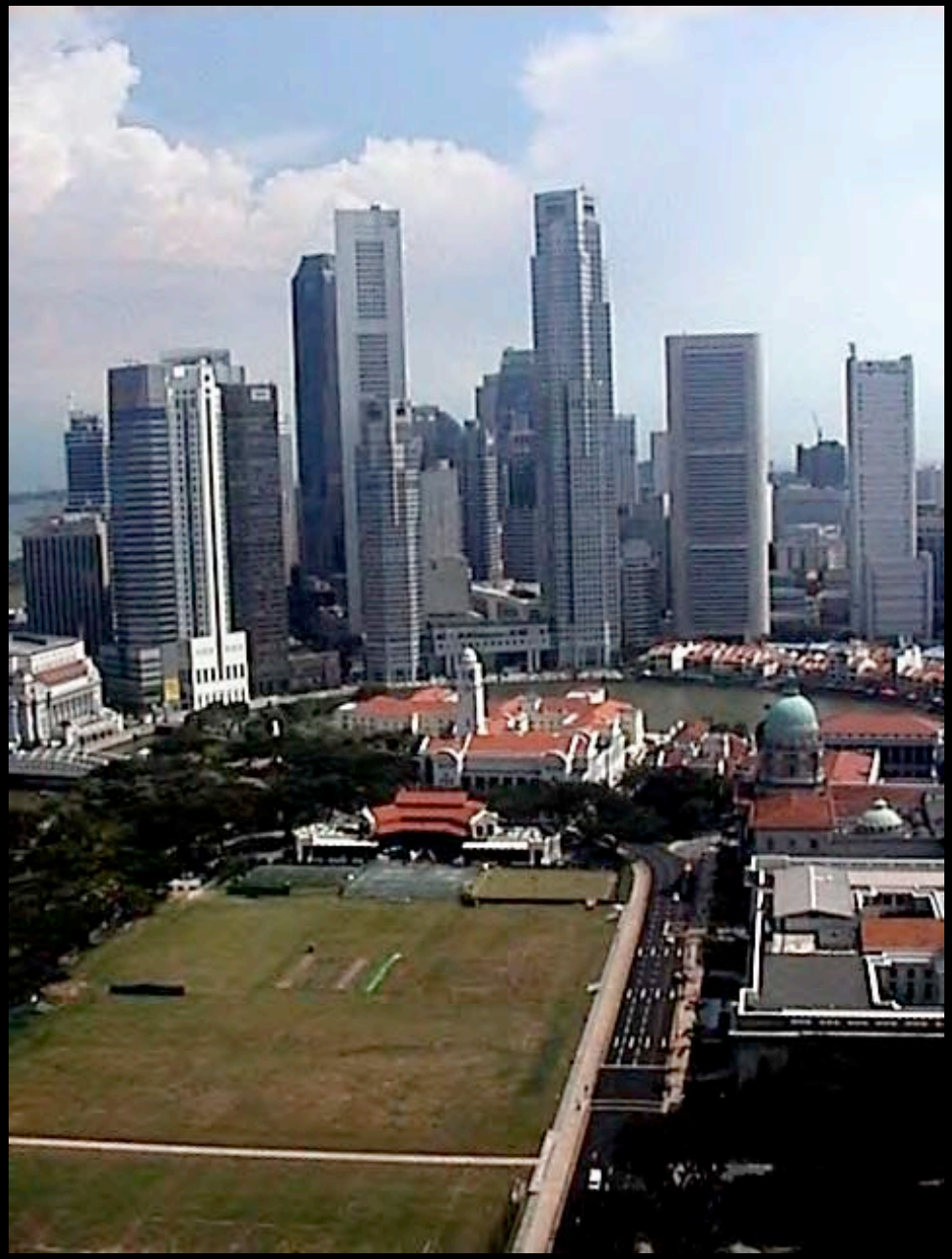
Exploring a collaboration between Caltech and the Singaporean government

Forecasting giant earthquakes of the Sumatran subduction zone and their impact on Singapore

