

An aerial photograph of a massive tsunami wave, showing the deep blue water of the trough and the white, churning water of the crest. The wave is moving from the top right towards the bottom left of the frame.

Tsunami ramp Asia 26 december 2004

Het ontstaan van tsunamis

Robert Hack

(met dank aan van Mark van der Meijde en Colin
Reeves voor een gedeelte van de slides)

ESA



Earth processes

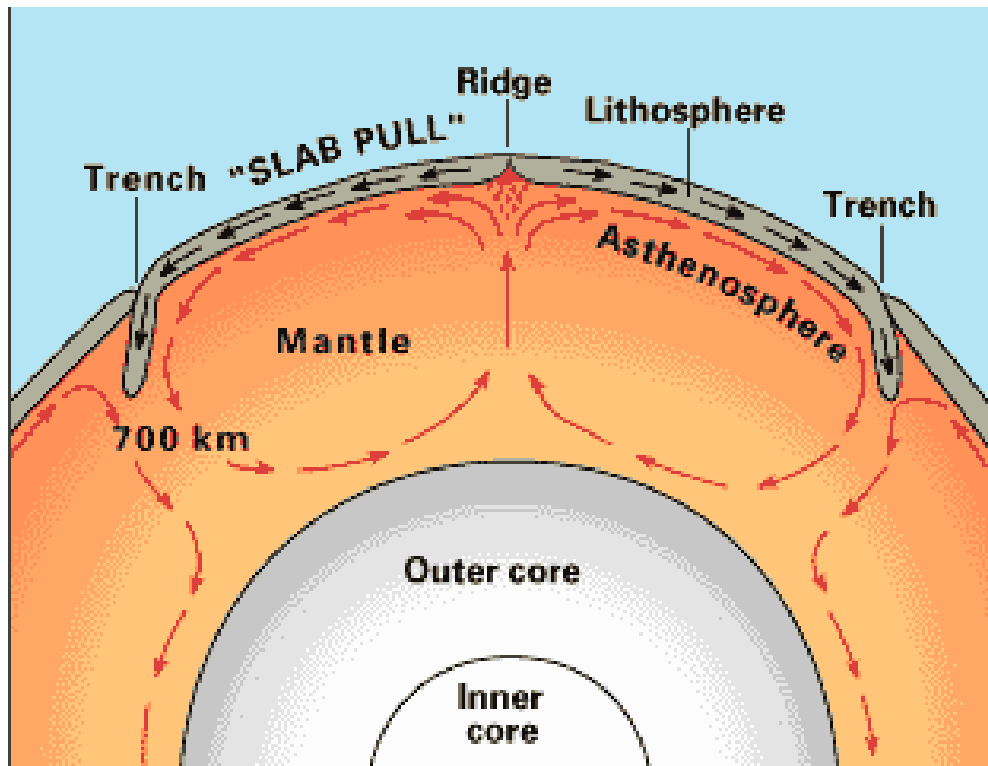


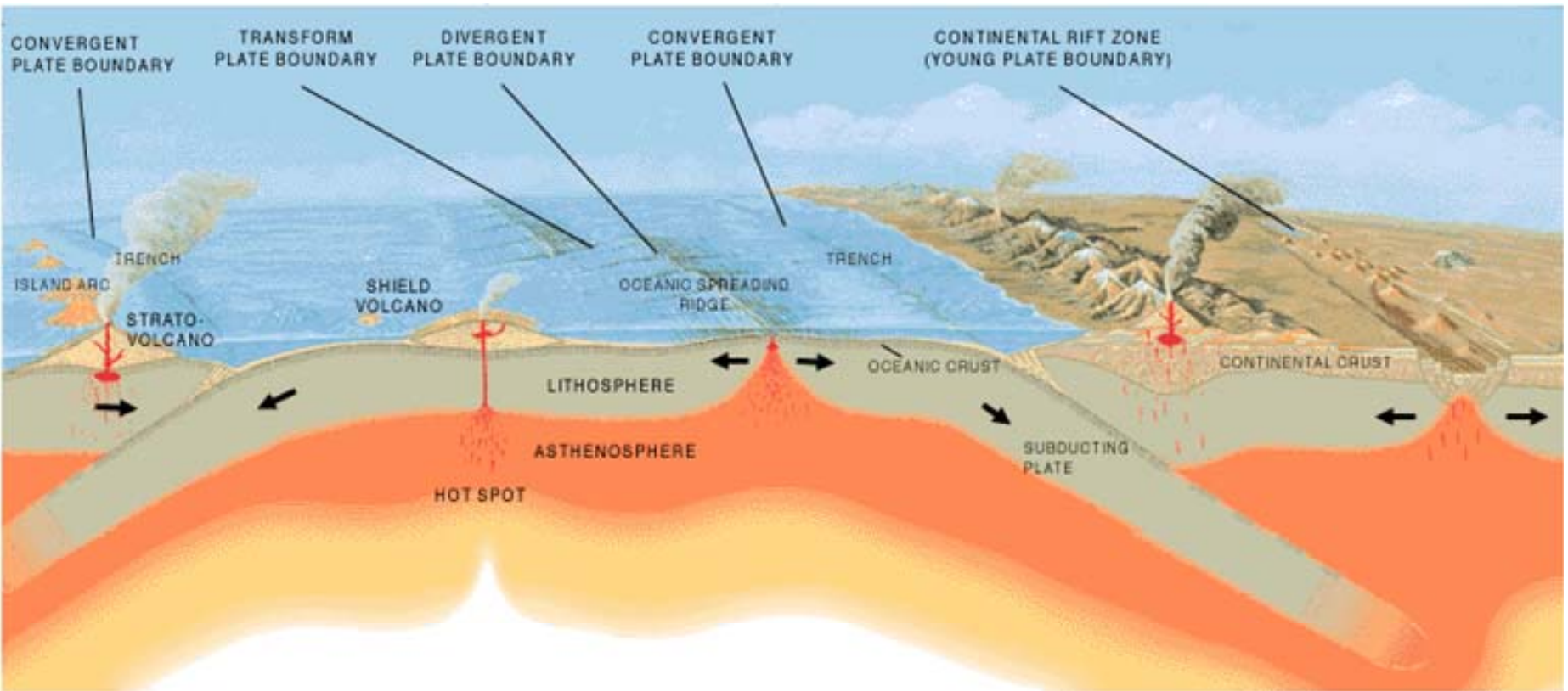
Plate tectonics

- A simulation of tectonic processes in the last 200 Ma (Prof. Colin Reeves, ITC)

[gondwana\gondwana.exe](#)

