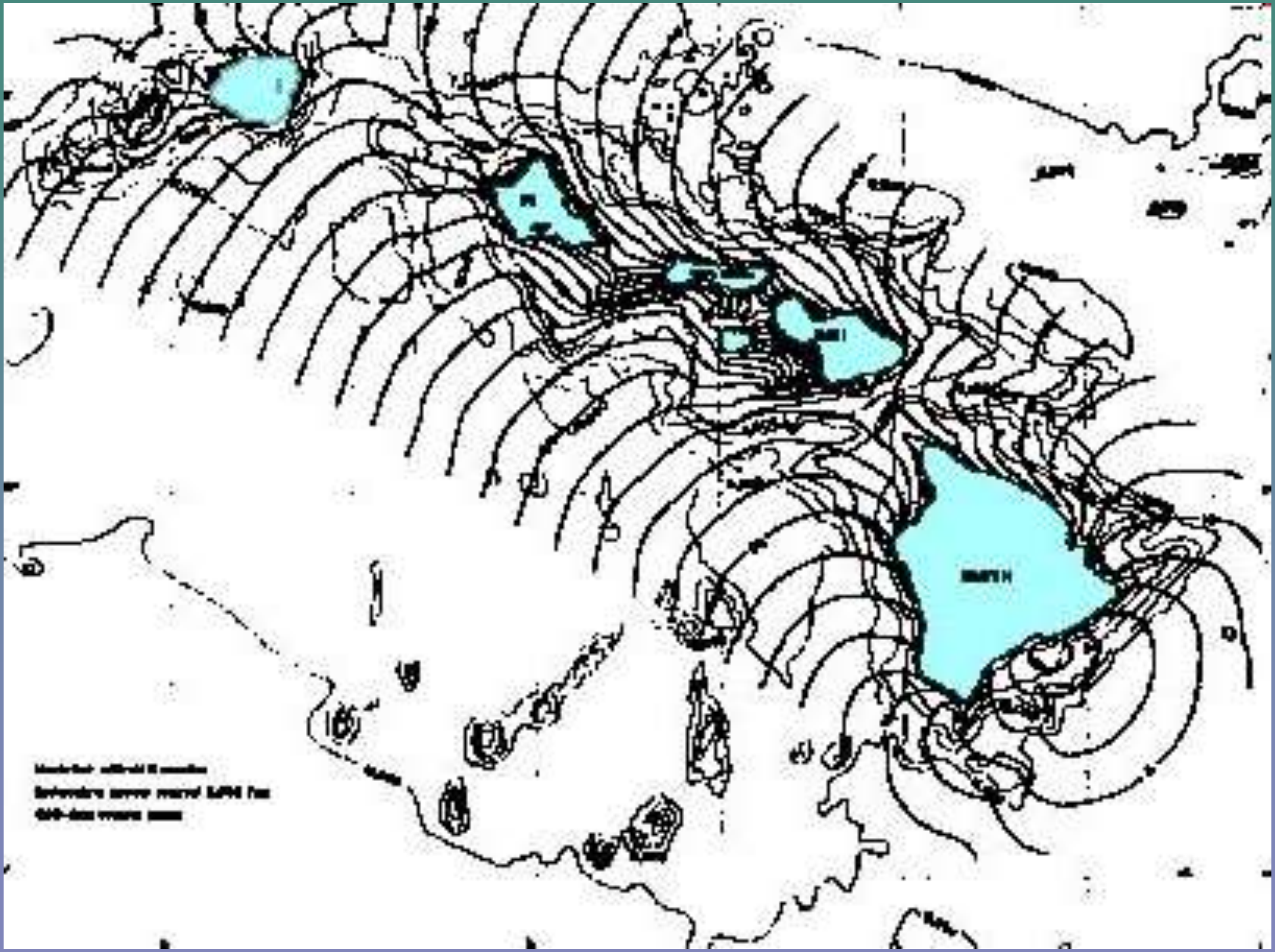
Photograph of dead coconut trees at Halapē, Jan. 1979, ~3 years after the earthquake

1975 Tsunami wave-fronts (modeled) SE Hawa‘i Island



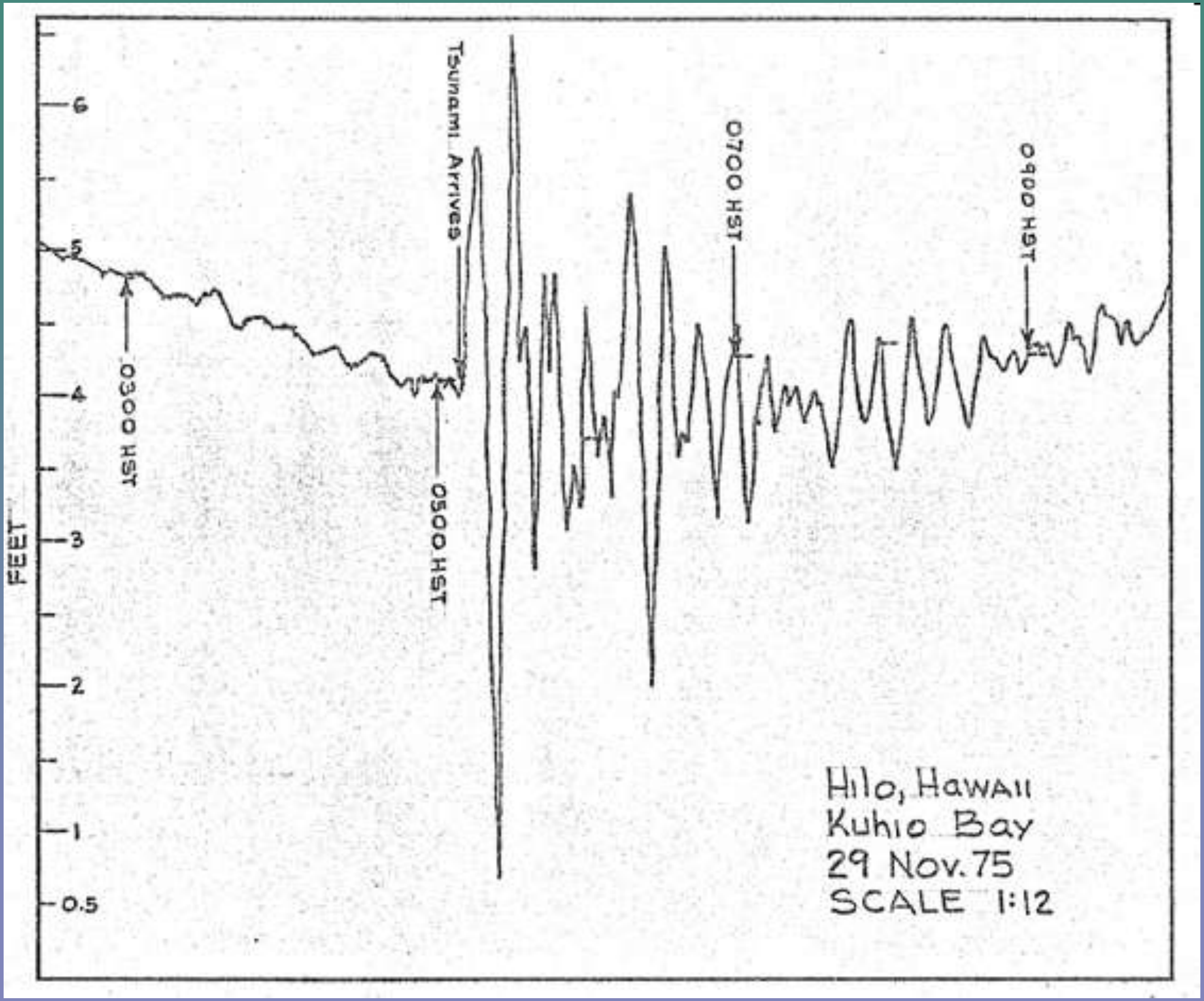
http://www.drgeorgepc.com/tsu1975HawaiiTsuGenArea1.jpg

1975 Tsunami wave-fronts (modeled) main Hawaiian islands



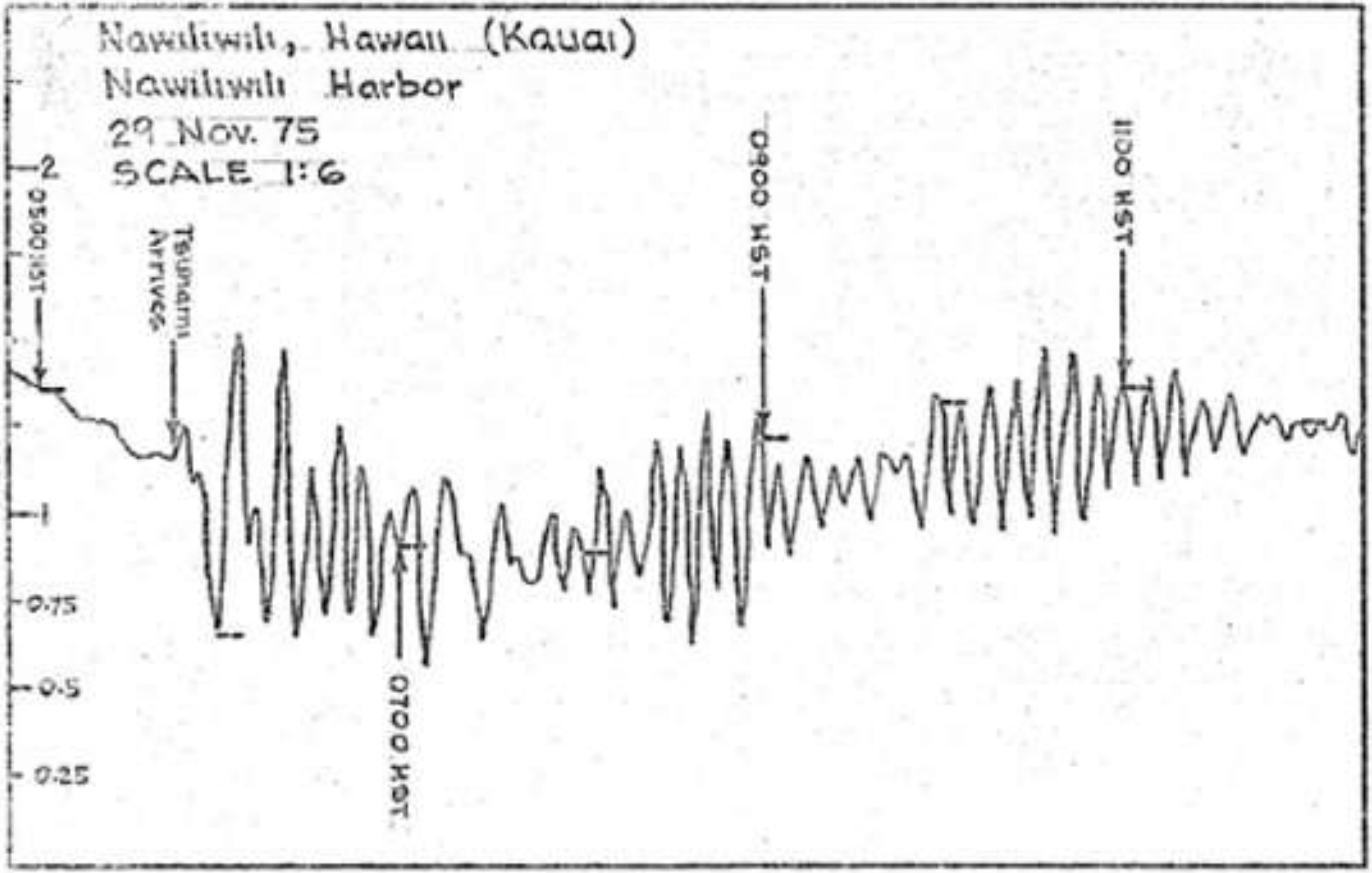
http://www.drgeorgepc.com/tsu1975HawaiiTTTAll.jpg