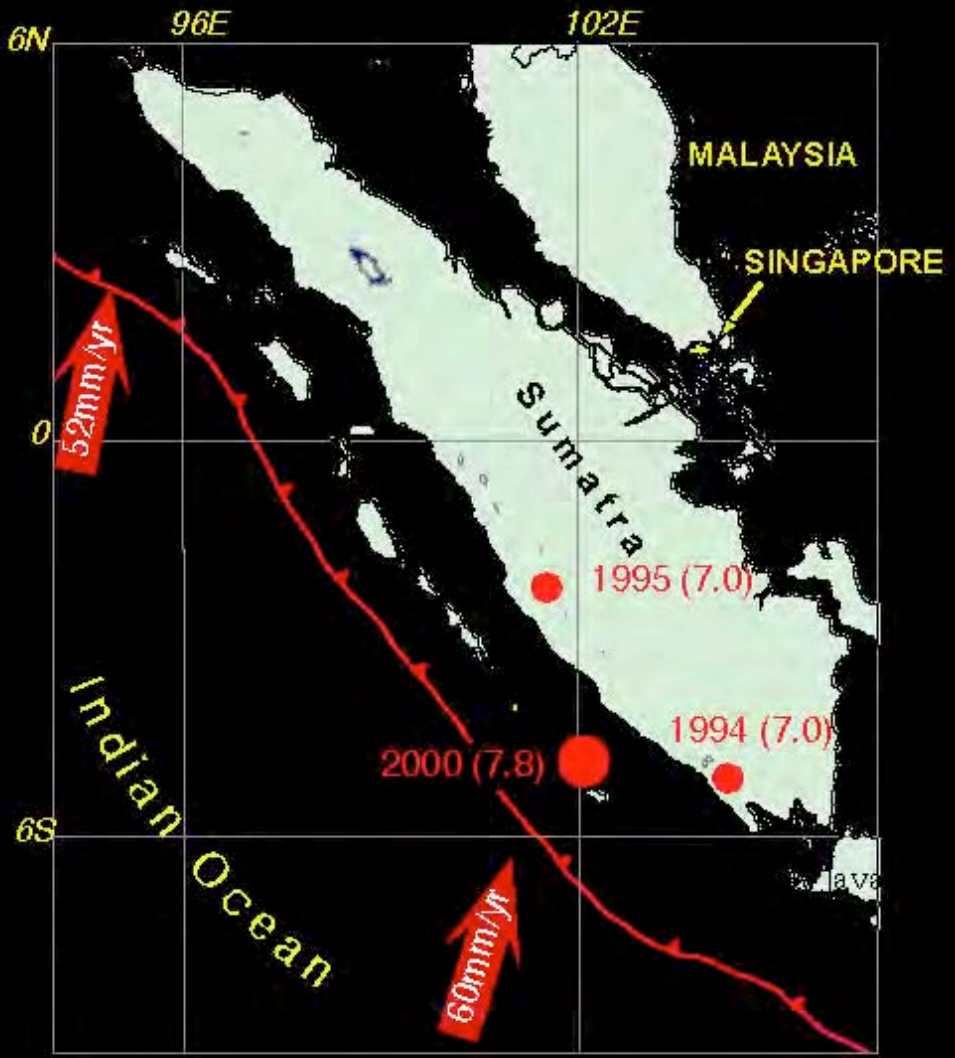
Singapore, April 2003 Kerry Sieh

Two interests:

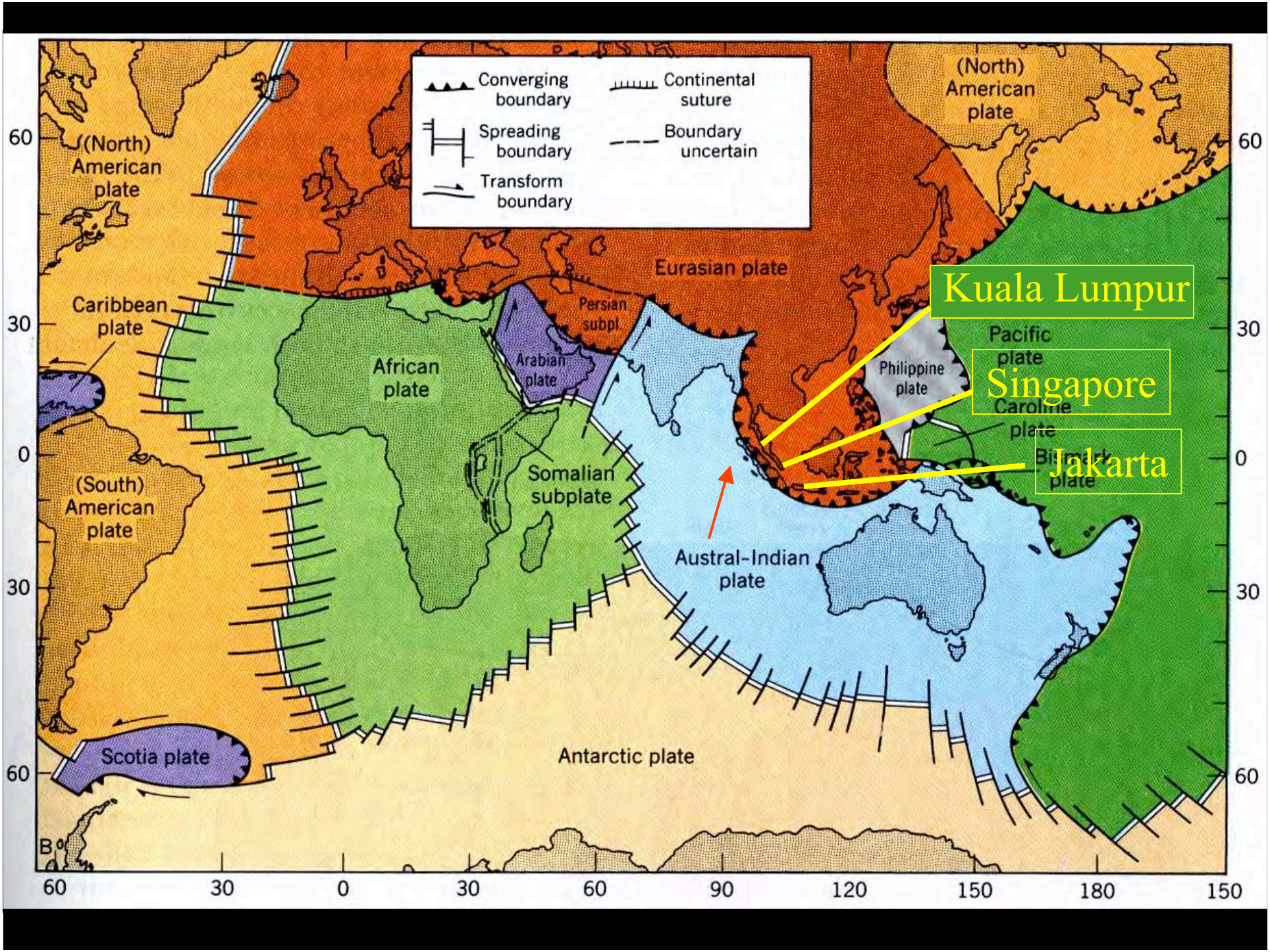
- Singapore is threatened by giant earthquakes emanating from western Sumatra
- Caltech is initiating a Tectonic Observatory, with one “regional focus” likely to be the source of great earthquakes near Singapore -- the Sumatran subduction zone