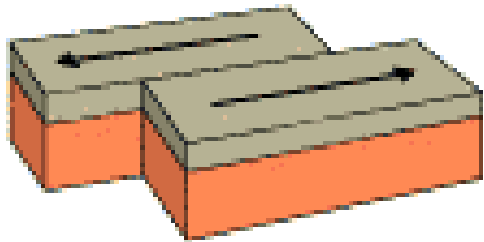


Plate tectonics

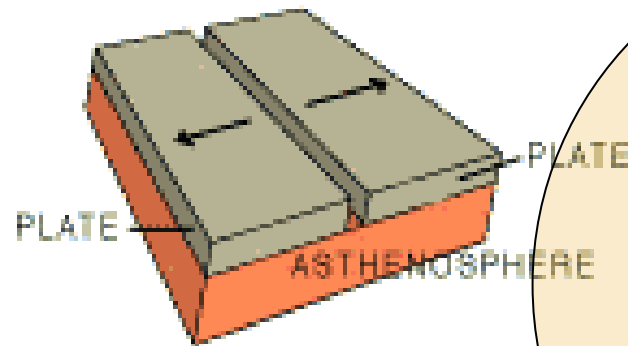


Faulting mechanisms

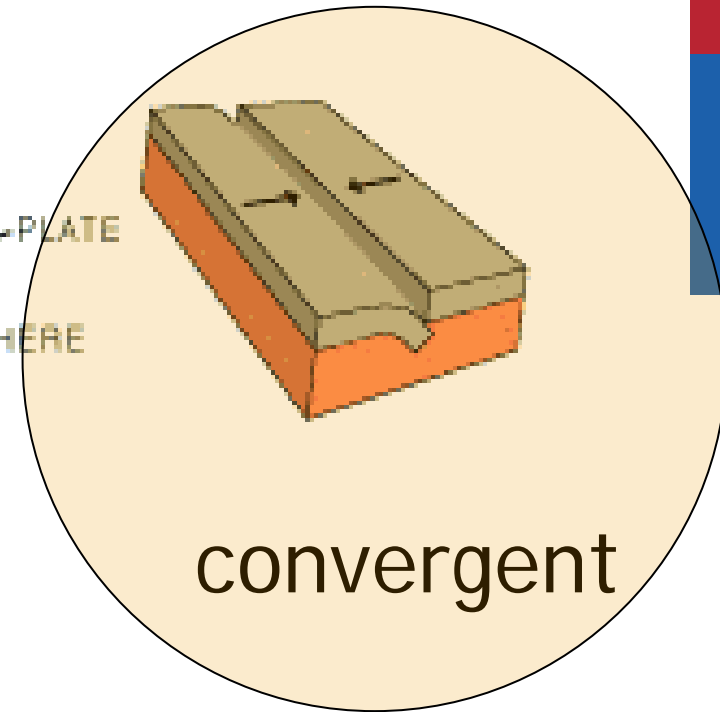
- Three types of plate boundaries:



transform



divergent



convergent

*possible cause
for tsunami*

Worldwide plate boundaries



Active Volcanoes, Plate Tectonics, and the "Ring of Fire"