Tide gauge record from Hilo, recording the arrival of the 1975 tsunami

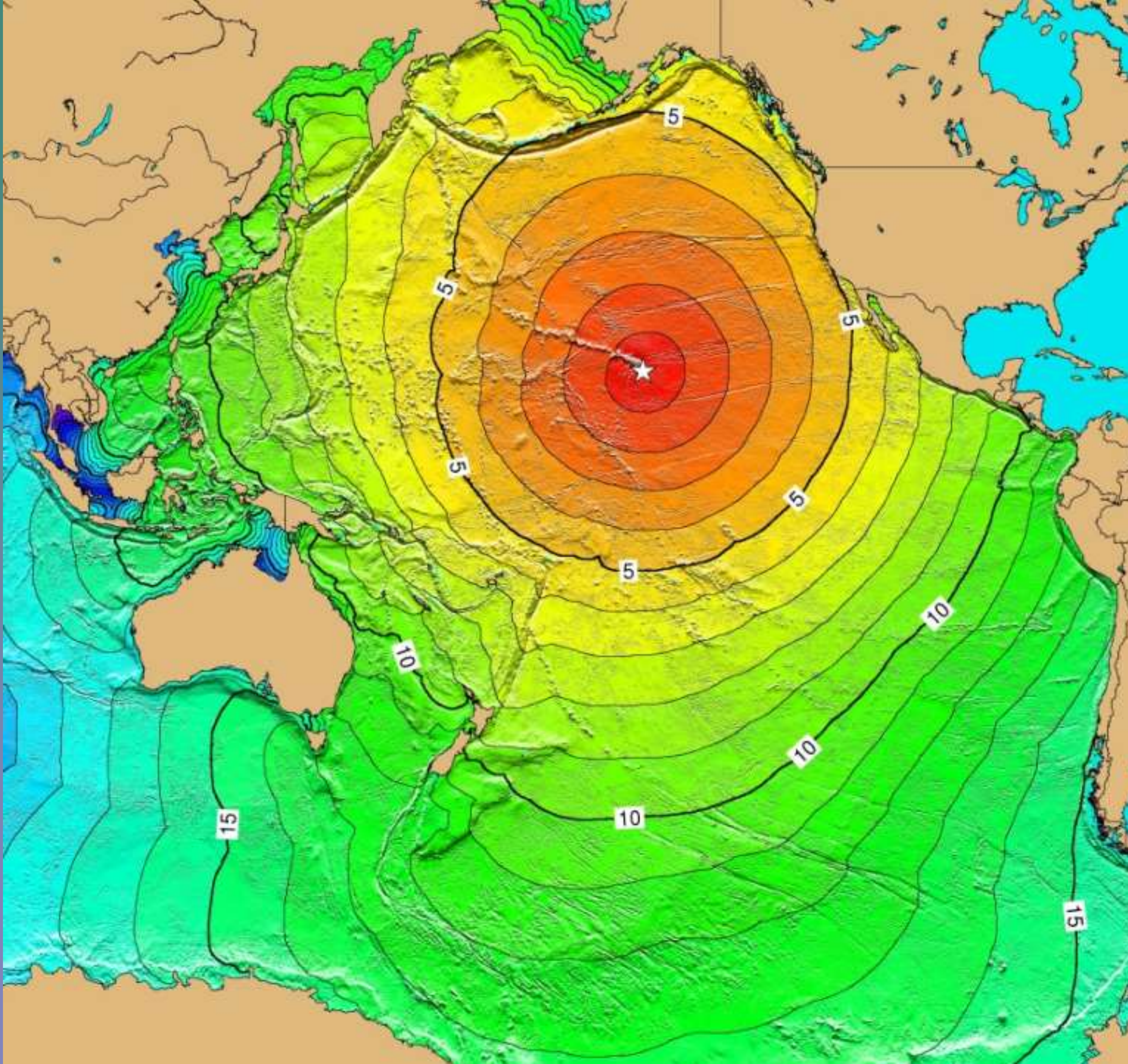


http://www.drgeorgepc.com/tsu1975HawaiiHilo.jpg

Tide gauge record from Nāwiliwili, recording the arrival of the 1975 tsunami



http://www.drgeorgepc.com/tsu1975HawaiiNawiliwili.jpg

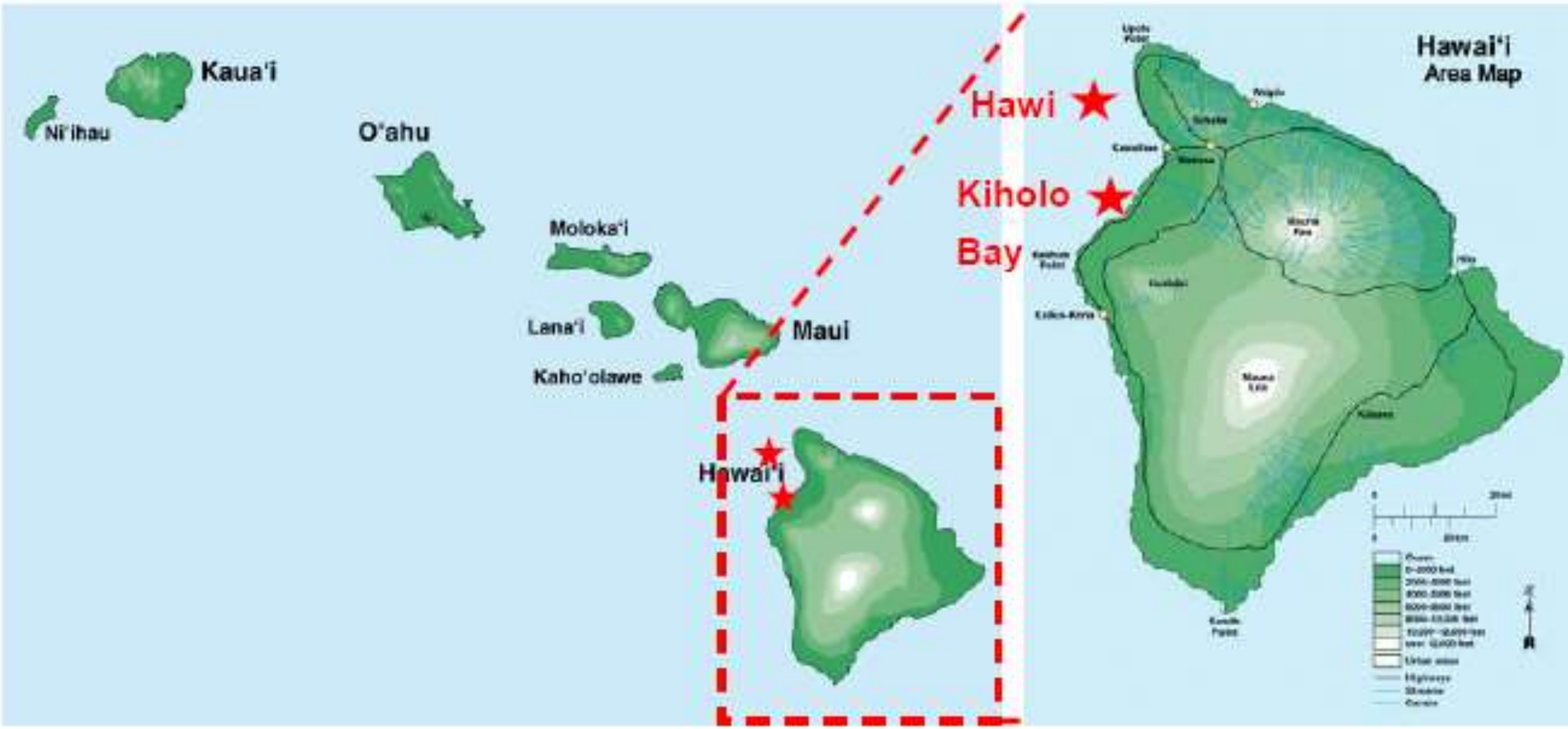


http://www.ngdc.noaa.gov/hazard/icons/1975_1129.jpg

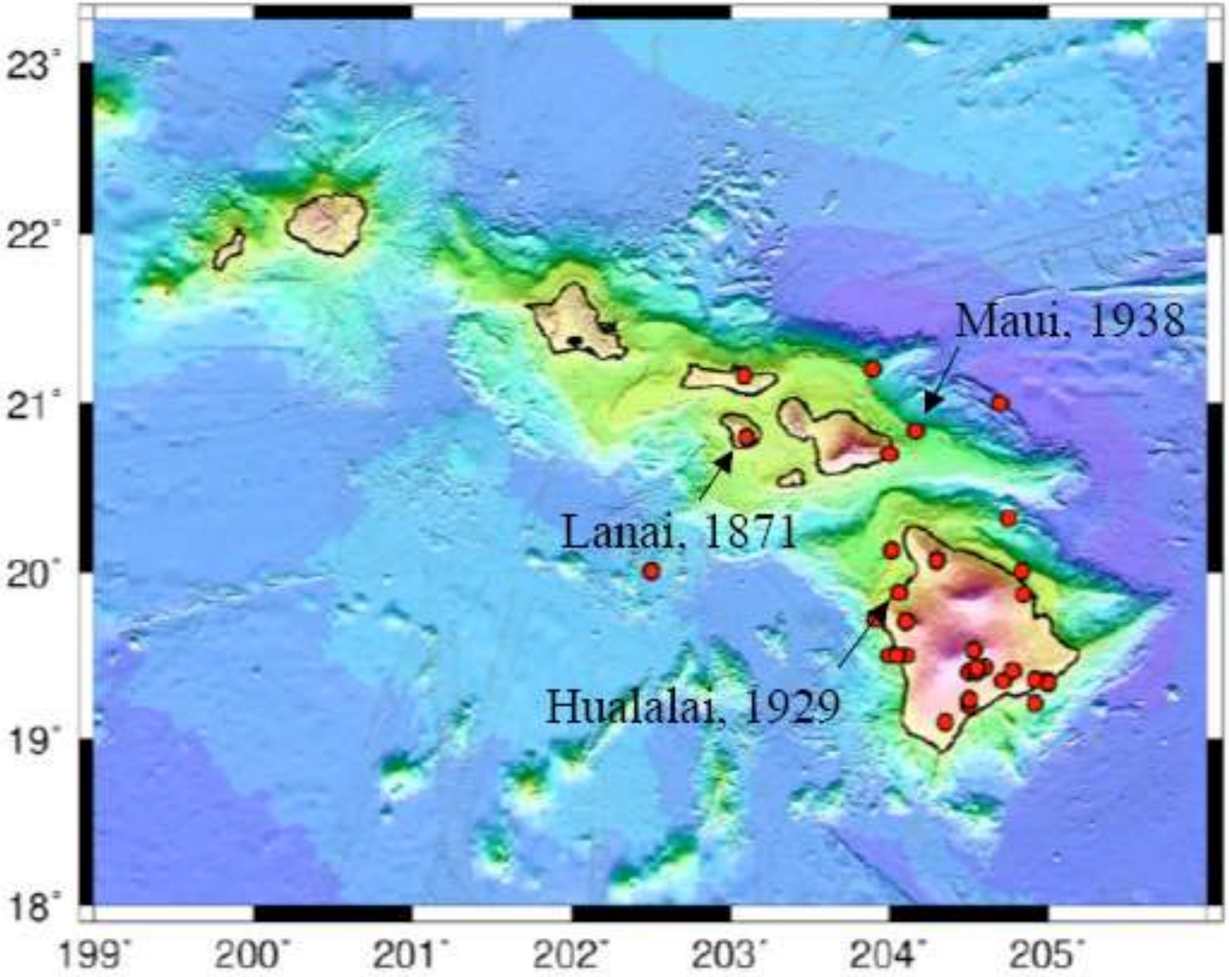
Small, short-lived eruption in Kīlauea caldera following the Kalapana earthquake

http://hvo.wr.usgs.gov/earthquakes/destruct/1975Nov29/75erup_l.jpg

The October 15, 2006 Kīholo Bay and Hāwī earthquakes



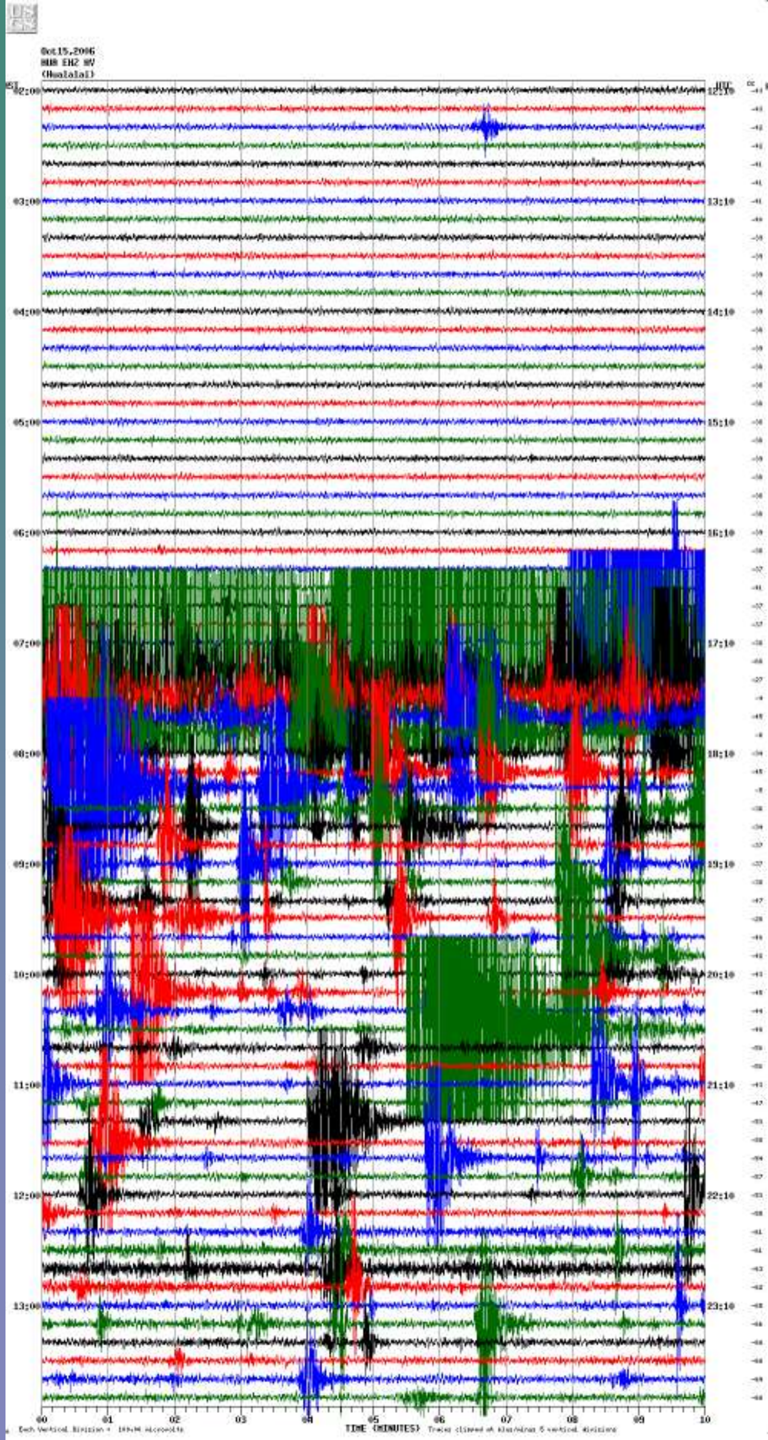
From: **Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i**
By Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)



The Kiholo Bay earthquake was a large, deep mantle earthquake. Past large historic earthquakes of this type likely included 1871 Lanai, 1938 Maui, and 1929 Hualalai. The 1973 M 6.2 Honomu earthquake also occurred at 40 km depth.