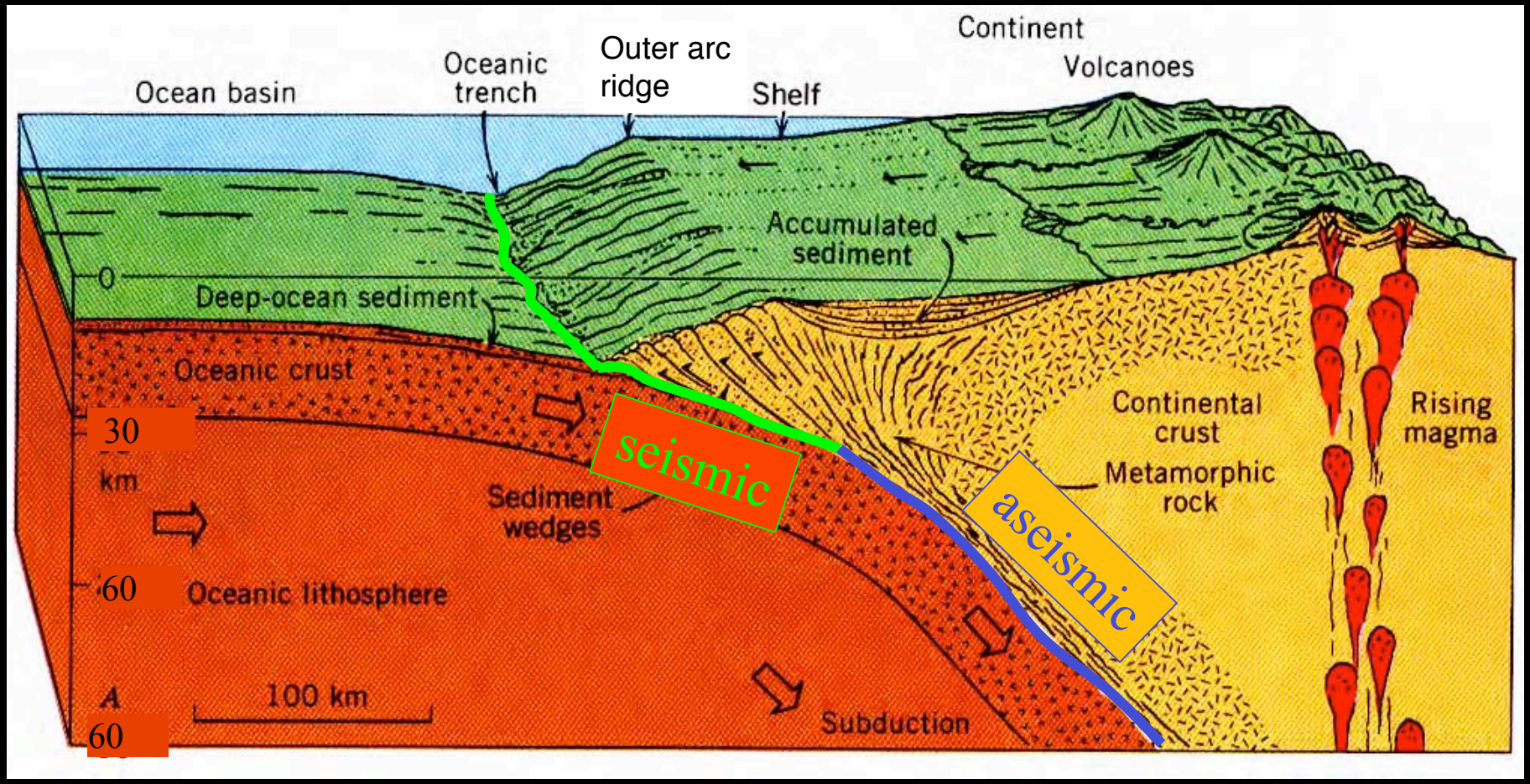


Singaporean skyscrapers may well experience long-period seismic shaking from rupture of the Sumatran subduction zone that is several times greater than that for which they have been designed