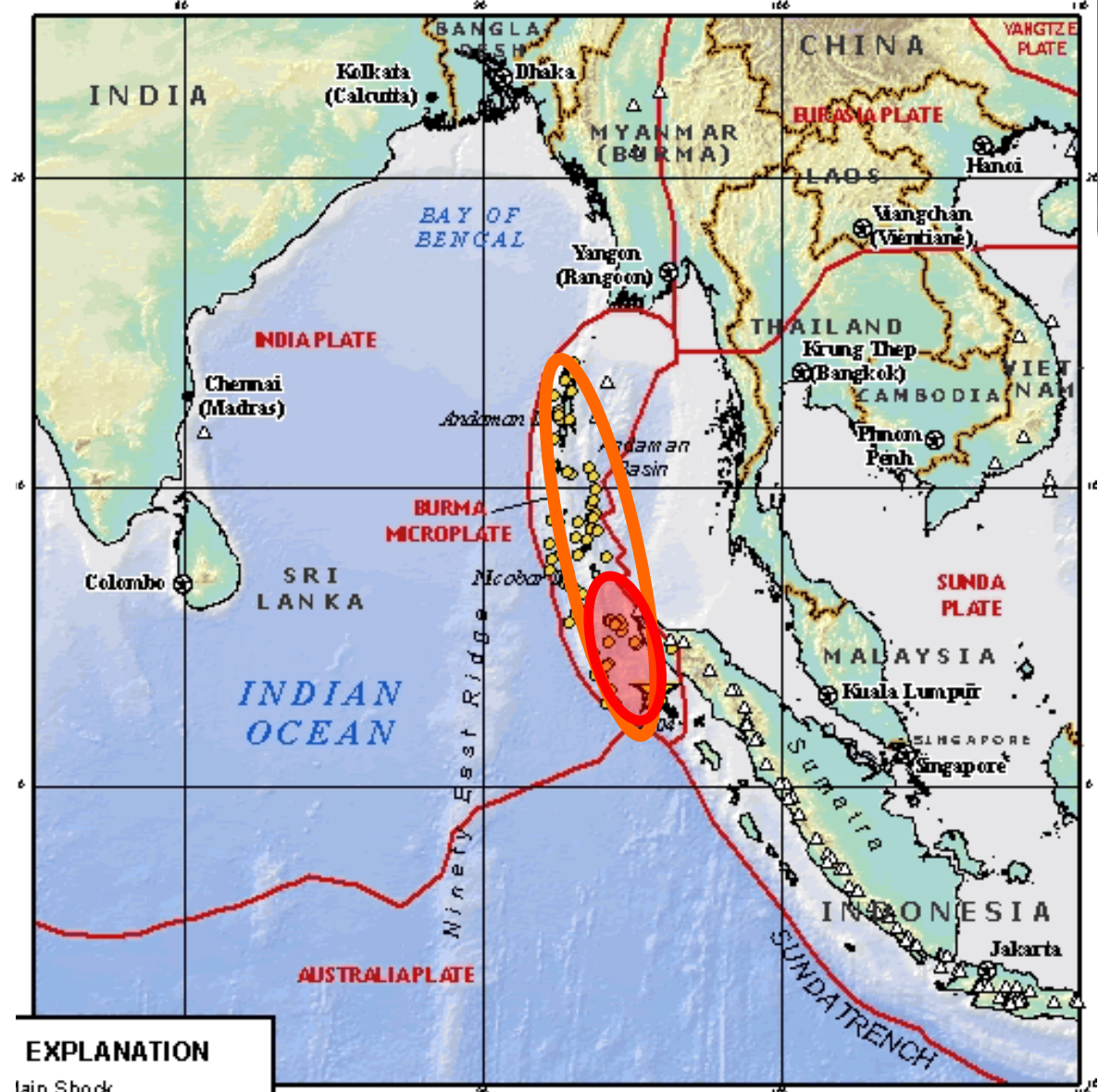
Tectonic Setting

Breuk 1200-1300 km

Hoogste intensiteit in de zuidelijke 400 km

Horizontale verplaatsing 15-20 m

Verticale verplaatsing ongeveer 15 meter

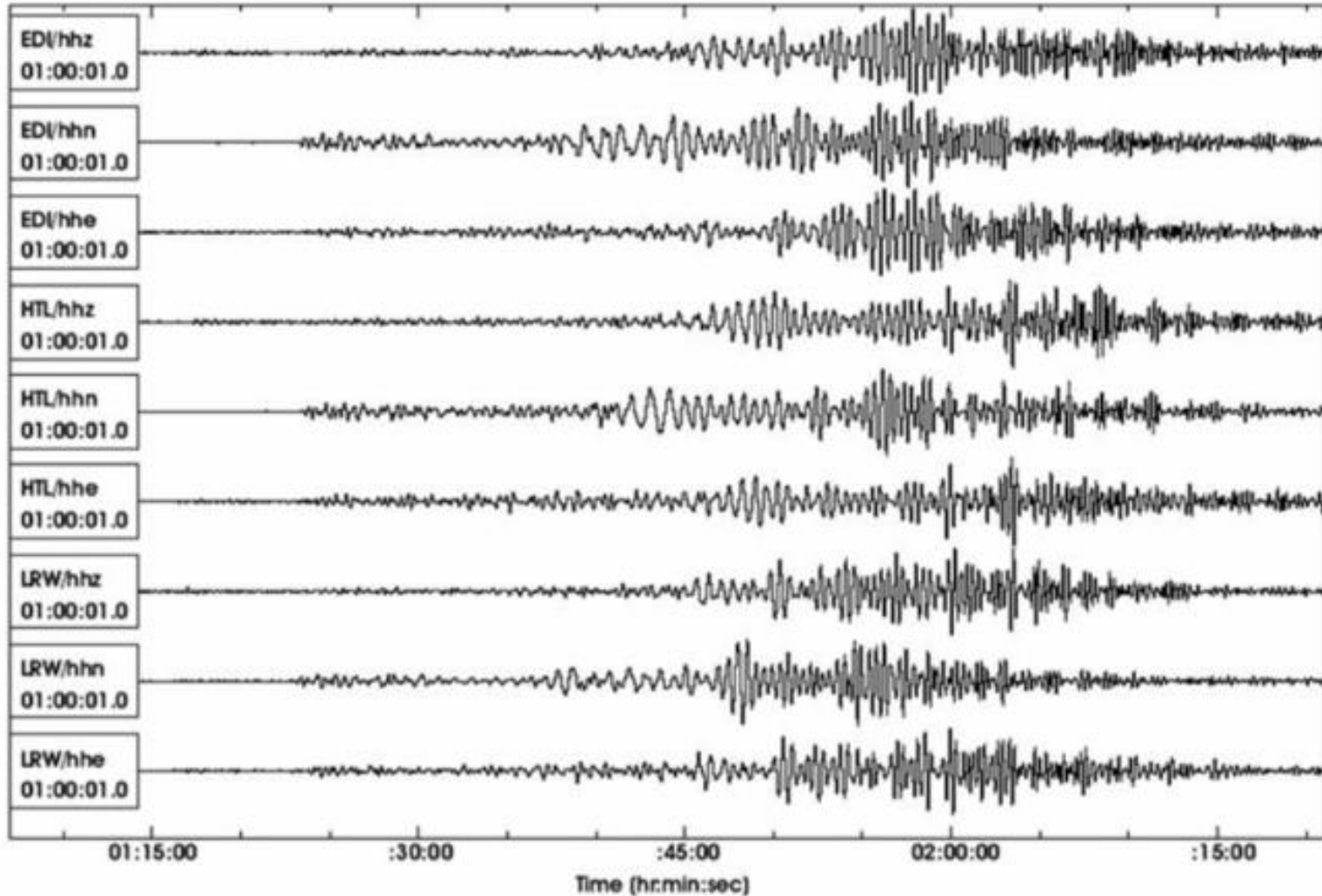


EXPLANATION

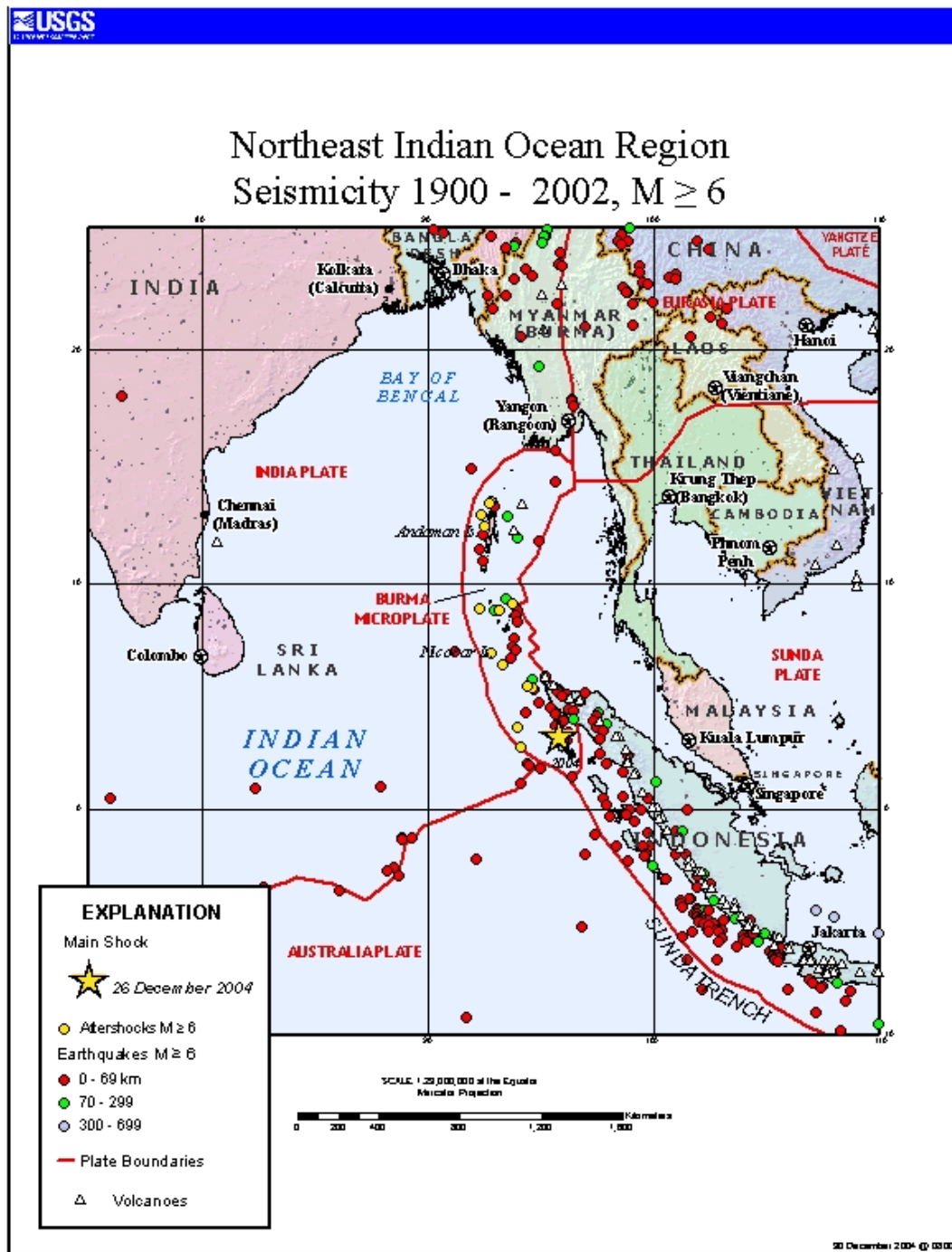
- Main Shock
- ★ 26 December 2004
- △ Aftershocks $M \geq 4$
- Plate Boundaries
- △ Volcanoes