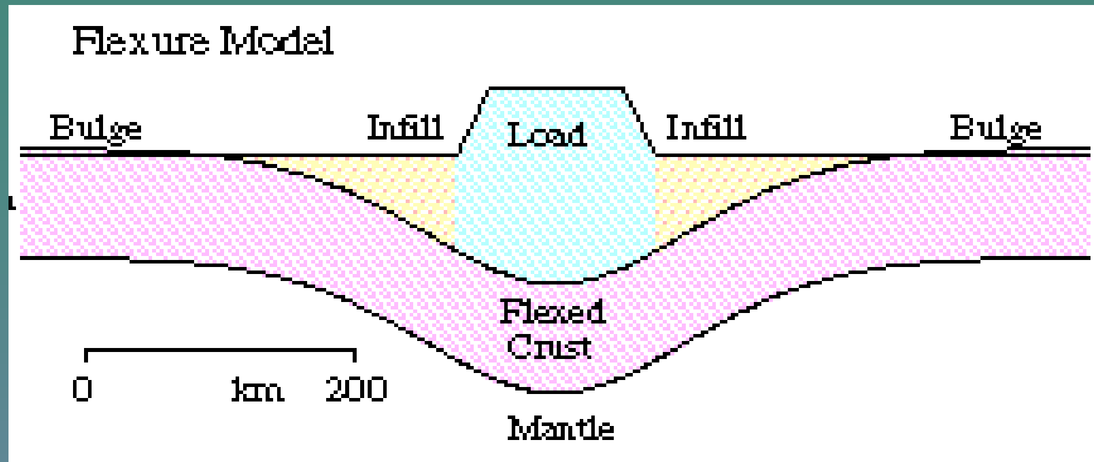
Slide by Carolina Anchieta and Cecily Wolfe

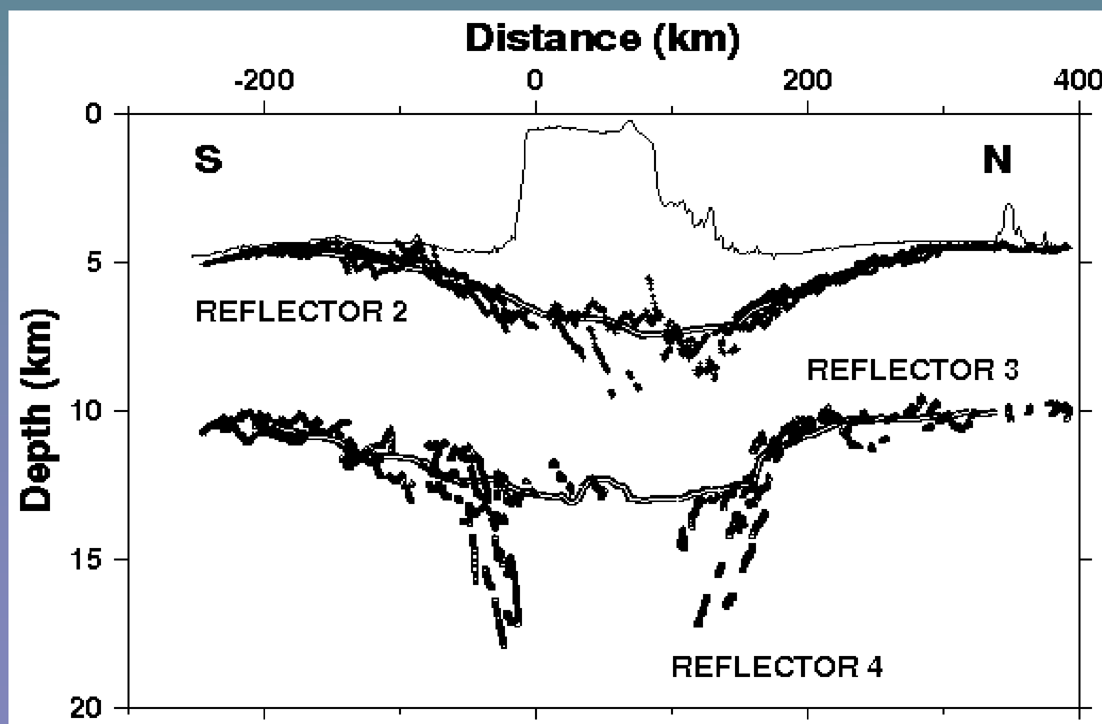
Seismic record from HVO, showing the 2006 Kiholo Bay earthquake



http://hvo.wr.usgs.gov/archive/HUA_EHZ_HV.2006101512.gif

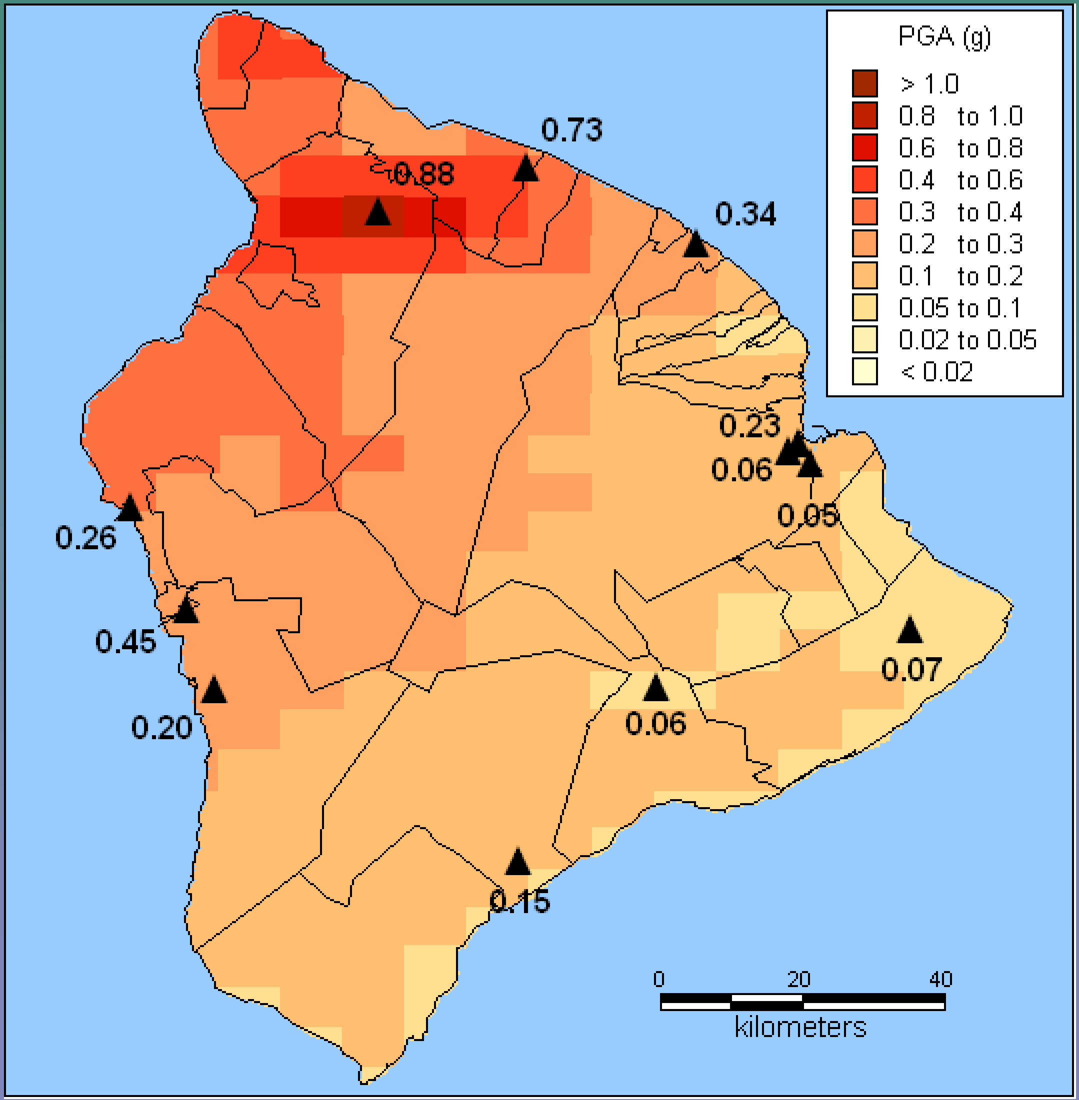
[*Watts and Ten Brink*, 1989]





Slide by Carolina Anchieta and Cecily Wolfe

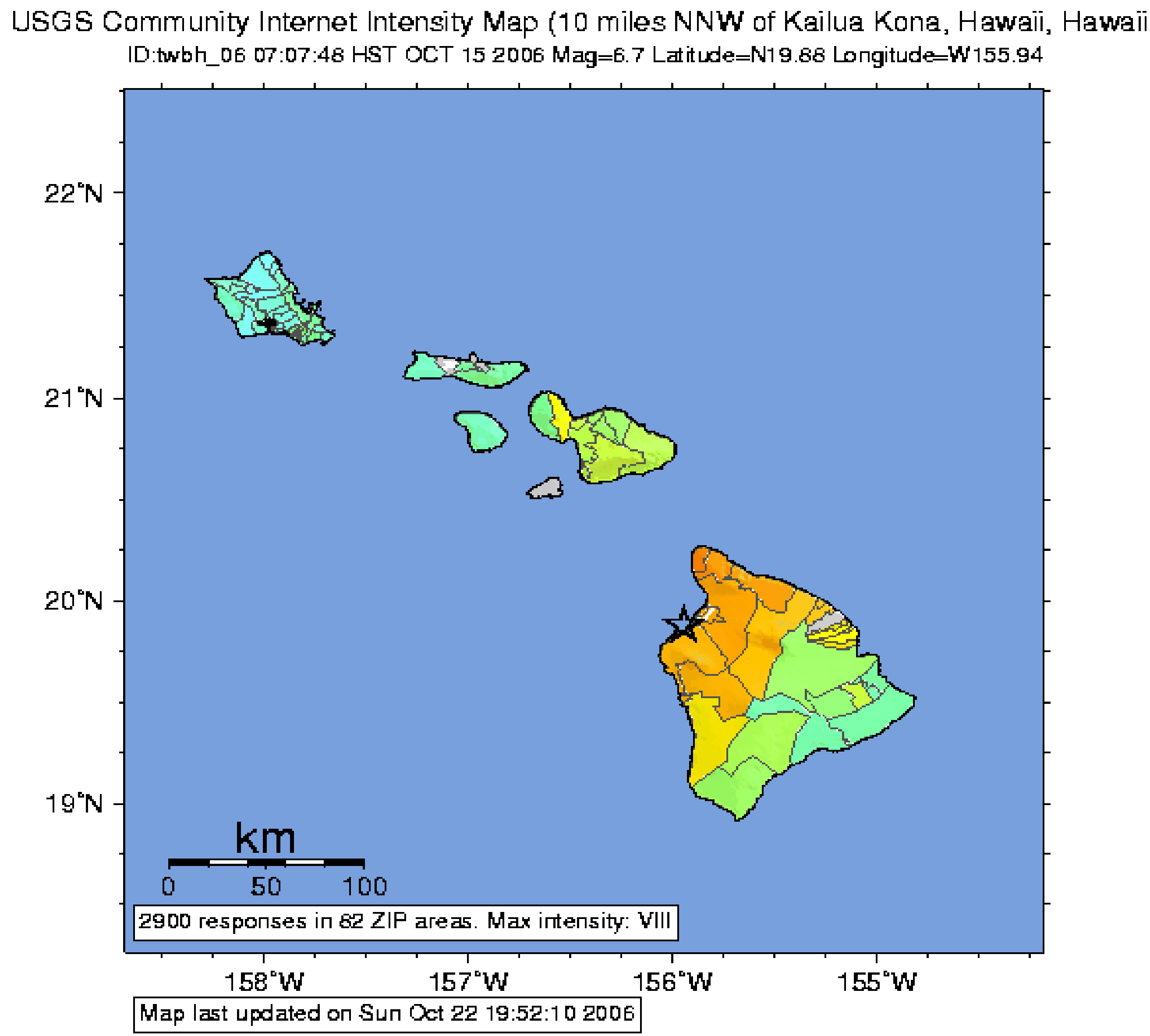
USGS “Shake map”, showing peak ground acceleration



From: 2006 Kiholo Bay, Hawaii Earthquake, RMS Event Report

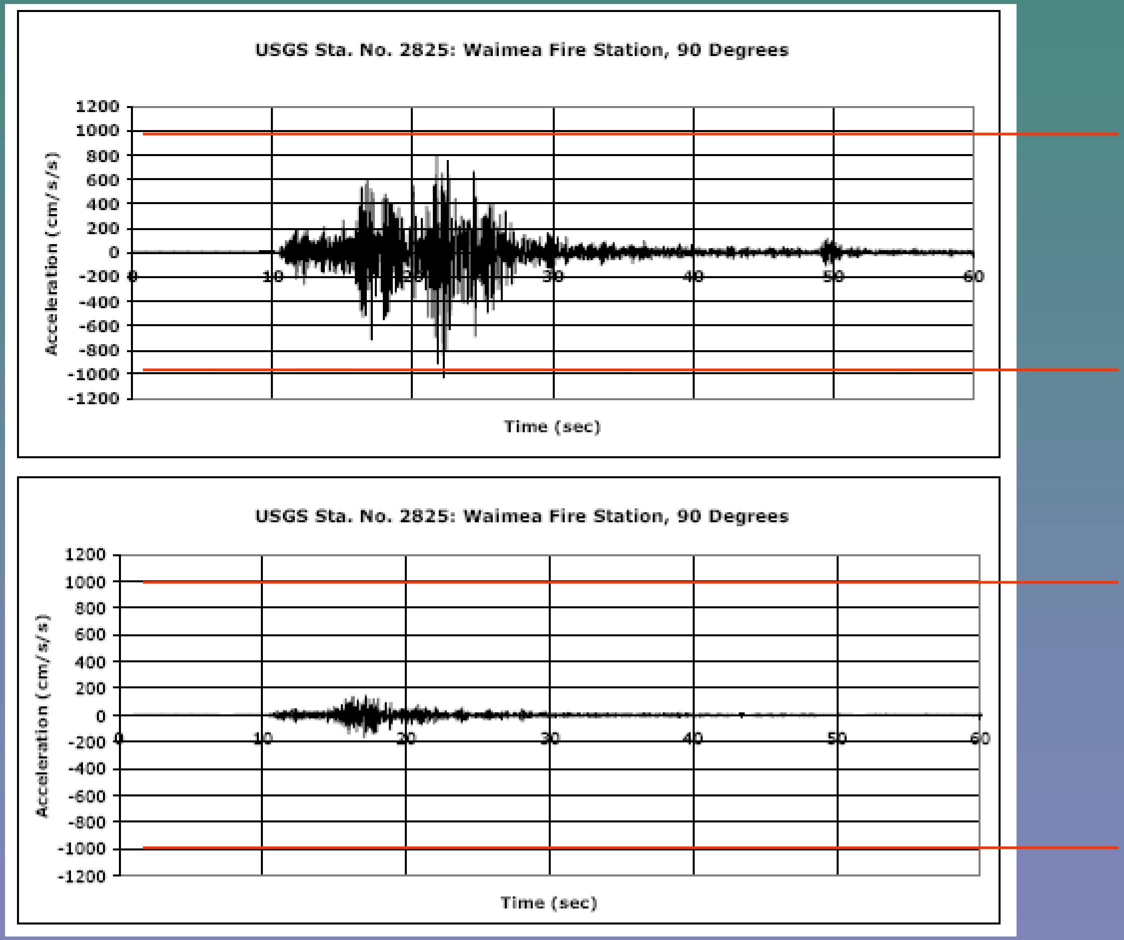
RMS™ Risk Management Solutions

“Did you feel it?”