The Tectonic Observatory is dedicated to understanding tectonic processes, including earthquakes. One of the regional foci of the Observatory is likely to be the subduction zone of western Sumatra

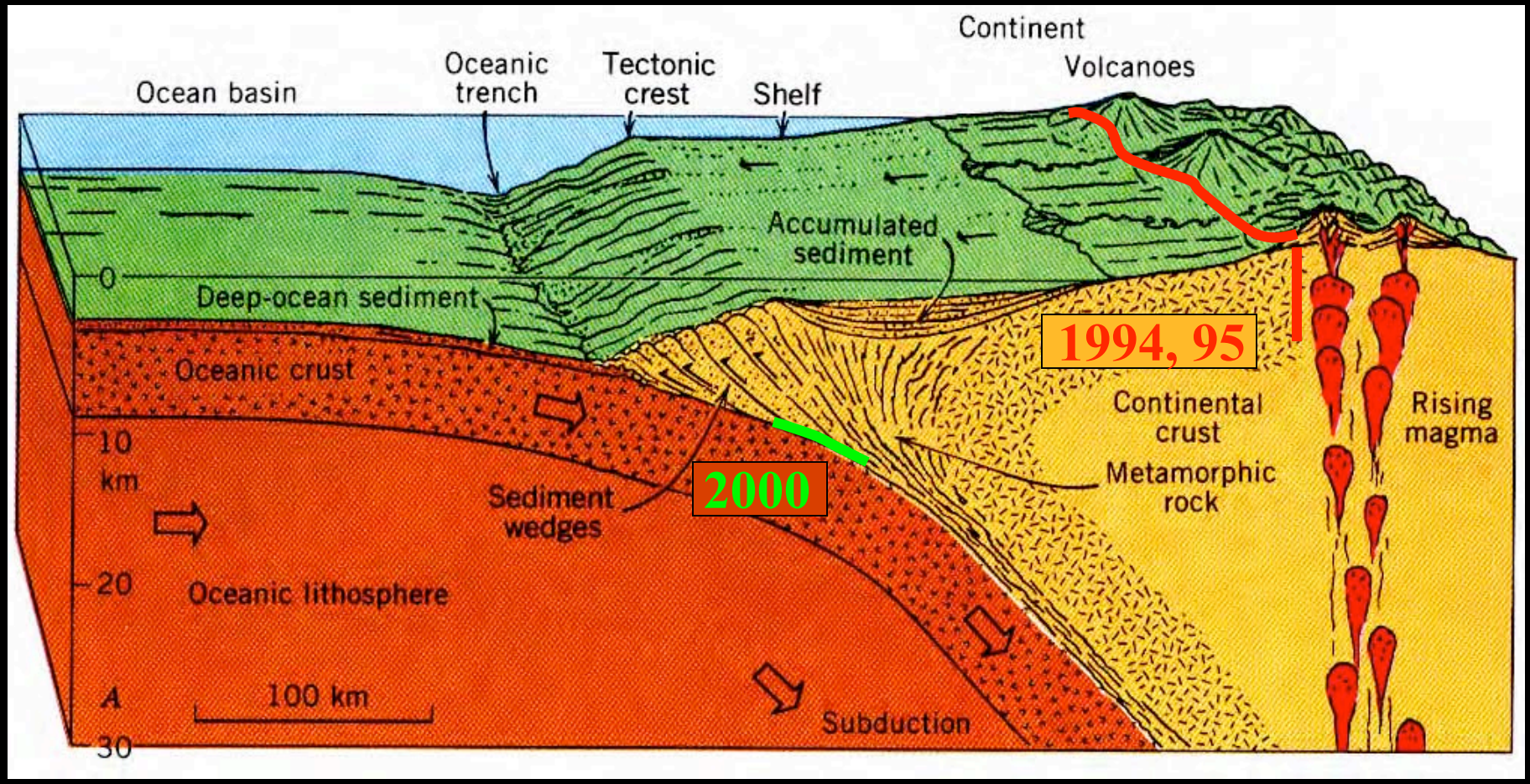

Converging boundary
Continental suture
Spreading boundary
Boundary uncertain
Transform boundary
(North) American plate
(North) American plate
Eurasian plate
Kuala Lumpur
Singapore
Jakarta
Caribbean plate
Persian subpl.
Arabian plate
African plate
Pacific plate
Philippine plate
Caroline plate
Bismarck plate
Somalian subplate
(South) American plate
Austral-Indian plate
Scotia plate
Antarctic plate
60
30
0
30
60
90
120
150
180
150



Commonly, rupture of a subduction zone is seismic and episodic at shallow depths and aseismic and continuous below depths of a few tens of kilometers

The most recent earthquake was a relatively small one that many Singaporean felt, especially those in high-rise structures.