Seismic record

OFF W COAST OF NORTHERN SUMATRA 26 DEC 2004 00:58 UTC 8.5 MS



Historical Epicenter map



Source: BGS

What is een tsunami?

- Een “wave train”, of een serie van golven, veroorzaakt in water door een plotselinge *verstoring* die vertikaal of horizontaal de water kolom verplaatst.



Wat veroorzaakt een tsunami?



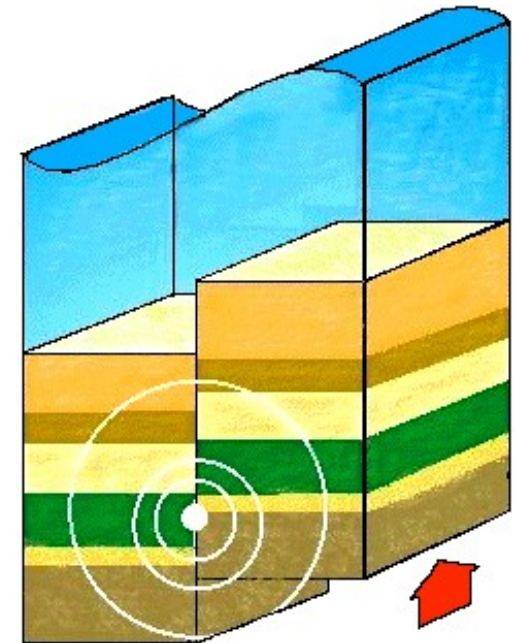
- In het algemeen:

Alles dat in staat is een grote watermassa te verplaatsen kan een tsunami veroorzaken

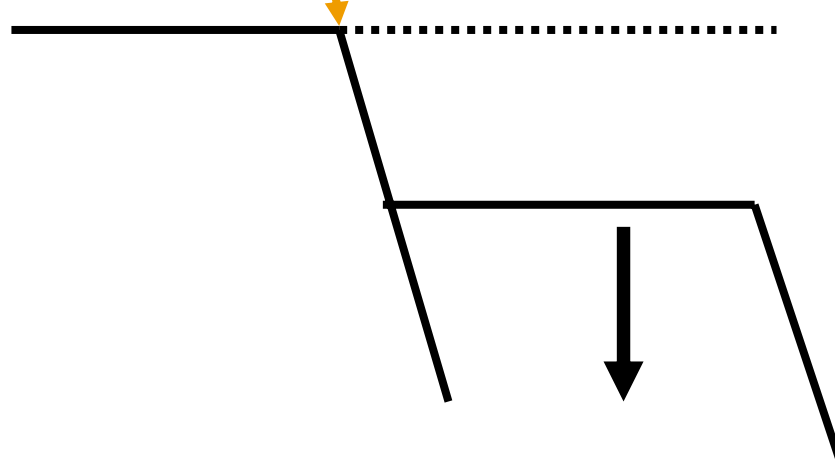
- B.v. aardbevingen, landslides, vulkanische uitbarstingen, explosies, meteorieten, etc.

Hoe veroorzaakt een aardbeving een tsunami?

- Tsunamis kunnen veroorzaakt worden indien de zeebodem plotseling vervormd en vertikaal de bovenliggende waterkolom verplaatst
- De volledige waterkolom wordt verstoord door de beweging van de zeebodem
- De golf (tsunami) ontstaat doordat in het water weer evenwicht moet herstellen



Displacement



15 meter!

A tsunami is NOT:

- A tidal wave

Tides result from the imbalanced, extraterrestrial, gravitational influences of the moon, sun, and planets.

- A seismic sea wave

"Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a non-seismic event, such as a landslide or meteorite impact.

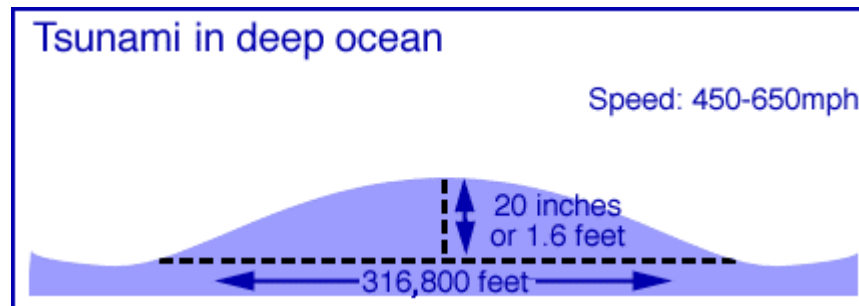
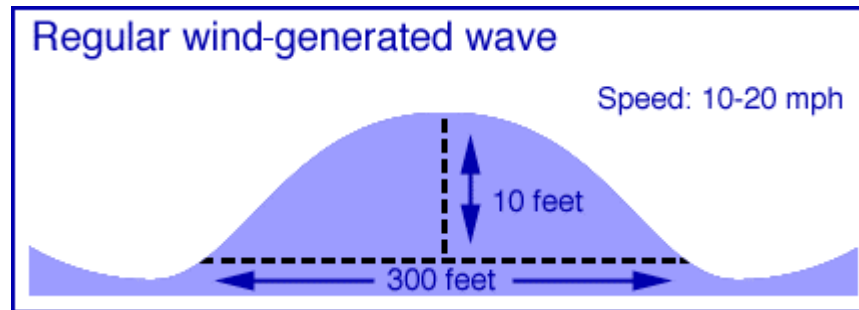
- A wind-generated wave (storm wave)

- wind/storm generates disturbance at the surface of the water column
- Wavelength can be up to 150 meters, with a period of up to 10 sec.