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

Ground accelerations recorded at Waimea Fire Station during the Mw 6.7 Kiholo Bay (top) and Mw 6.0 Hawi (bottom) earthquakes. Note: gravitational acceleration (i.e., the force of gravity that we feel) is 980 cm s^{-2} (red lines).



From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i
By Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

Kalahikiola Church in Hāwī

From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i
By Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

Mauna Kea Beach hotel

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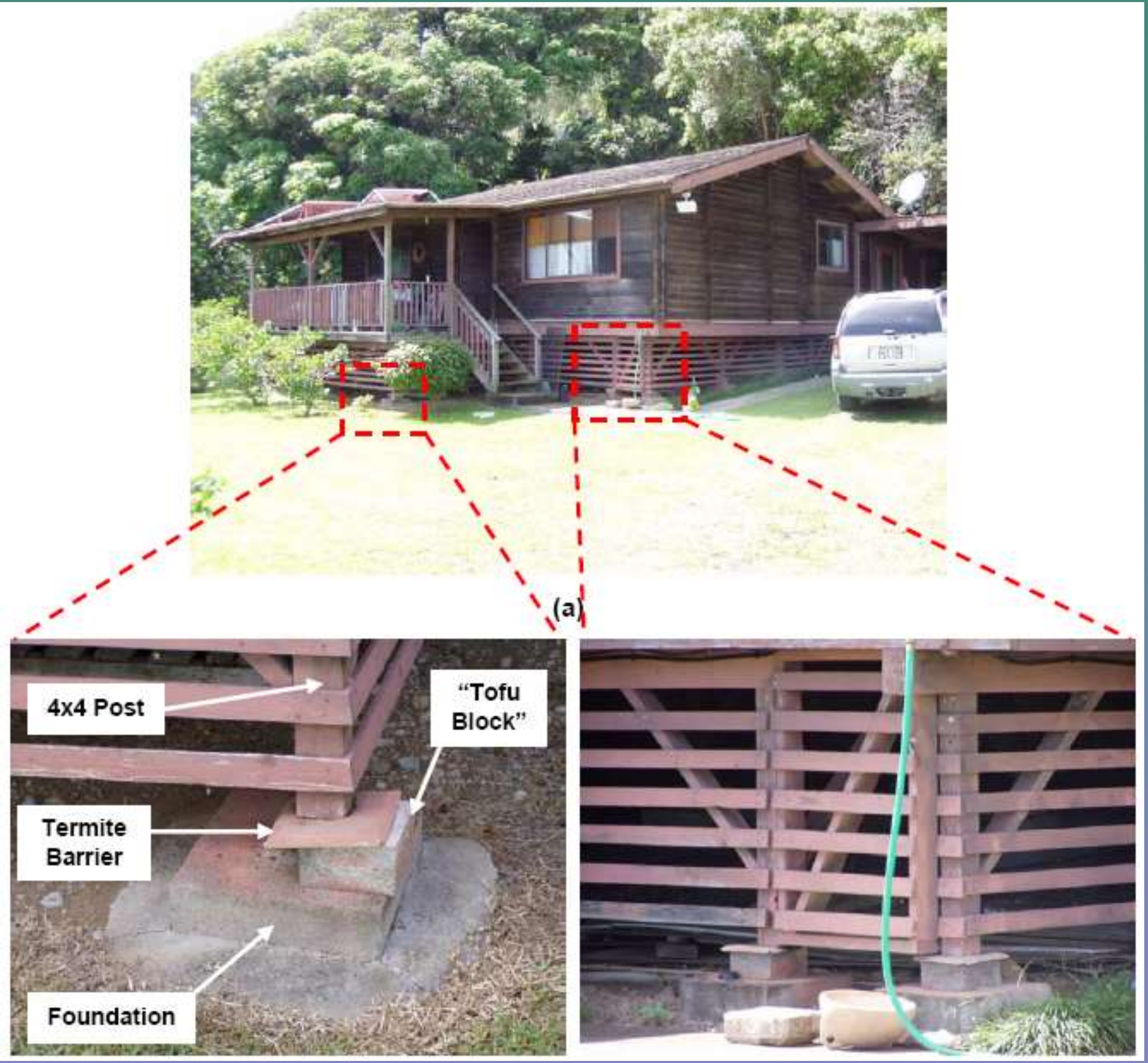
Mauna Kea Beach hotel

From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i
By Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

Typical timber framed residence at Pololū Valley Lookout on pier-and-beam construction



From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i by Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

Shear failure of bolts securing girt to corner column

From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i
by Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

Example of discontinuous geology where dense ‘a‘ā core overlies weaker and less stable clinker

From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i by Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

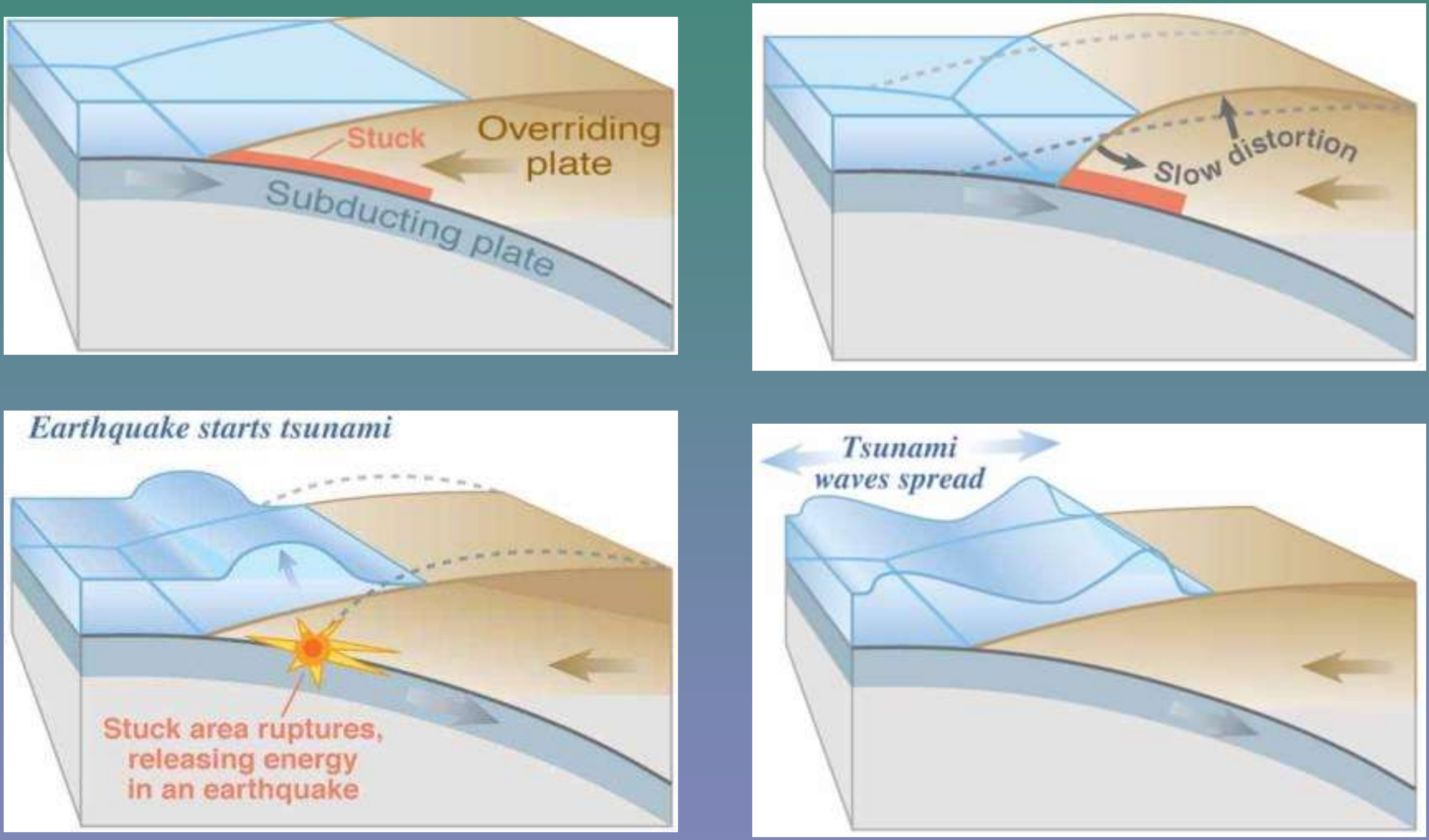
Rockslides from pali near Waipiʻo Valley lookout, shortly after (during?) Kīholo Bay EQ

Hilo Tribune Herald

Collapse of un-mortared and unreinforced retaining wall in Honoka‘a

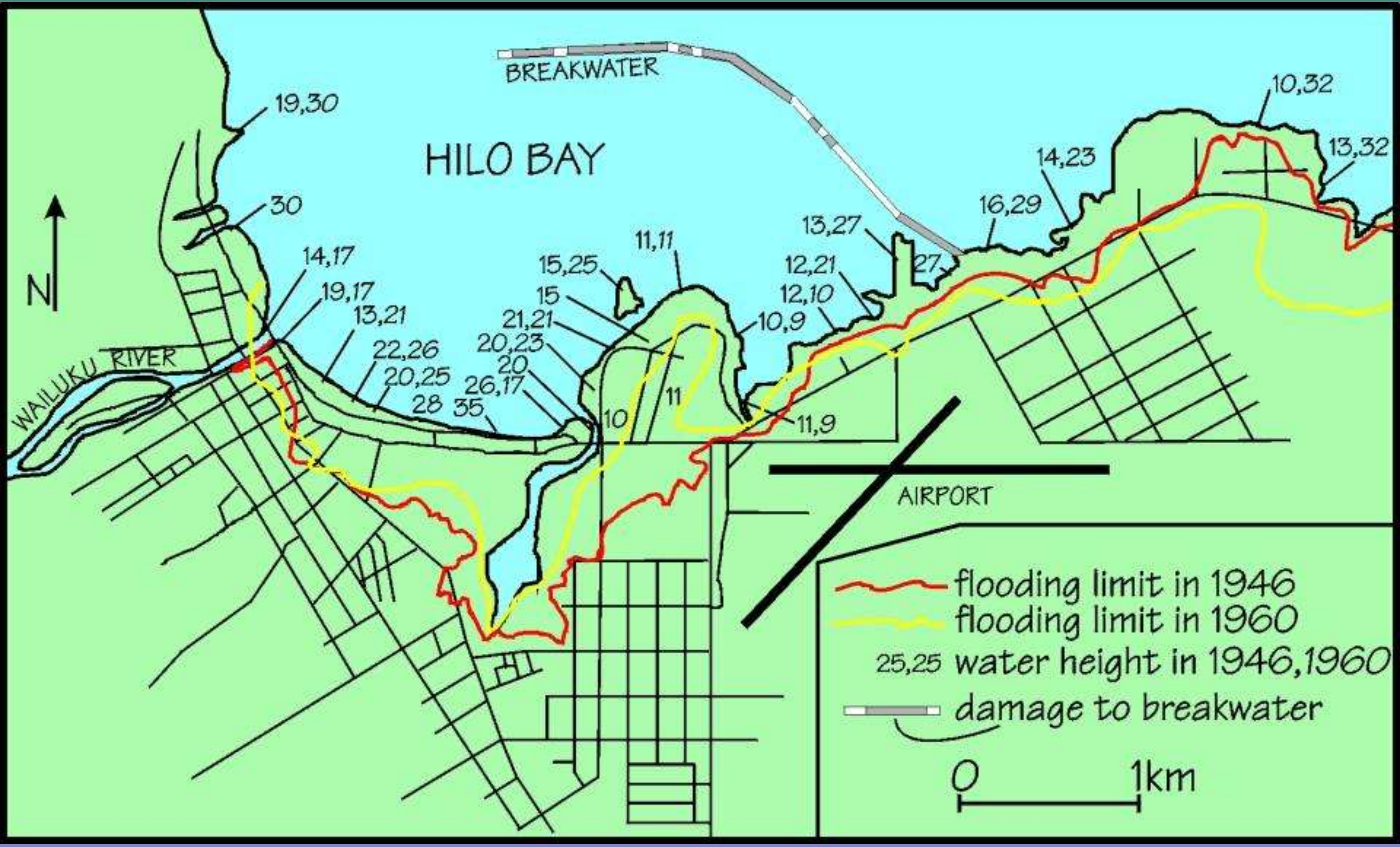
From: Reconnaissance Following the October 15th, 2006 Earthquakes on the Island of Hawai`i
by Ian Robertson, Peter Nicholson, Horst Brandes (UH Mānoa School of Engineering)

Generation of a tsunami by a subduction zone earthquake



http://pubs.usgs.gov/circ/c1187/

Tsunami inundation at Hilo in 1946 (red) and 1960 (yellow)



(Macdonald 1958)