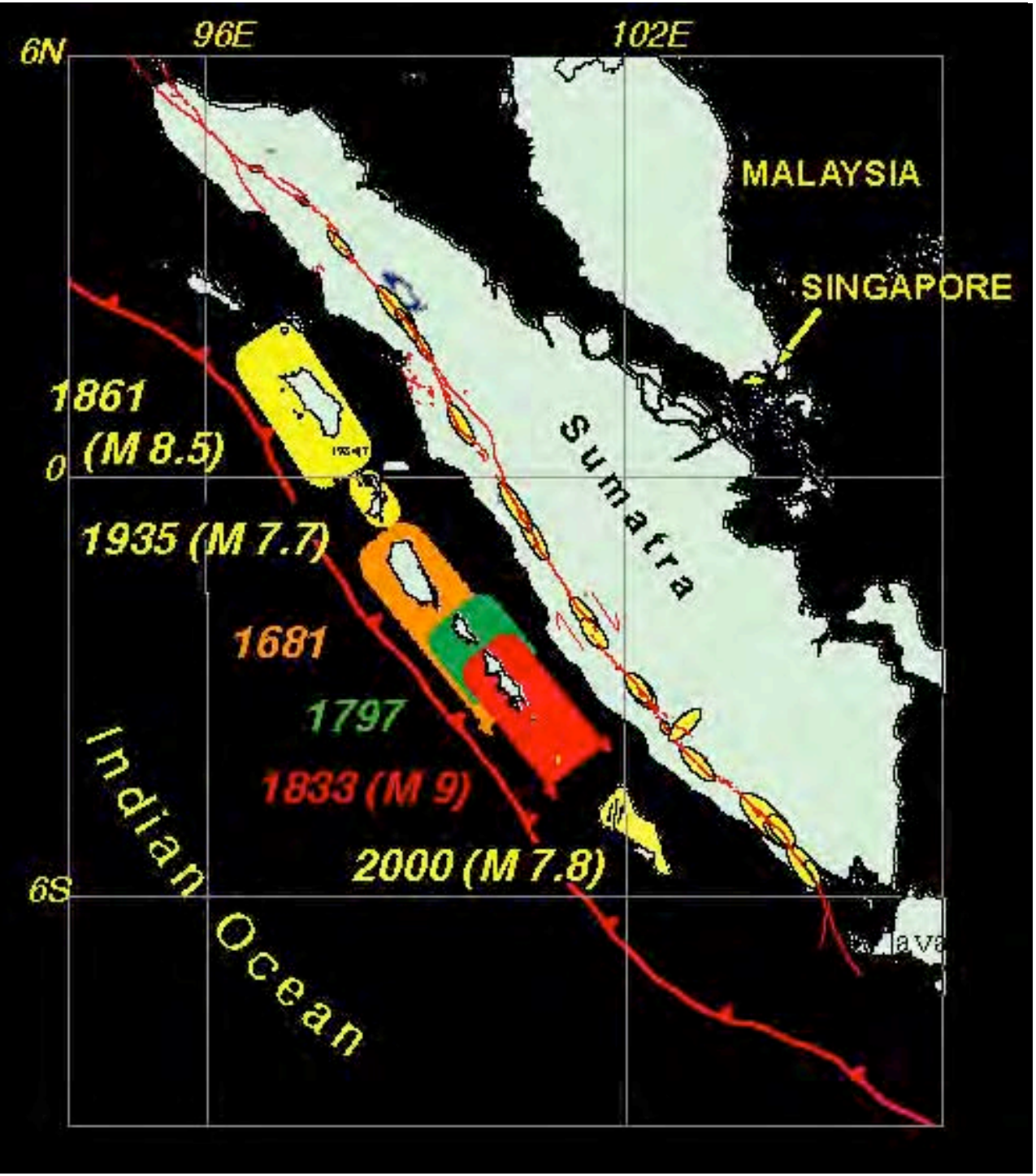
It had a magnitude of 7.8 and originated 700 km away.



The 2000 earthquake resulted (partly) from rupture of the subduction interface. The 1994 and 95 earthquakes resulted from slip another fault in the mountains of Sumatra.

The shallow part of the subduction interface produces the biggest earthquakes in the region.