Different waves

- Vergelijking tussen een golf veroorzaakt door wind en een tsunami



Shallow water waves

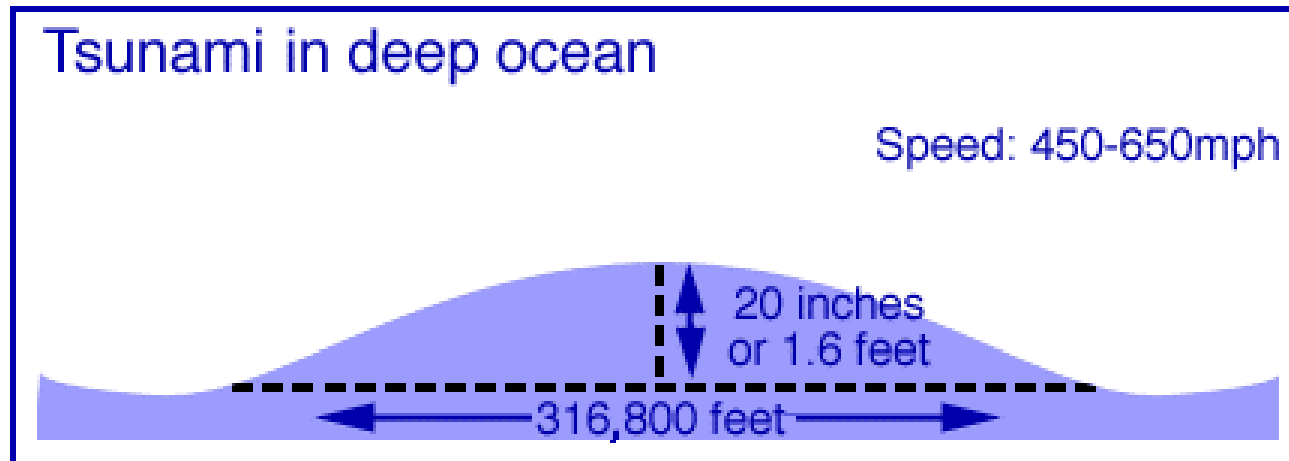


- Tsunami waves have long period and wavelength
 - wavelength can be in excess of 100 km with
 - a period in the order of one hour.
- It behaves as a shallow-water wave
 - the ratio between the water depth and
 - its wave length is very small.
- Tsunamis not only propagate at high speeds, they can also travel great, transoceanic distances with limited energy losses.

(the rate at which a wave loses its energy is inversely related to its wave length)

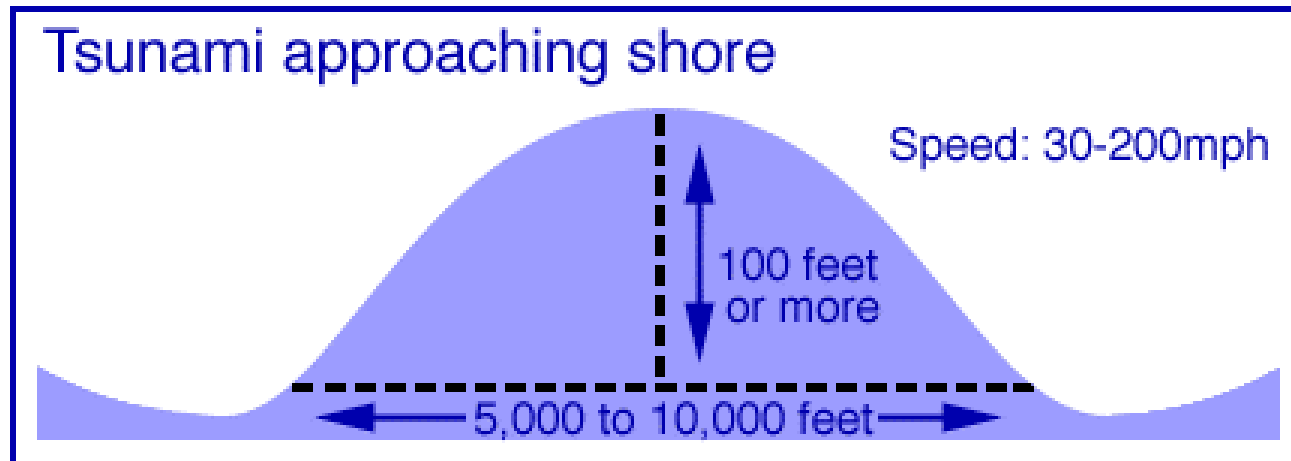
Tsunami in deep ocean

- Speed is 700 km/hr in 4 km deep ocean.
- Amplitude is in the order of several centimeters to decimeters.



Tsunami approaching shore

- Slows down to <50 km/hr in shallow water (<100 - 200 m).
- Amplitude is in the order of a few meter up to 30 meters.