THE TSUNAMI OF APRIL 1, 1946, IN THE HAWAIIAN ISLANDS

BY

G. A. MACDONALD
U. S. Geological Survey

F. P. SHEPARD
Scripps Institution of Oceanography

and

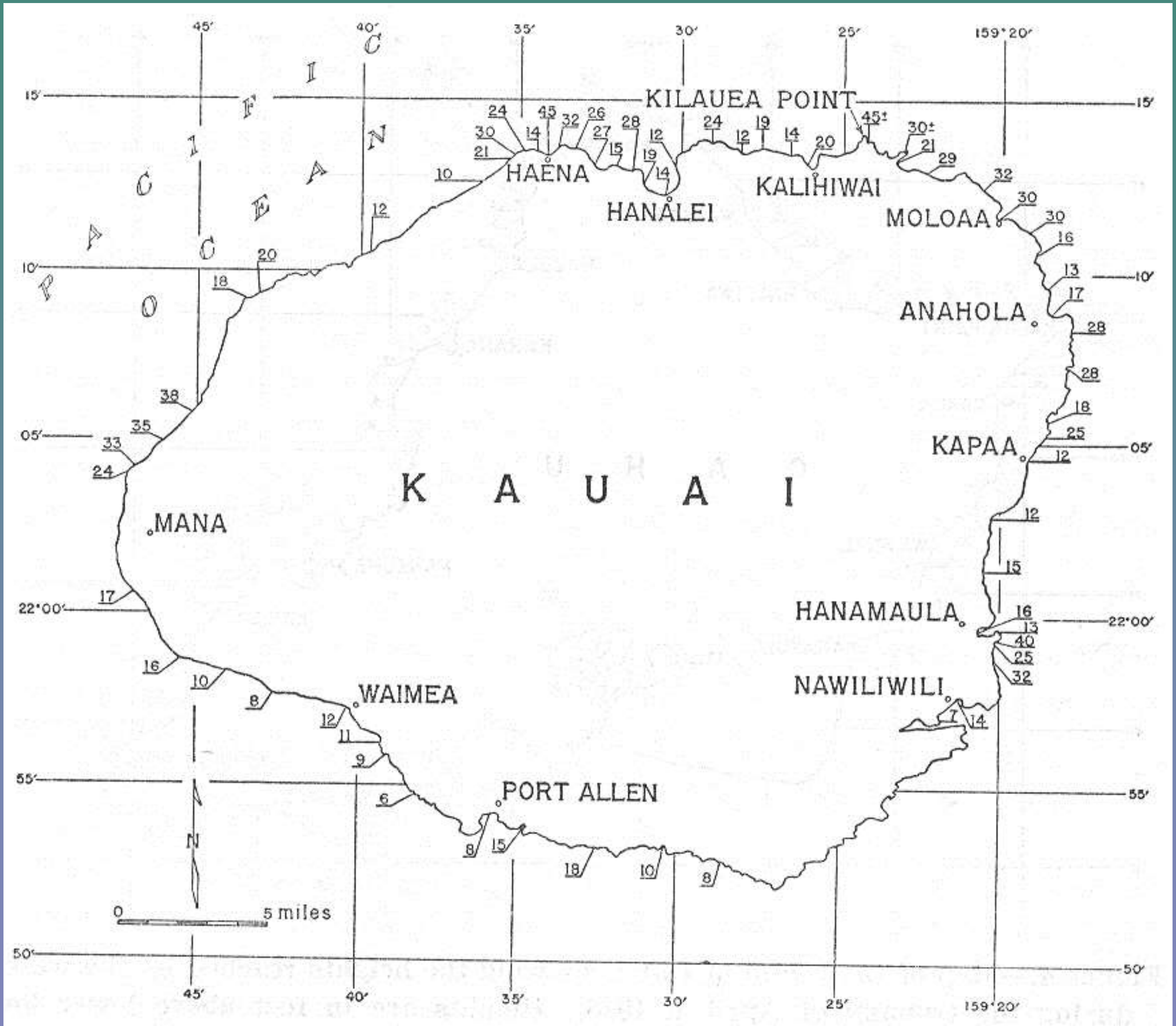
D. C. COX
Hawaiian Sugar Planters' Association
Experiment Station

FROM THE SMITHSONIAN REPORT FOR 1947, PAGES 257–280
(WITH 6 PLATES)

(Publication 3929)

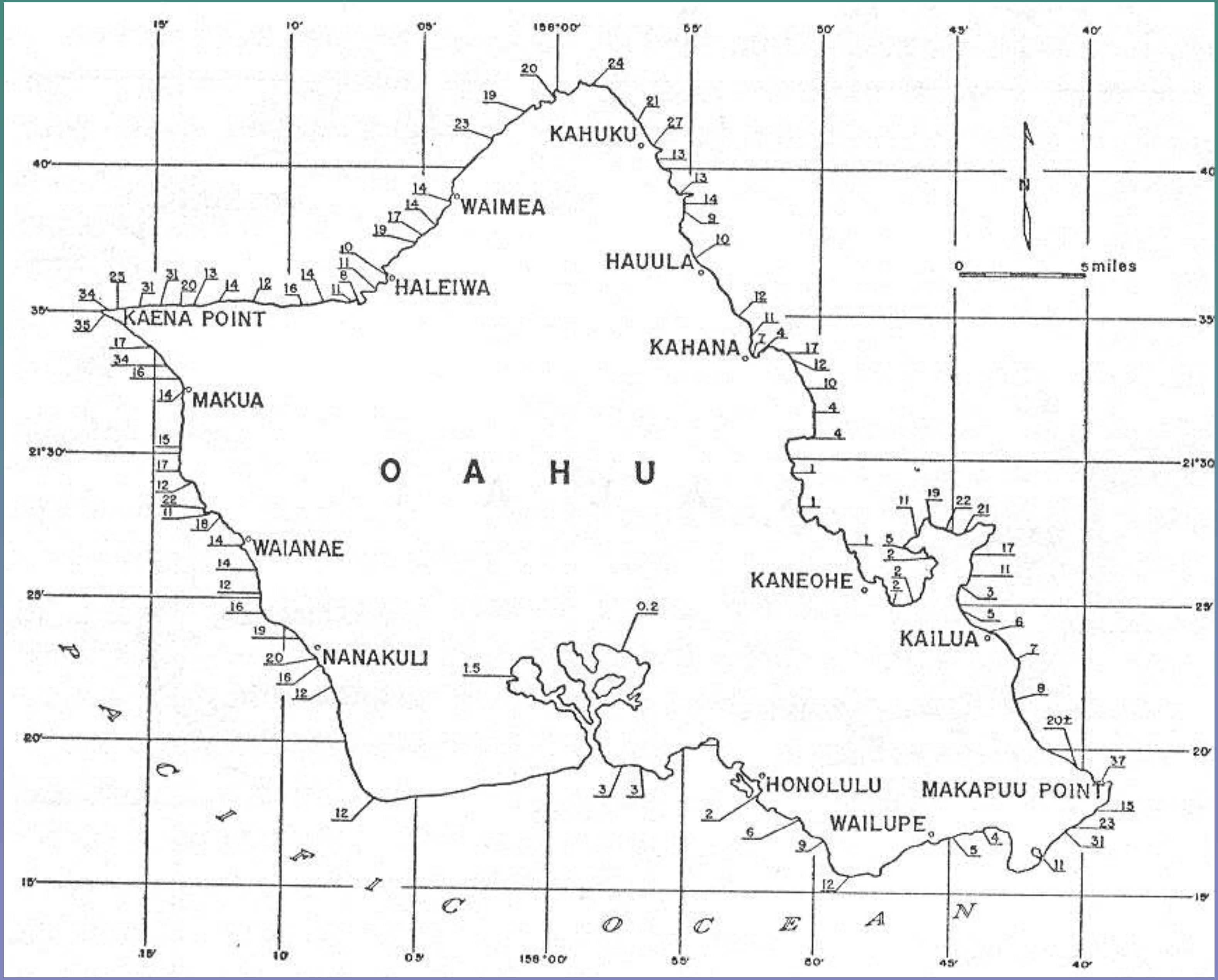
SMITHSONIAN INSTITUTION
WASHINGTON
D. C.

Tsunami run-up (in feet) during the 1946 tsunami



From: Macdonald *et al*. (1947)

Tsunami run-up (in feet) during the 1946 tsunami



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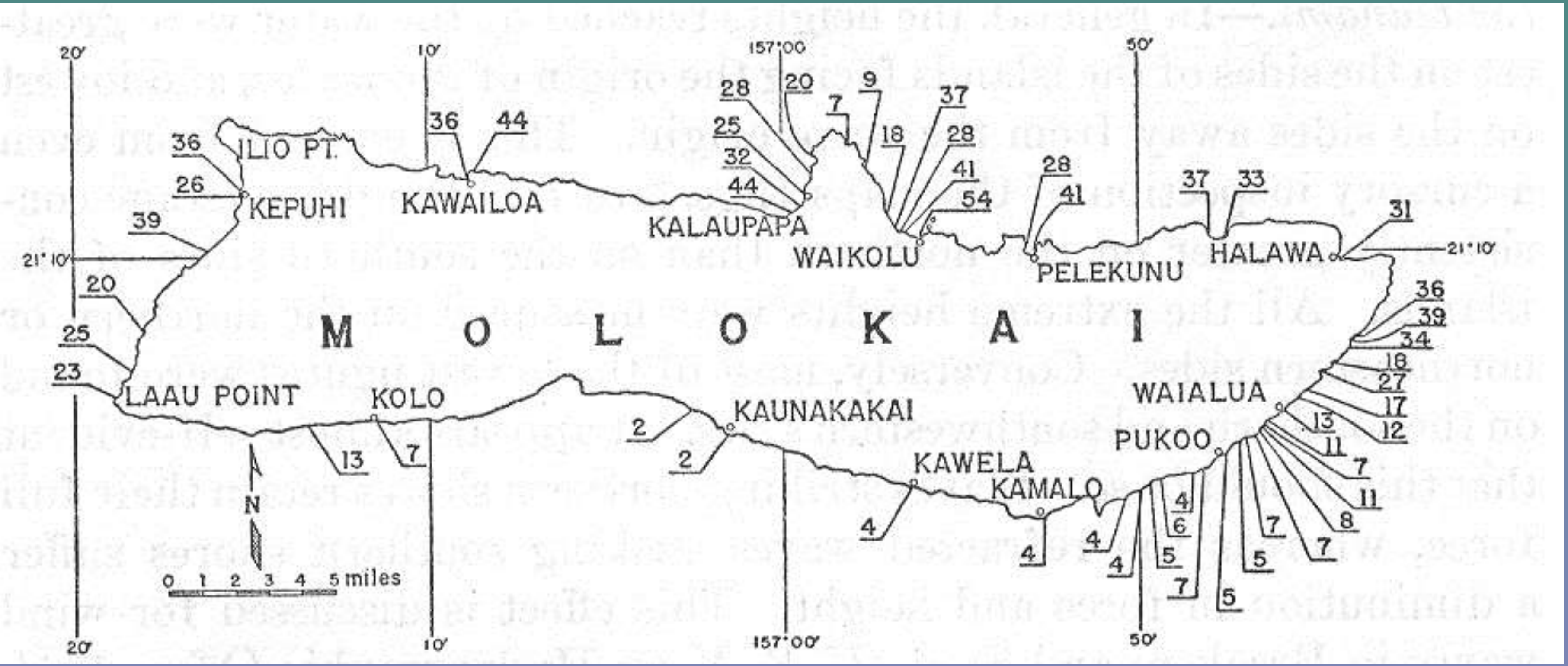

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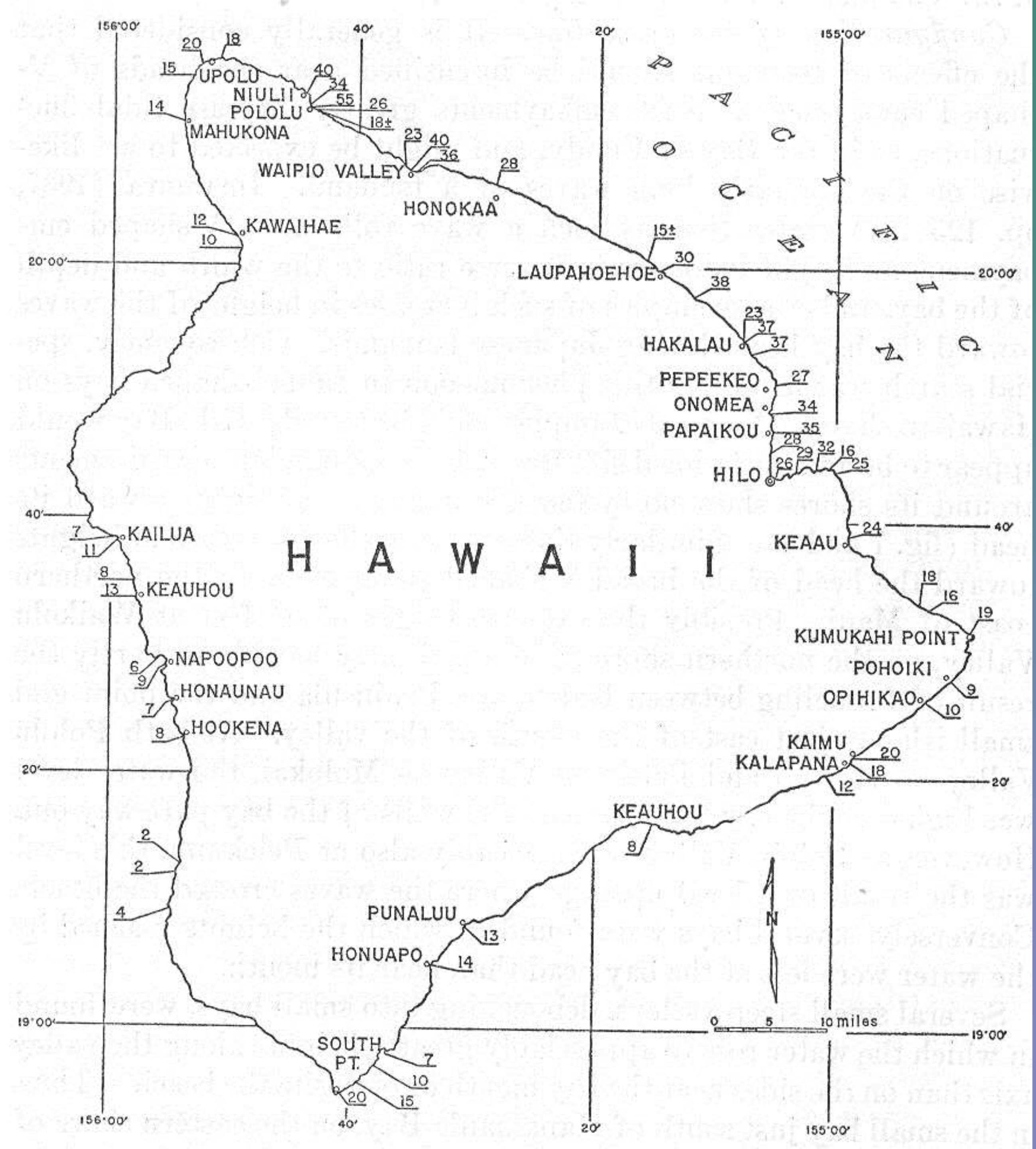


From: Macdonald *et al.* (1947)

Tsunami wave (a bore) advancing up the Wailua river, 1946. Note that one span of the bridge had been destroyed by an earlier wave.