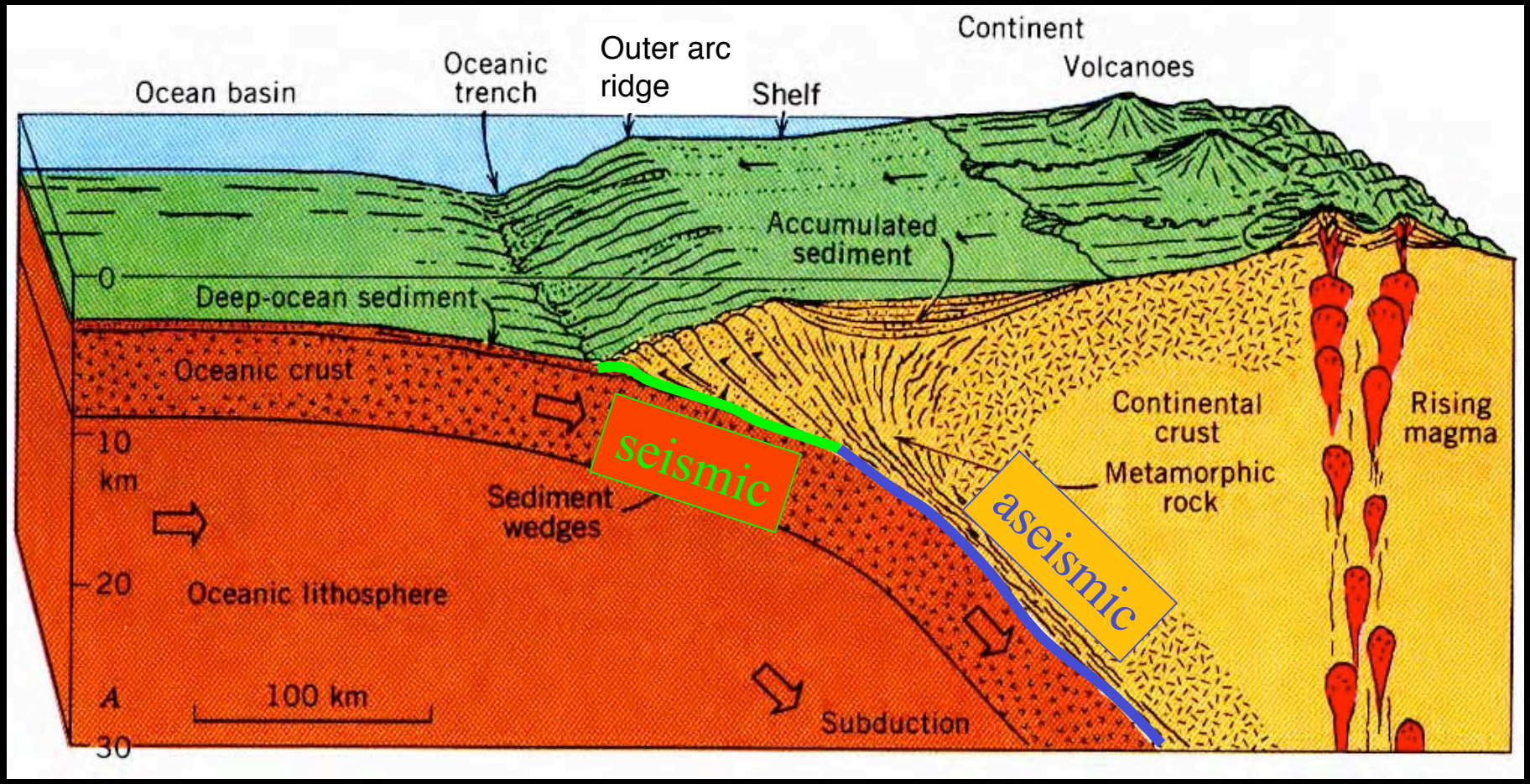
Earthquakes in 1833 (M 9) and 1861 (M 8.5) may be the largest in the historic period. But very large events occurred in the1600s and 1797 as well.



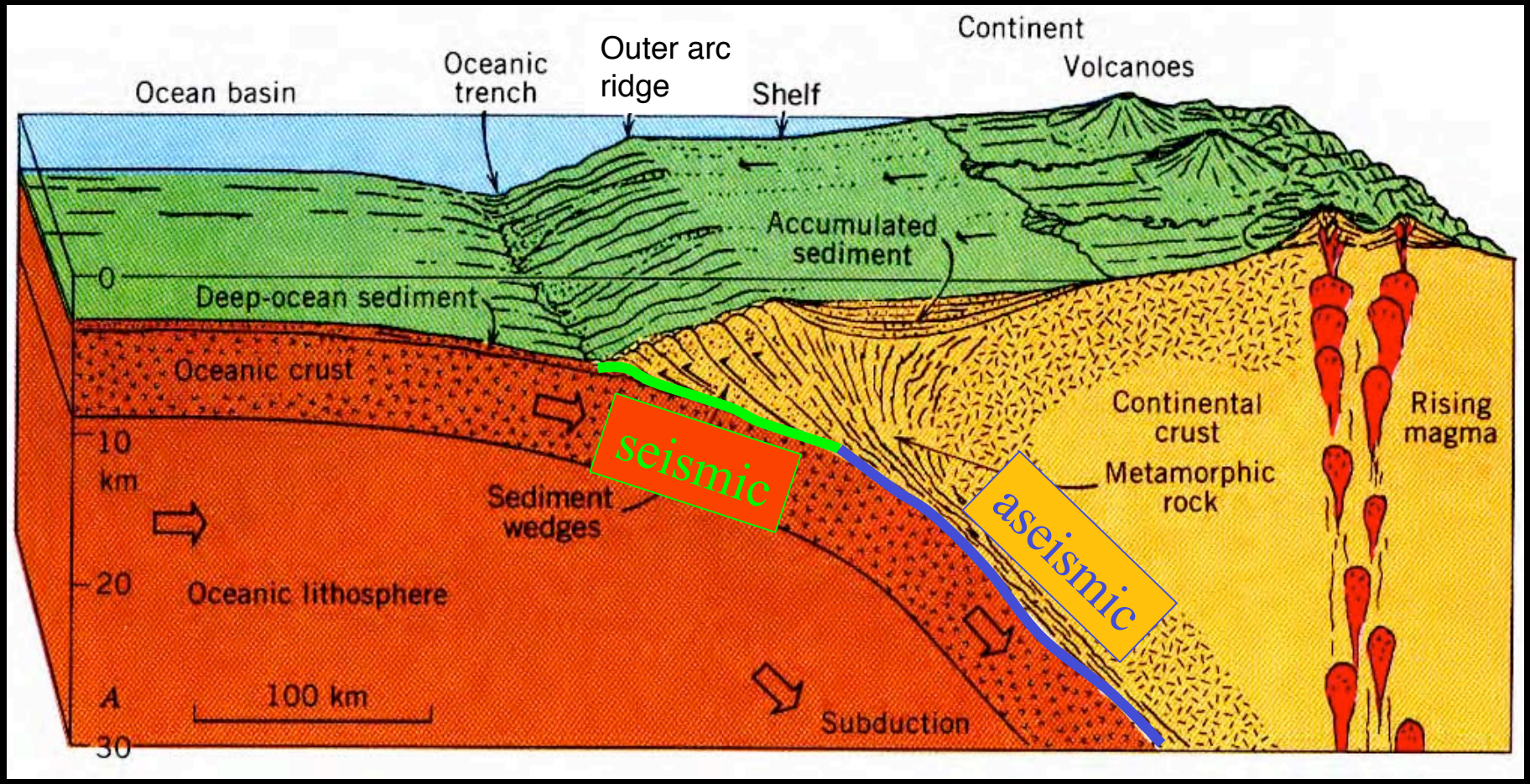
Caltech has been determining the nature and history of these great earthquakes over the past decade