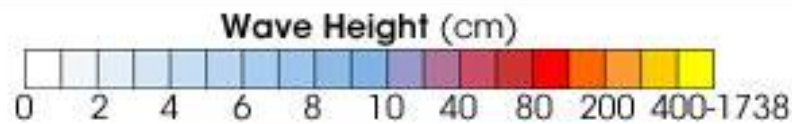
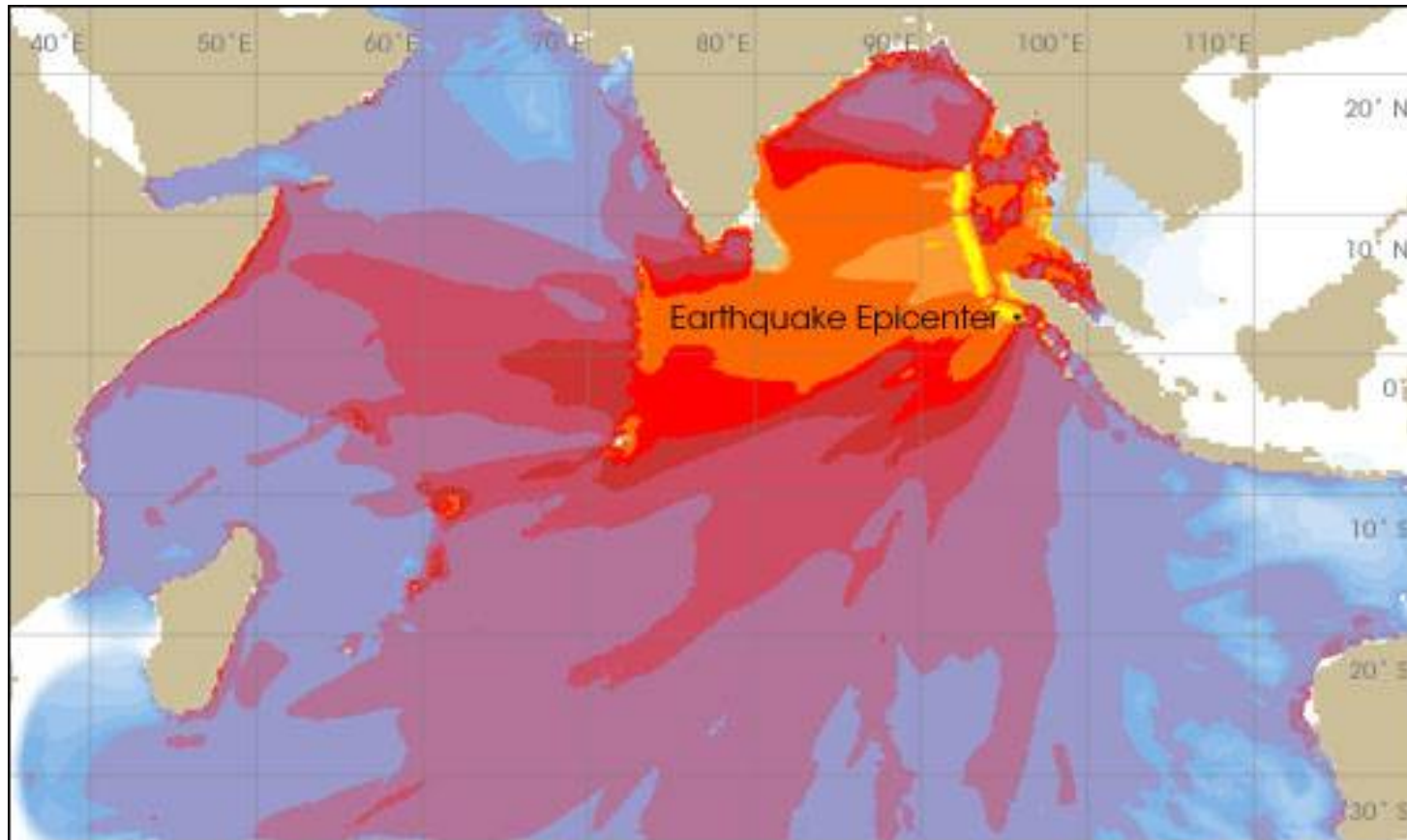


Tsunami simulation



[indo2004\TITOV-INDO2004.mov](#)