A SMALL, LATE WAVE, APPROACHING ALREADY-SMASHED HILO

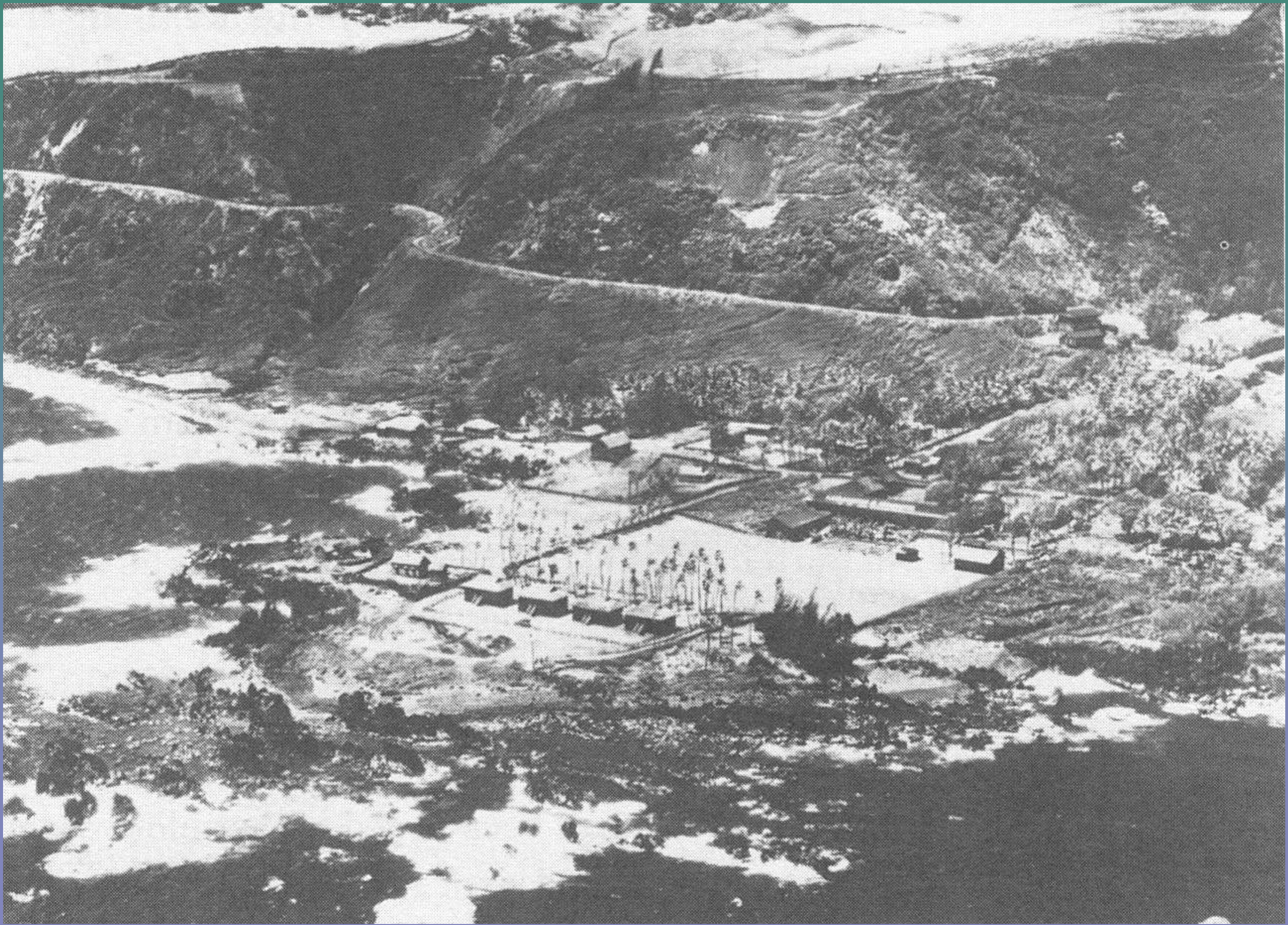
Downtown Hilo after the 1946 tsunami

http://www.drgeorgepc.com/tsu60Hilo7.jpg

Laupāhoehoe

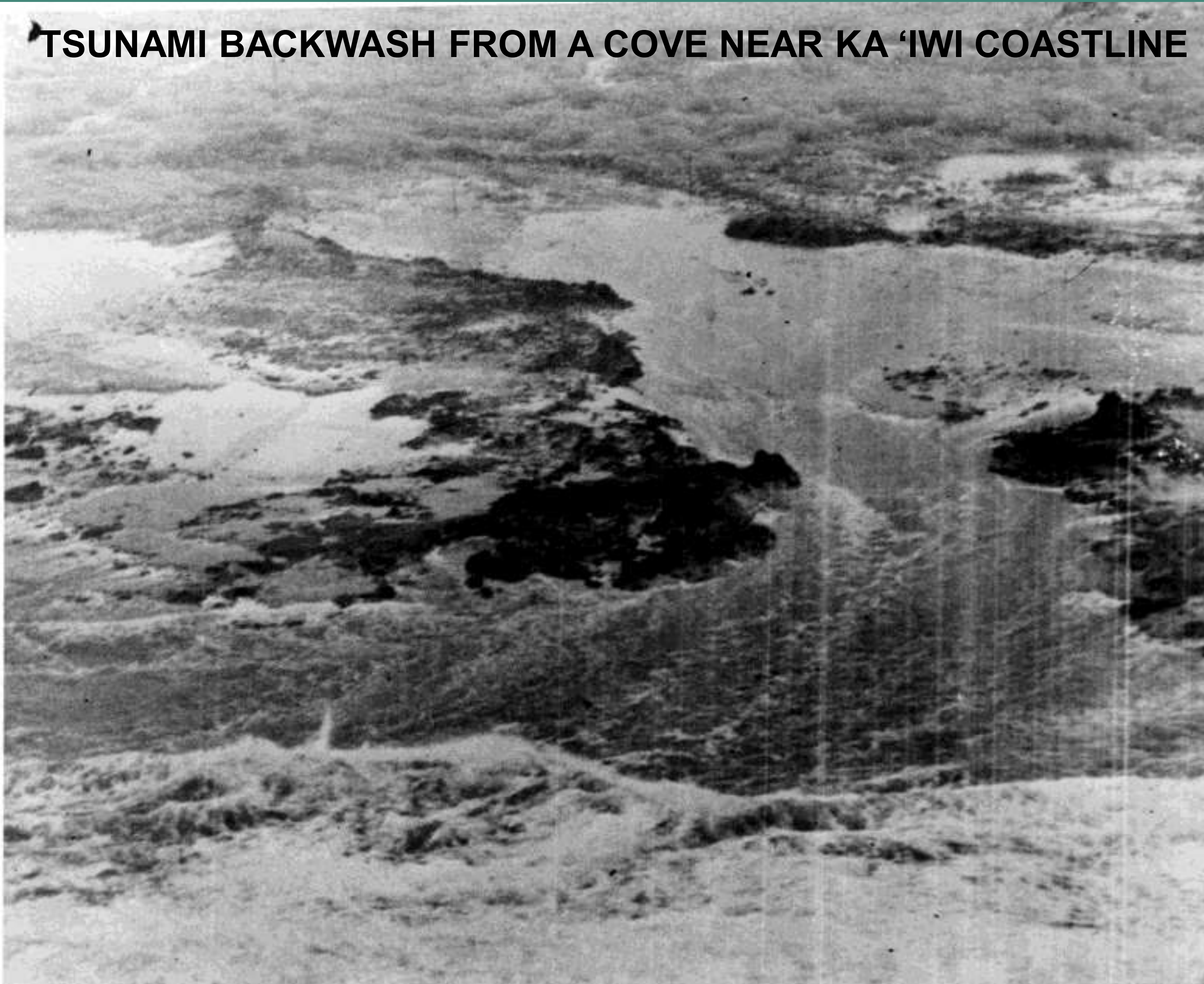
peninsula formed from lava that flowed down a large stream valley

Laupāhoehoe point prior to the 1946 tsunami

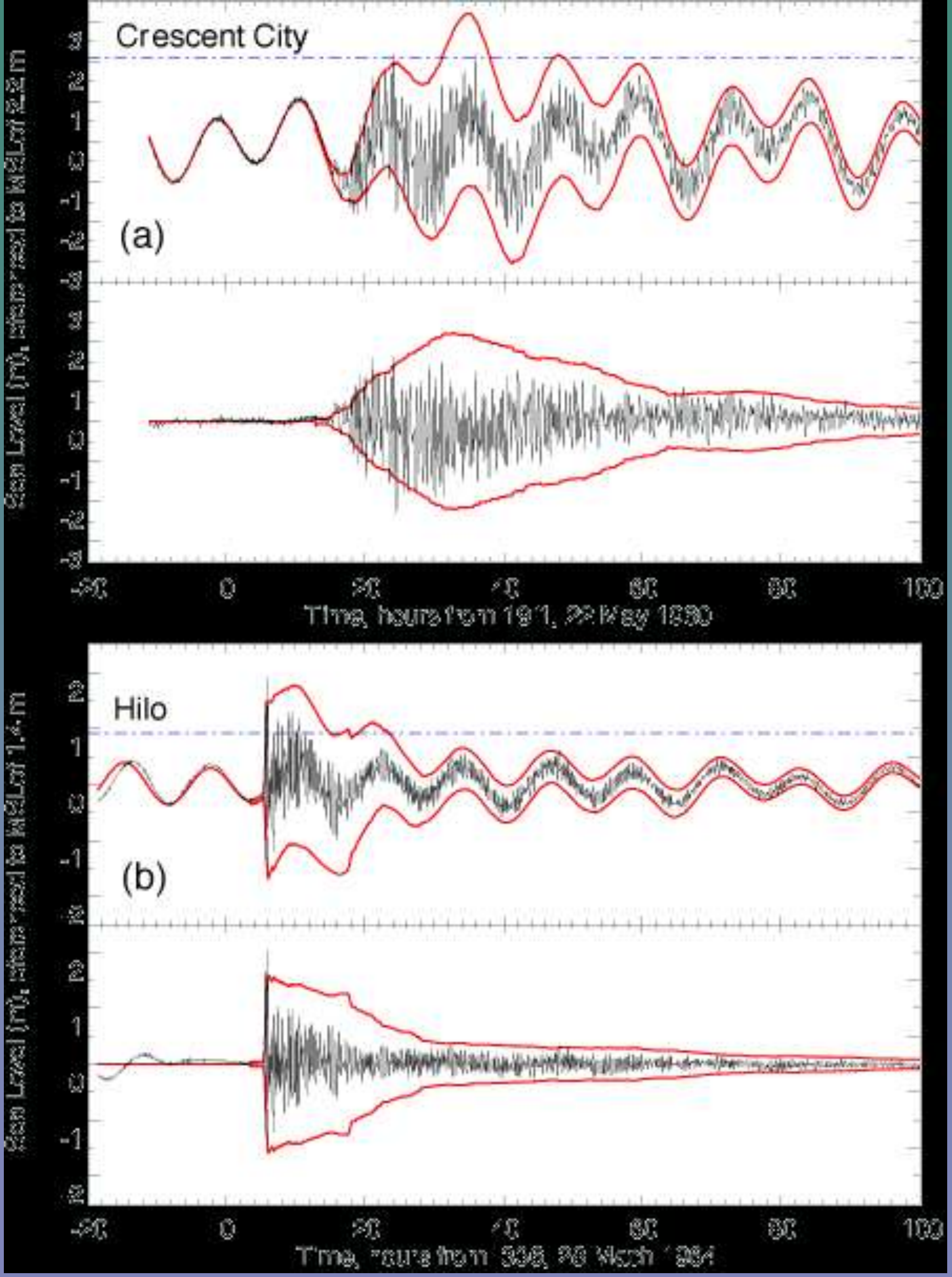


IN MEMORY OF
THOSE WHO LOST THEIR LIVES IN THE TIDAL WAVE
APRIL 1, 1946
AKIONA, DANIEL 15
DUFIL, MACARIO 19
DE CAIRES, JANET 10
DE CAIRES, JOHN 15
DE CAIRES, MADELINE 16
DRAKE, DOROTHY LA VERNE
FUJIMOTO, TOSHIOMI 14
ISAKI, SHOSO 17
ISHIZU, MAMORU
JOHNSON, FAY BYRD 21
KINGSEED, HELEN JOAN 22
KRUSE, FRED
NAKAMURA, SEISHI 13
NAKANO, FLORENCE 32
NAKANO, STELLA
NAKATA, HATSUICHI 12
SAKAMOTO, TAKAYOSHI 15
SUNAHARA, KIYOSHI
YAMAMOTO, MITSUJI 13
UYENO, BERT SETSUO 14
YAMAMOTO, JITSUMI 14