Using:

- ✓Sparse historical data
- ✓Geological evidence for uplift and submergence



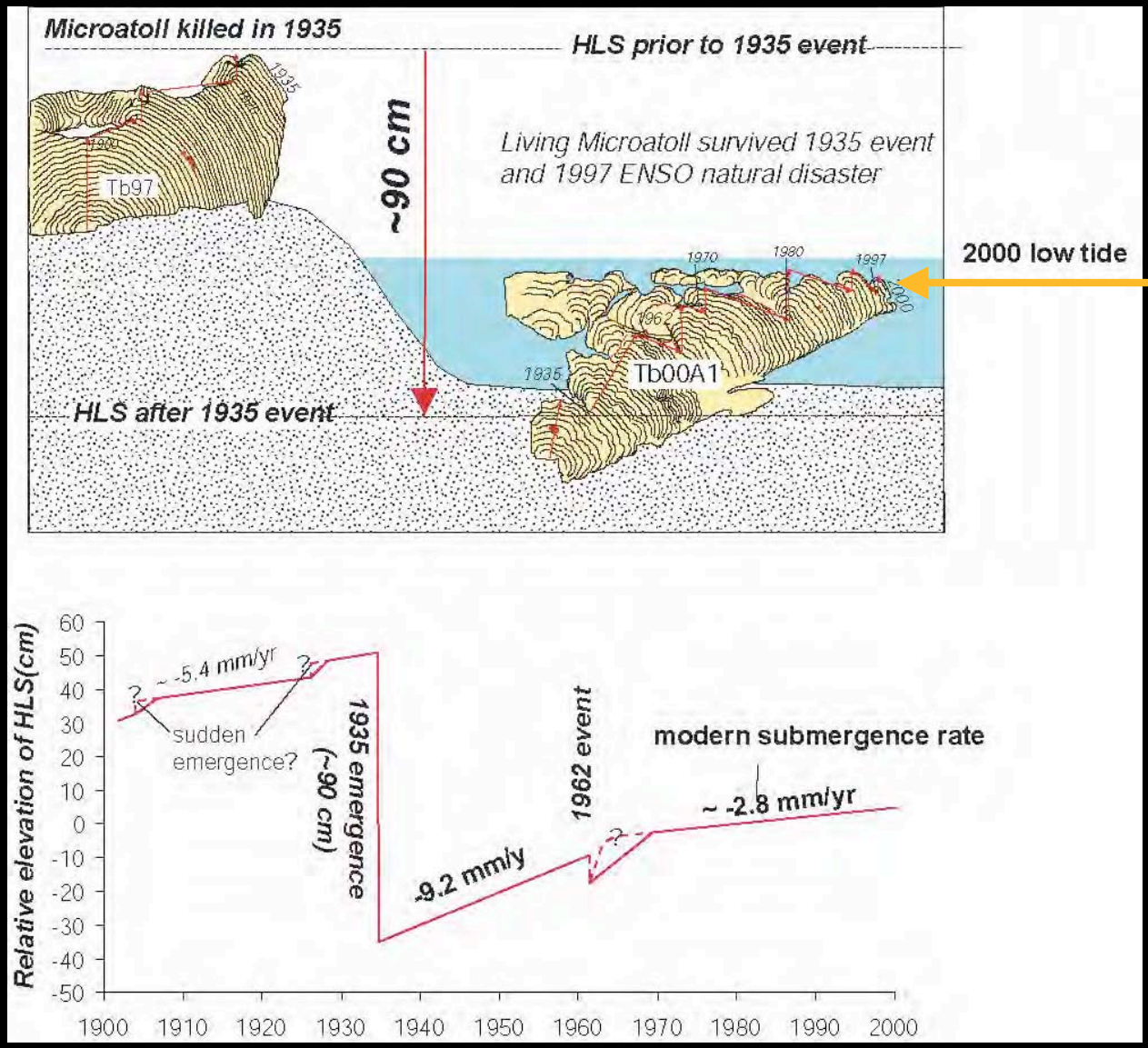
Seismic slip on the subduction interface produces uplift of the overlying outer-arc ridge as it lurches oceanward.