Tsunami simulation

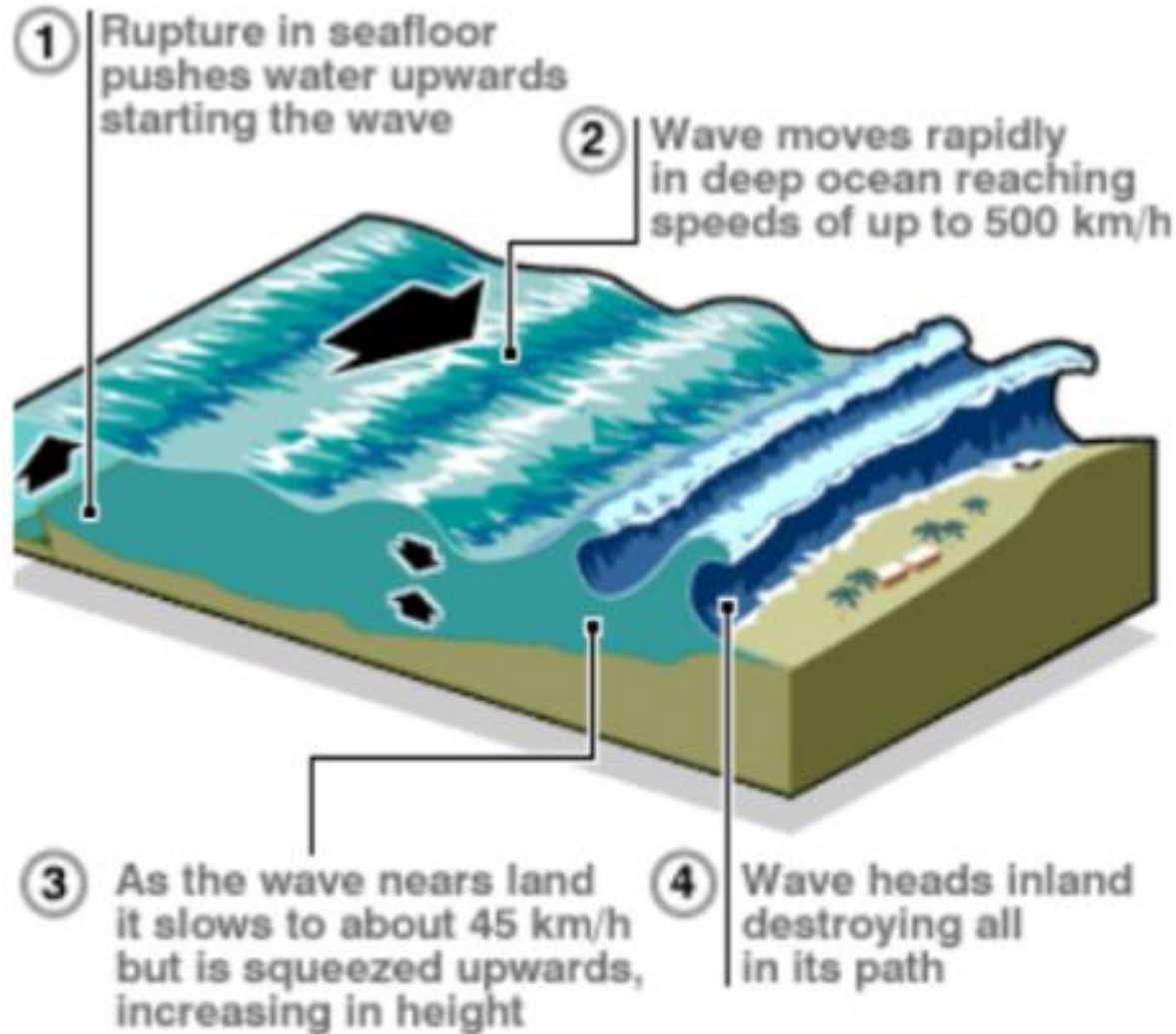


Tsunami effects



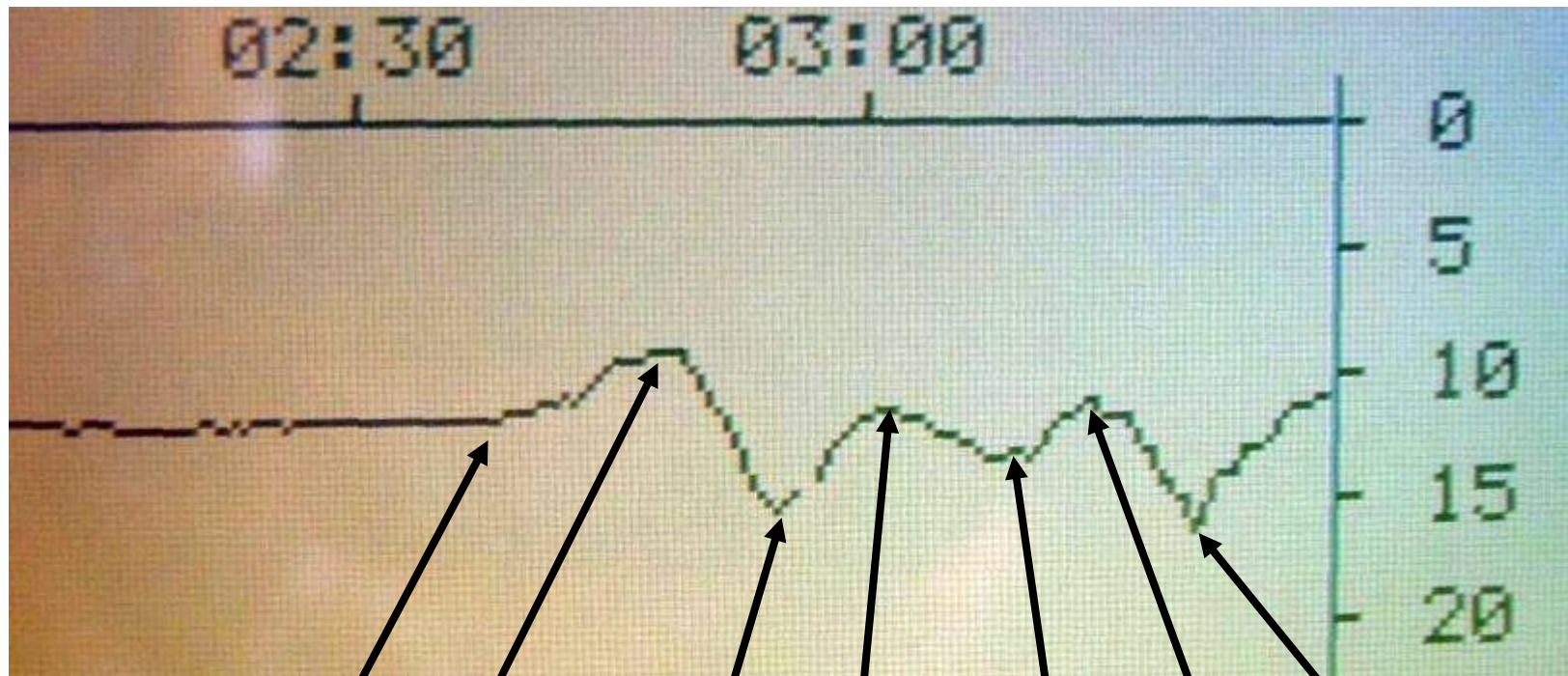
- Tsunamis can last for several hours.
- A tsunami consists of several wave trains following each other.
- A pattern of high water levels is alternated with a low water level.
- This is most indicative of tsunamis!

Tsunami effects



Tsunami effects

high-low pattern on boat 1 km offshore Thailand



start	low	high	low	high	low	high
0m	-3.2m	+3.9m	-0.5m	+2m	-0.6m	+5.5m
t=0	t=9:30	16:15	23:03	29:03	35:00	41:15

Tsunami effects



Schade Aceh (1)