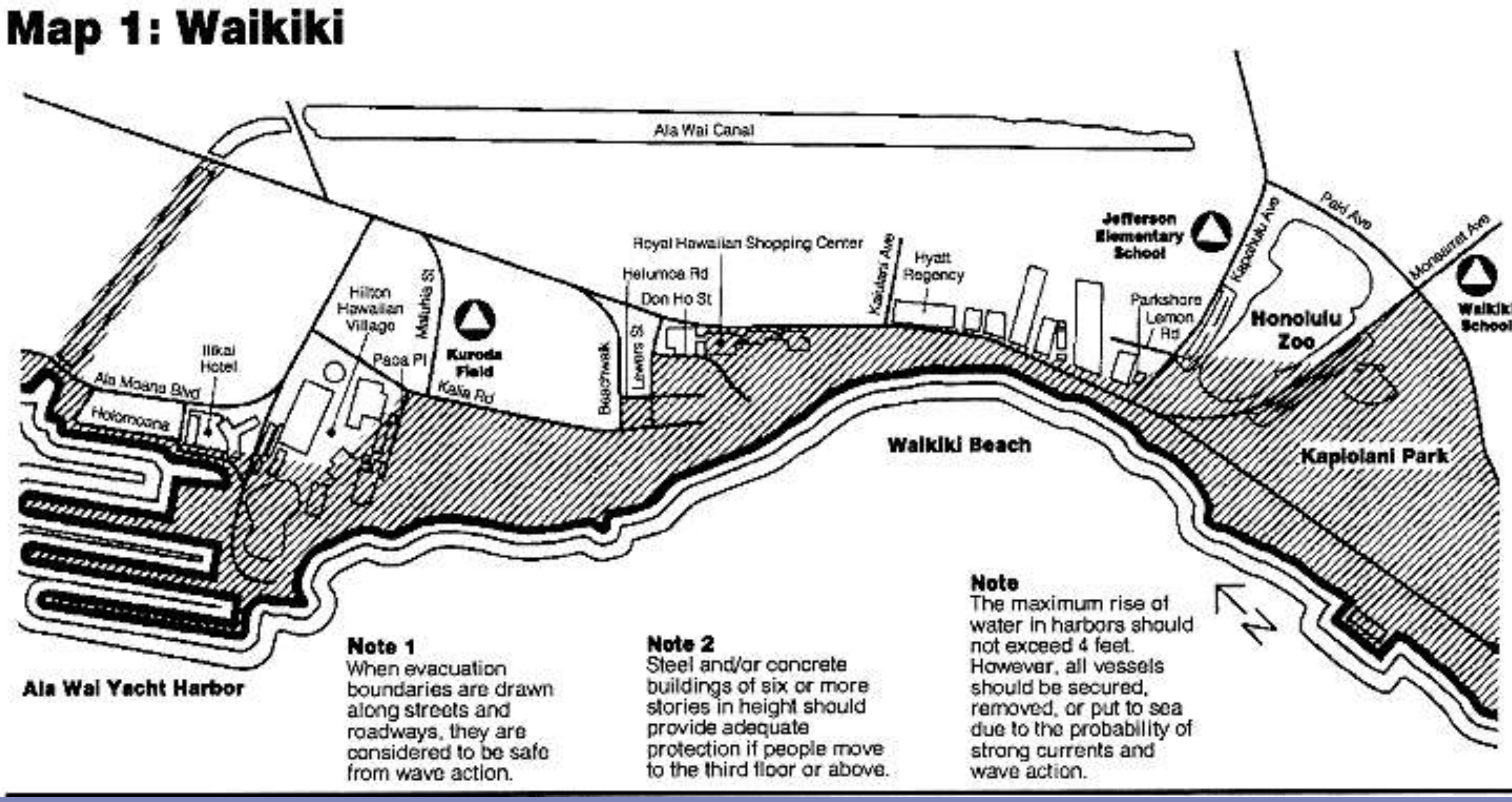
TSUNAMI BACKWASH FROM A COVE NEAR KA ‘IWI COASTLINE



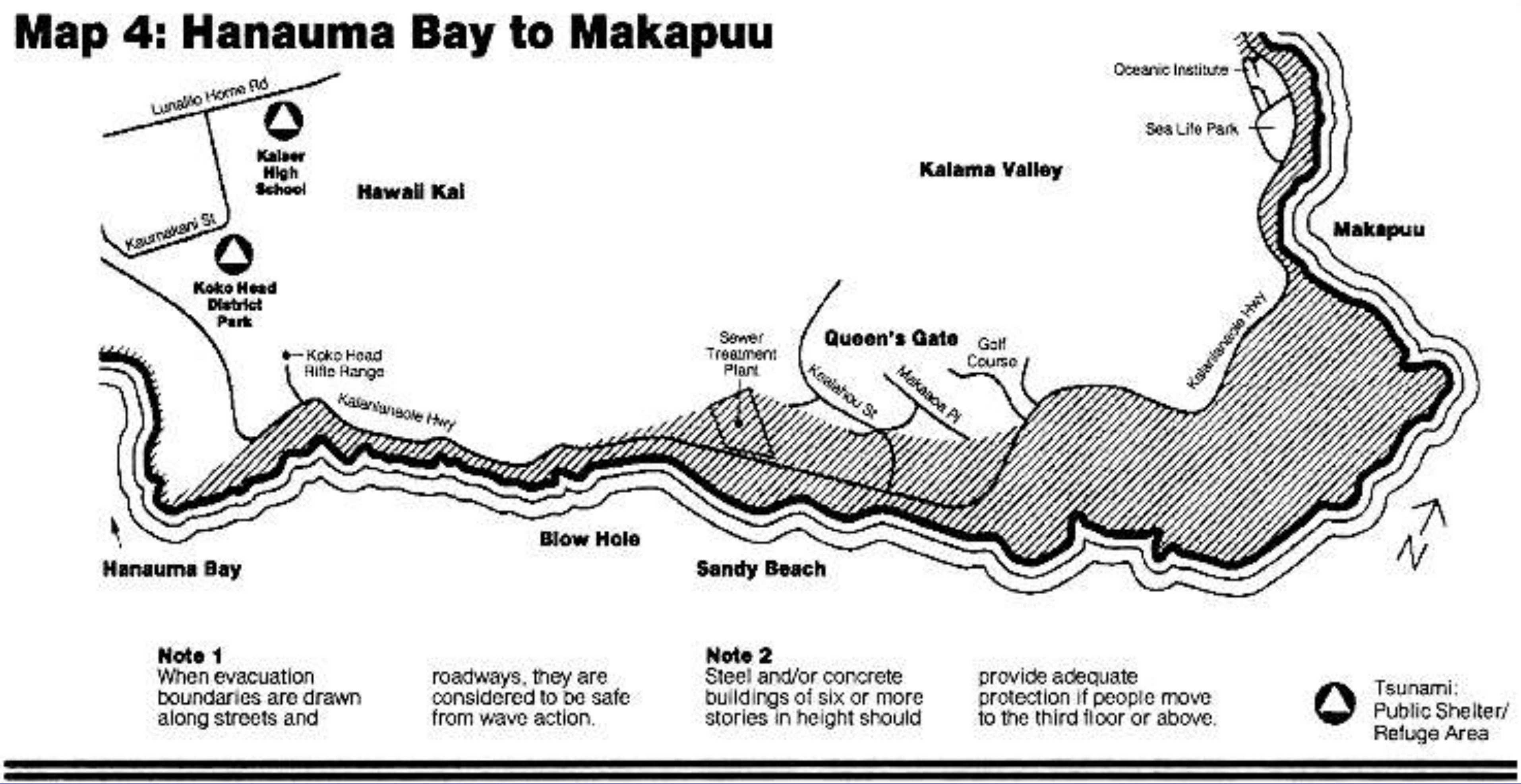
April 1, 1946. This photograph was taken by a pilot early on the morning of April 1. It is of the same region as the preceding photographs and seems to have been taken immediately subsequent to the arrival of a major wave.



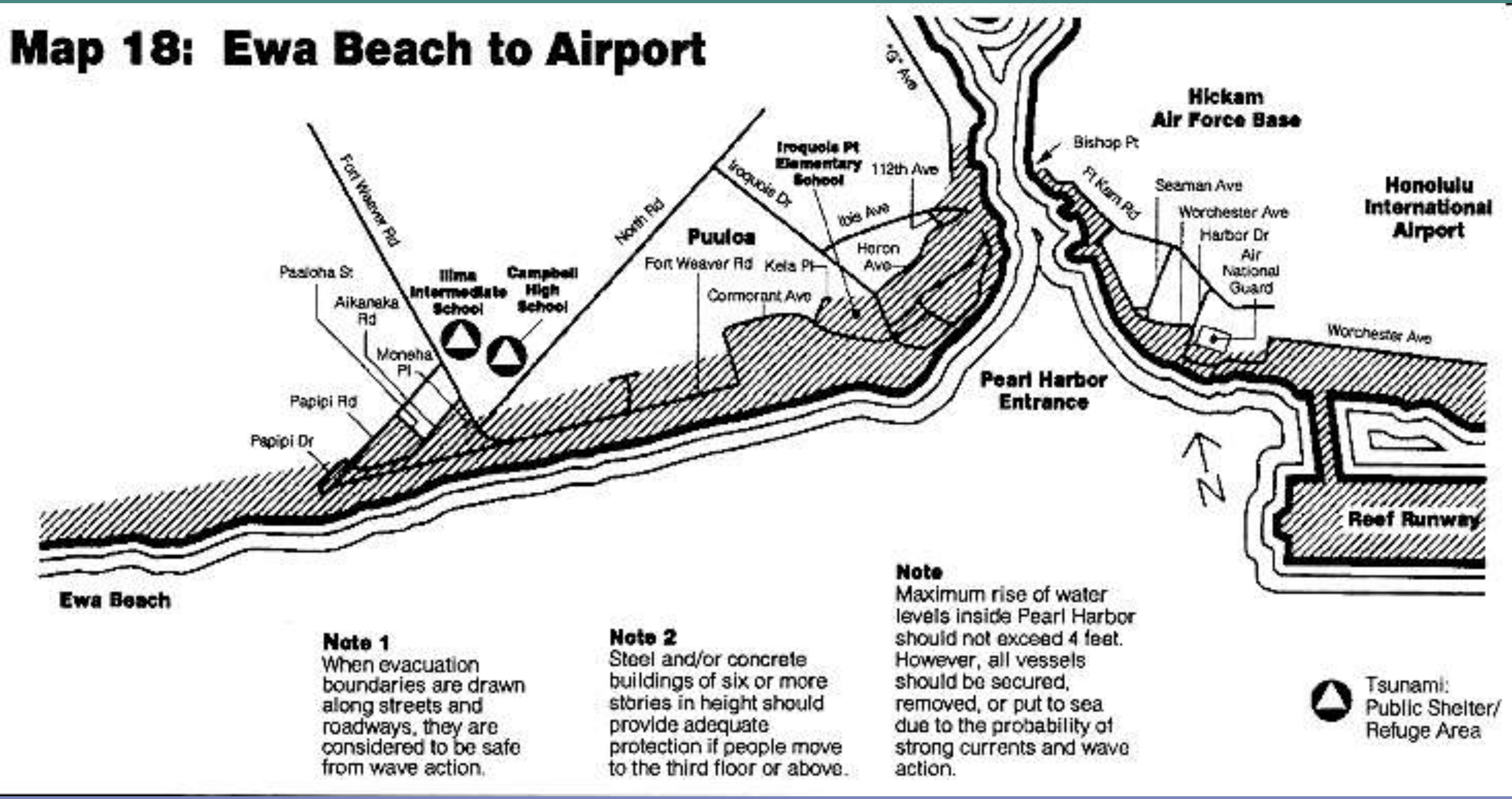
http://nctr.pmel.noaa.gov/Gif/tsu_cc60hh64.gif



http://www.pdc.org/DisasterInfo/Shelters/CDmaps/Oahu/Oahu-map01.gif



http://www.pdc.org/DisasterInfo/Shelters/CDmaps/Oahu/Oahu-map04.gif



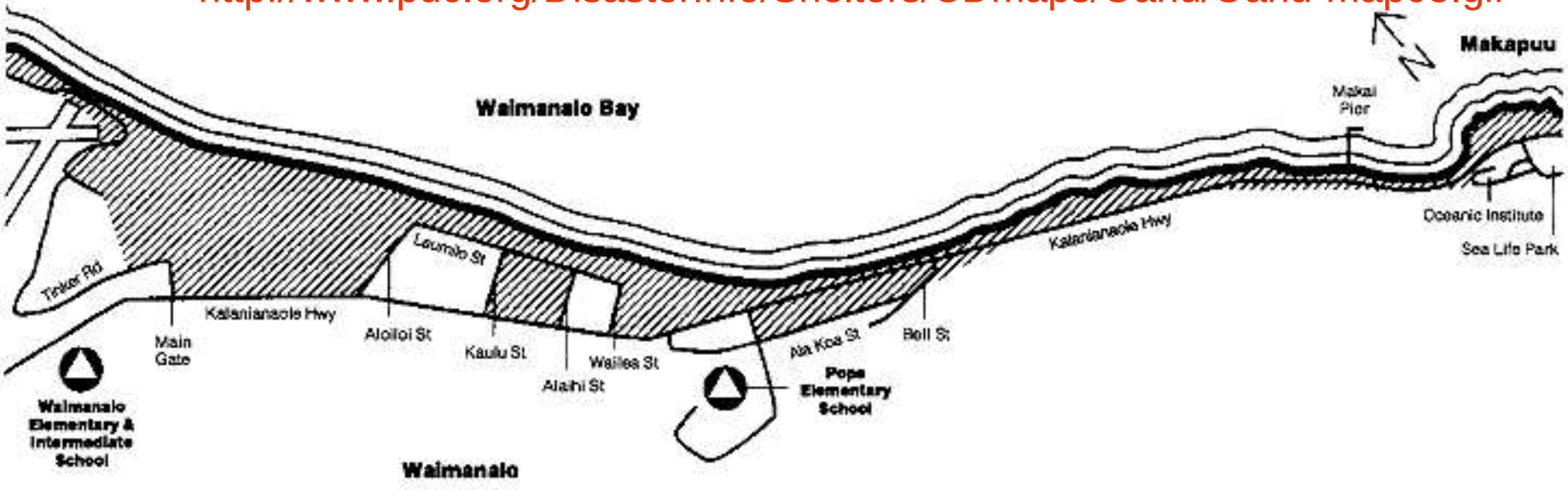
http://www.pdc.org/DisasterInfo/Shelters/CDmaps/Oahu/Oahu-map18.gif

Honolulu City & County Dept. of Emergency Management website: http://www.honolulu.gov/dem/

Map 5: Makapuu to Waimanalo

THE OLD MAP

http://www.pdc.org/DisasterInfo/Shelters/CDmaps/Oahu/Oahu-map05.gif



Note 1
When evacuation boundaries are drawn along streets and roadways, they are considered to be safe from wave action.