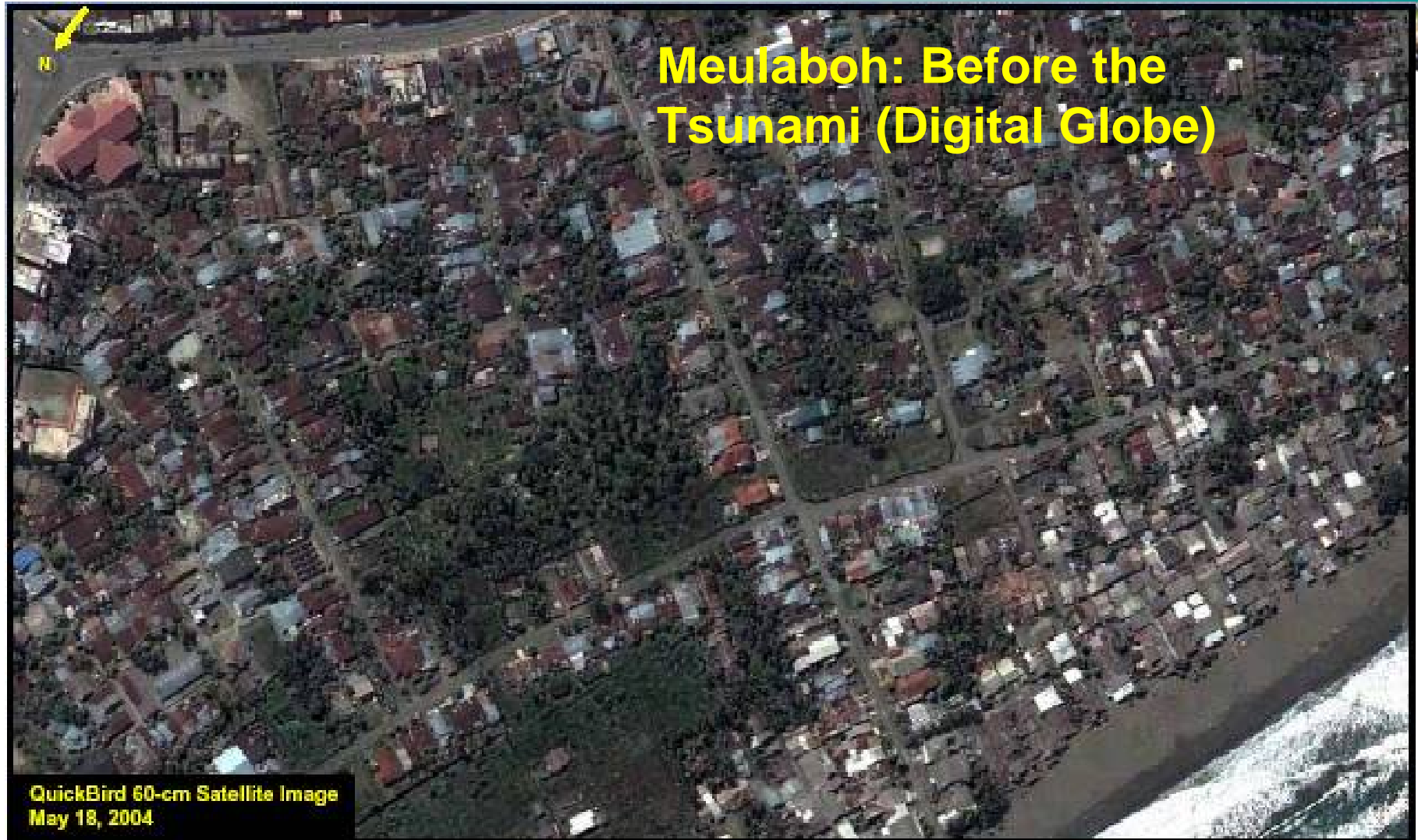
GLEEBRUK



Schade Aceh (2)



Schade Meulaboh (1)



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Meulaboh: Before the
Tsunami (Digital Globe)

QuickBird 60-cm Satellite Image
May 18, 2004

Schade Meulaboh (2)



Summary



- Earthquakes do not always cause tsunamis
- Why caused this earthquake such a devastating tsunami:
 - Very large magnitude
 - Occurred off coast in deeper water
 - Extreme large vertical displacement!!

How earthquakes generate tsunamis (extra)



- Large vertical movements of the earth's crust can occur at plate boundaries.
- Plates interact along these boundaries (faults).
- Around the margins in the Indian ocean denser oceanic plates slip under continental plates in a process known as subduction.
- Subduction earthquakes are particularly effective in generating tsunamis.

MEGA-tsunamis



Naast tsunamis bestaan ook
MEGA-tsunamis

MEGA-tsunamis



Mega-tsunamis ontstaan zover bekend niet door aardbevingen maar door grote landslides of meteorieten:

Golfhoogtes tot 1000's metres;
snelheden tot over 1000- 1500
km/uur

MEGA-tsunamis



Mega-tsunamis:

Lituya Bay, Canada, 1958:

Tsunami hoogte 500 M

(een kleintje in termen van mega-tsunamis)

MEGA-tsunamis



MEGA-tsunamis - Lituya Bay, Canada



MEGA-tsunamis

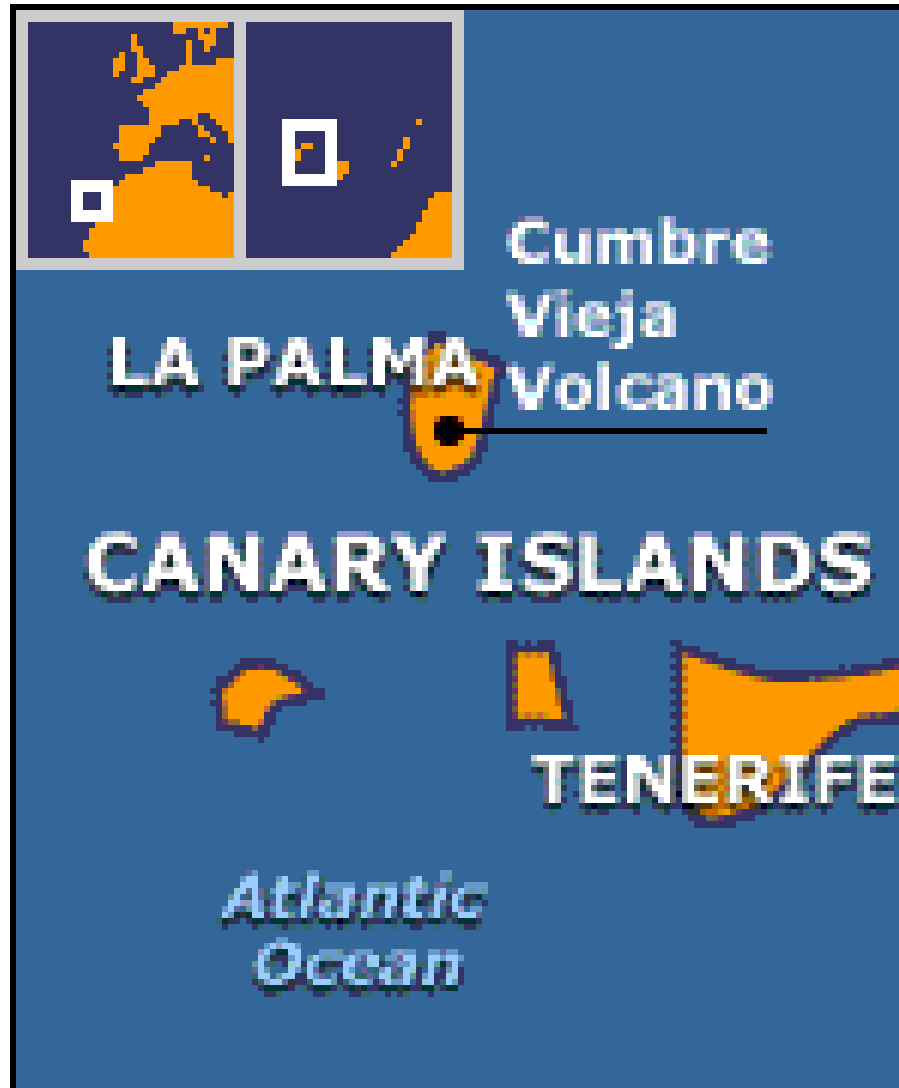
Naar verwachting eerstvolgende
mega-tsunami veroorzaakt door
gedeeltelijk instorten van de vulkaan
op La Palma (Canary Islands):

Voorspelling:

een mega-tsunami van 900 m hoog
met een snelheid van 1500 km/uur



MEGA-tsunamis: La Palma



MEGA-tsunamis: La Palma volcano



MEGA-tsunamis



La Palma tsunami voorspelling:

Volledige verwoesting van alles binnen 20 km van de Amerikaanse oostkust, Caraïben, en stukken Zuid Amerikaanse kust;

daarna weerkaatst de golf naar Europe met (iets mindere) volledige verwoesting van grote delen van de westkust van Europa

MEGA-tsunamis



Wat te doen bij een tsunami:
Op eerste teken van
terugtrekkend zeewater:
ga niet kijken, maar

REN

(de andere kant op !!!)

*En kom niet terug voordat de experts het
zeggen (er kan nog een golf komen)*