Note 2
Steel and/or concrete buildings of six or more stories in height should provide adequate protection if people move to the third floor or above.

Note
Due to the probability of strong currents and wave action, all vessels should be secured, removed or put to sea.

Tsunami: Public Shelter/ Refuge Area

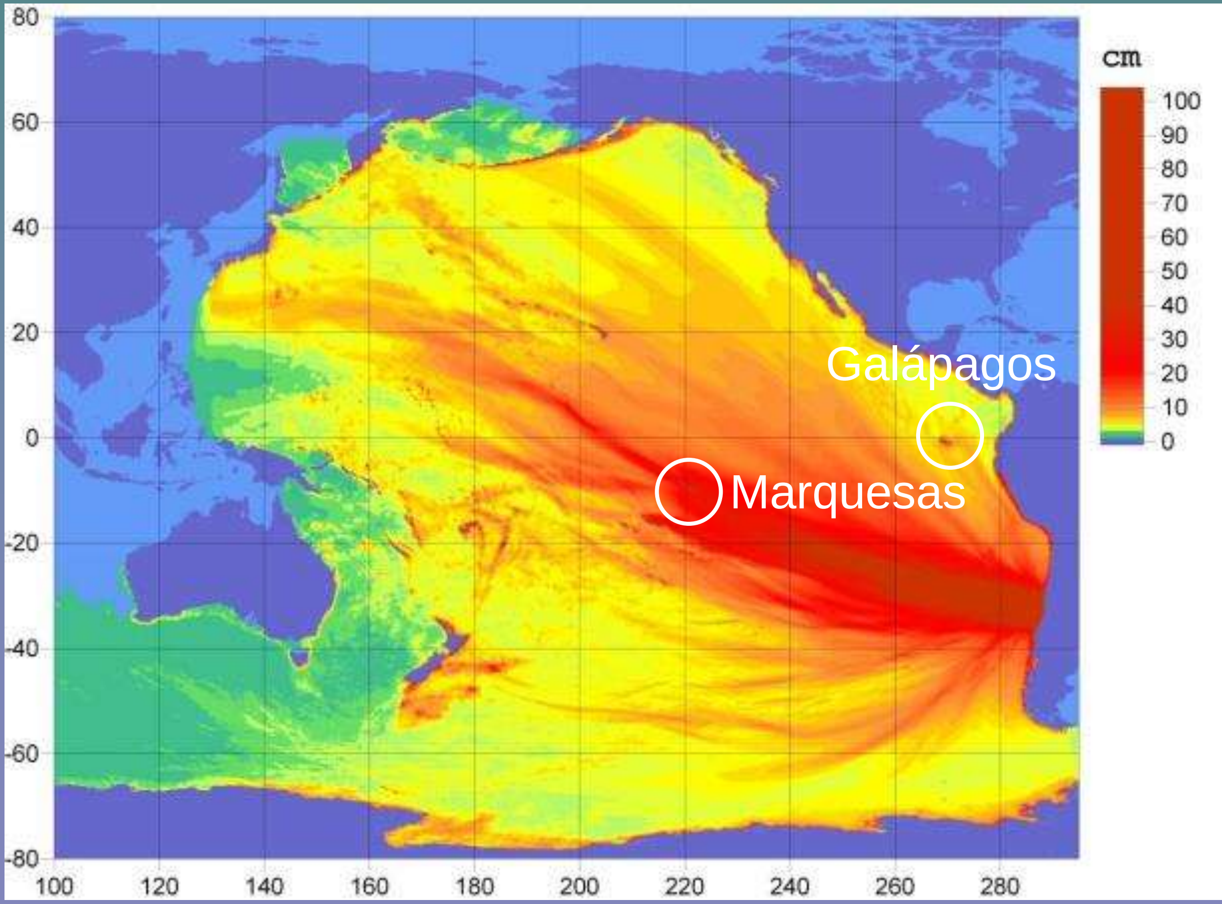
THE NEW MAP

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

In the open ocean, a tsunami travels at a speed of over 700 km/hr (~440 mph) and the wave moves the ocean water all the way to the sea floor. This "shallow water" behavior means that the velocity and projected wave heights of a tsunami can be calculated using a map of ocean depth.

The map on the right is from NOAA's West Coast and Alaskan Tsunami Warning Center. This map shows the predicted amplitudes of the tsunami produced by the M8.8 Chilean earthquake. Since tsunamis have such large wavelengths, they "experience" the ocean as shallow water. This makes tsunamis nondispersive and allows them to propagate without dispersion or significant loss of energy across entire ocean basins.

Preliminary Forecast Model Energy Map



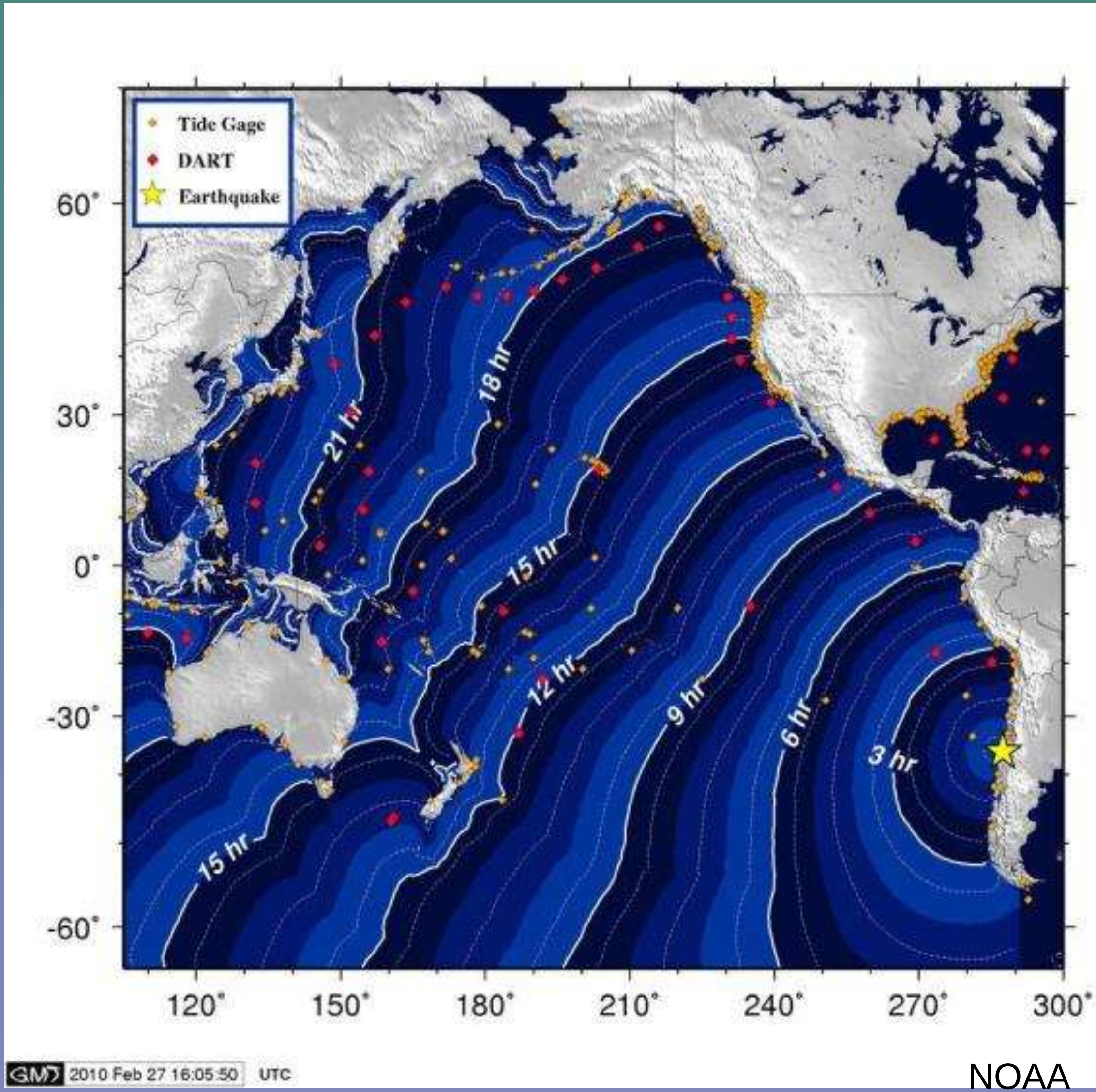
NOAA

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

In Hawaii, the state Department of Transportation is urging all shipping agents and shipping companies to get their ships out of port this morning. Hawaii has been put on alert to expect its largest waves since 1964.

In Hawaii, the tsunami warning alarms sounded at 6 am, giving residents 5 hours to evacuate to higher ground by the expected ~11 am arrival of tsunami waves.

Tsunami waves are likely to hit Asian, New Zealand, and Australian shores in the next 24 hours. Alaska and the U.S. West Coast, including California, are also under warning. The warning means there may be strong currents, but that widespread inundation is not expected to occur.



NOAA

Magnitude 8.8 OFFSHORE MAULE, CHILE

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

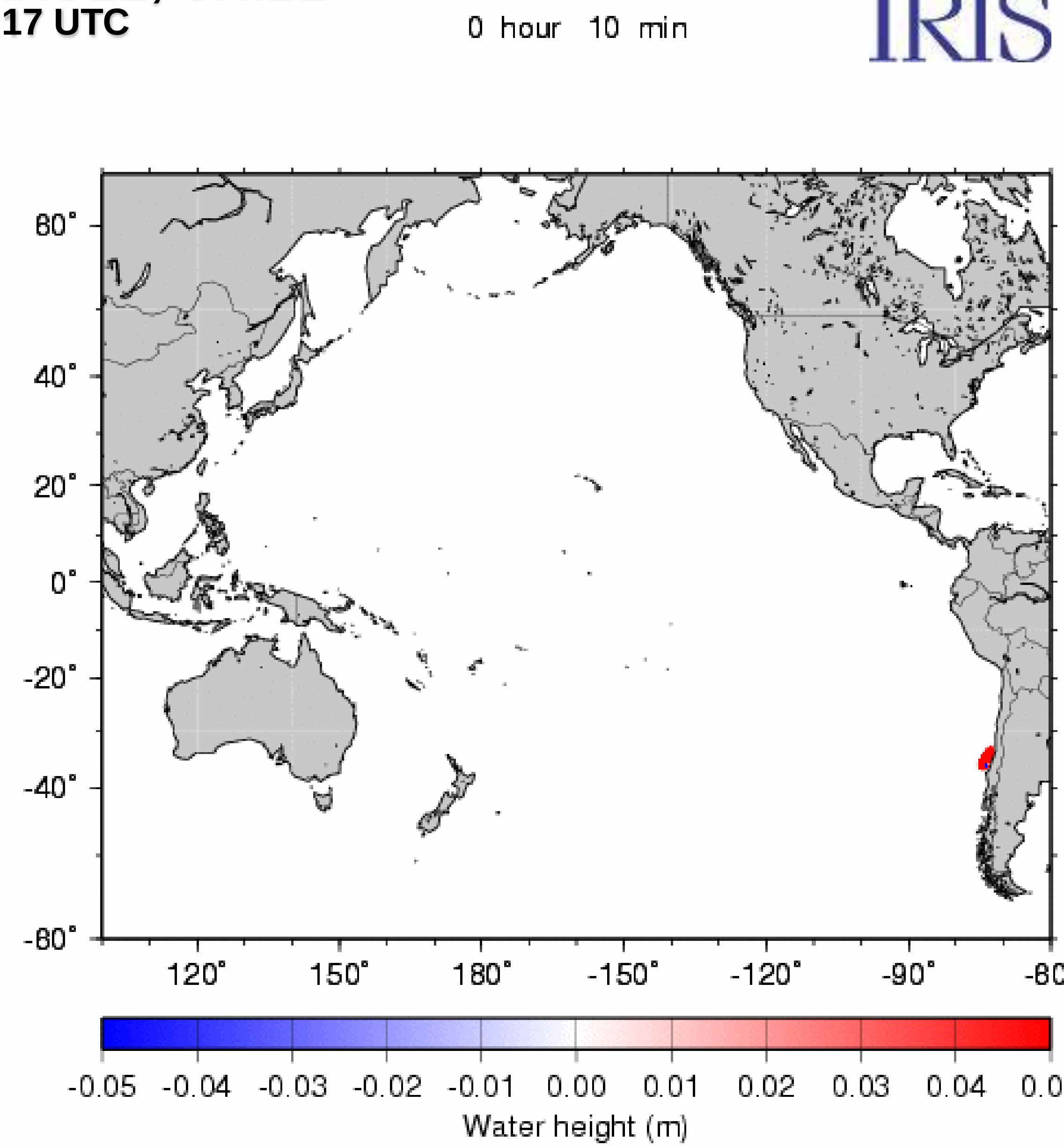
Tsunami Model for Chilean earthquake - Earthquake Research Institute, Tokyo

Animation model of the Tsunami propagation across the Pacific.

Tsunamis generated in Chile are a concern in the Pacific.

This earthquake originated about 230 km north of the source region of the magnitude 9.5 earthquake of May, 1960 the largest instrumentally recorded earthquake in the world.

This magnitude 9.5 earthquake killed 1655 people in southern Chile and unleashed a tsunami that crossed the Pacific, killing 61 people in Hawaii, Japan, and the Philippines.



Earthquake Research Institute, Tokyo

YOU TUBE!!

Coconut Island, Hilo

Wailuku river, Hilo

Sand/rock bar, Hilo

Mānele, Lānaʻi

…totally unrelated, the famous Greenland iceberg “tsunami”

…and another one…