Colonies of massive corals living on the fringing reefs of the ridge record the uplift quite precisely.

Full "*coseismic*" uplift during a moderate quake in 1935, recorded by two *coral heads*

Ancient, cup-shaped microatoll

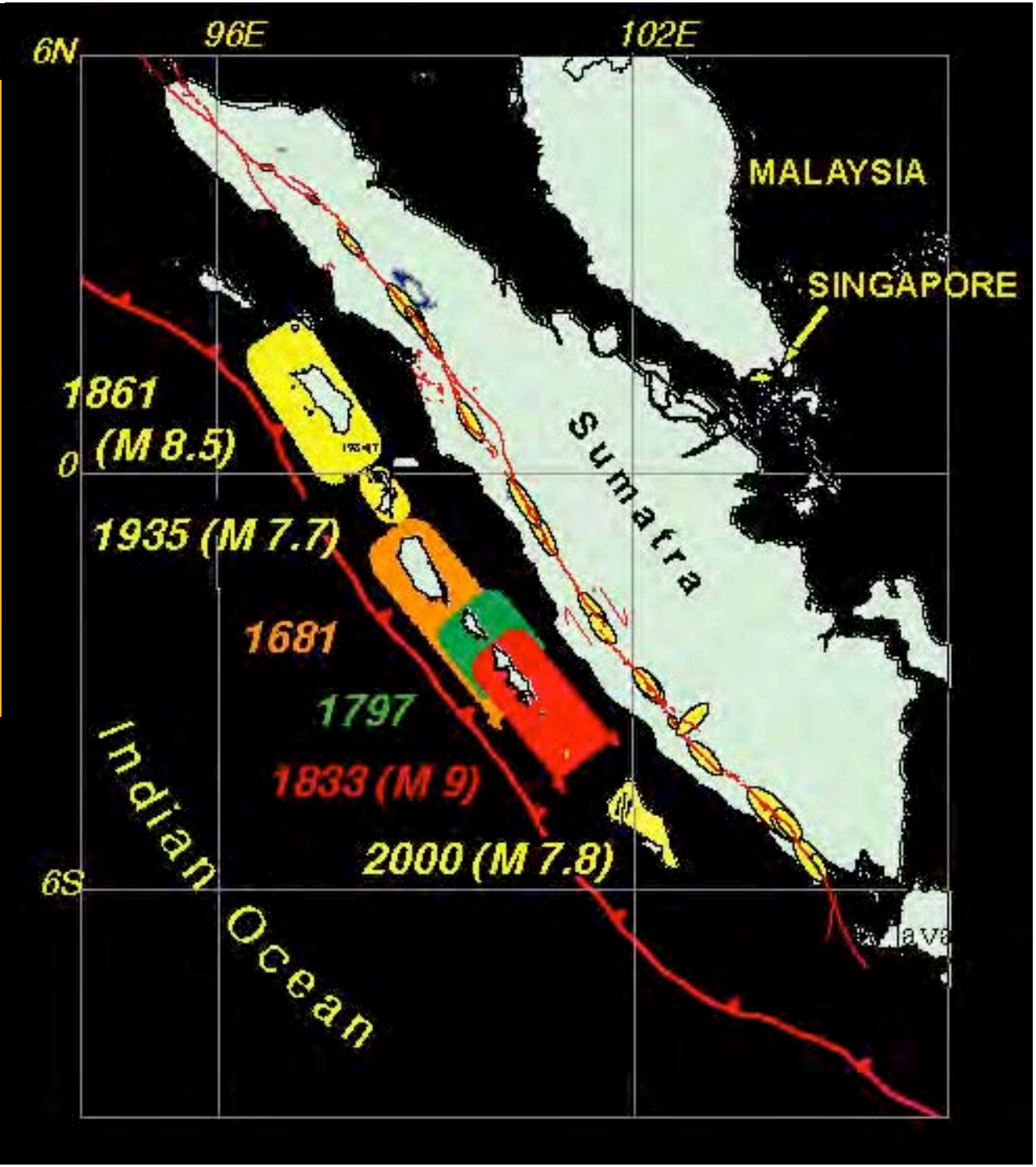


Modern, living microatoll

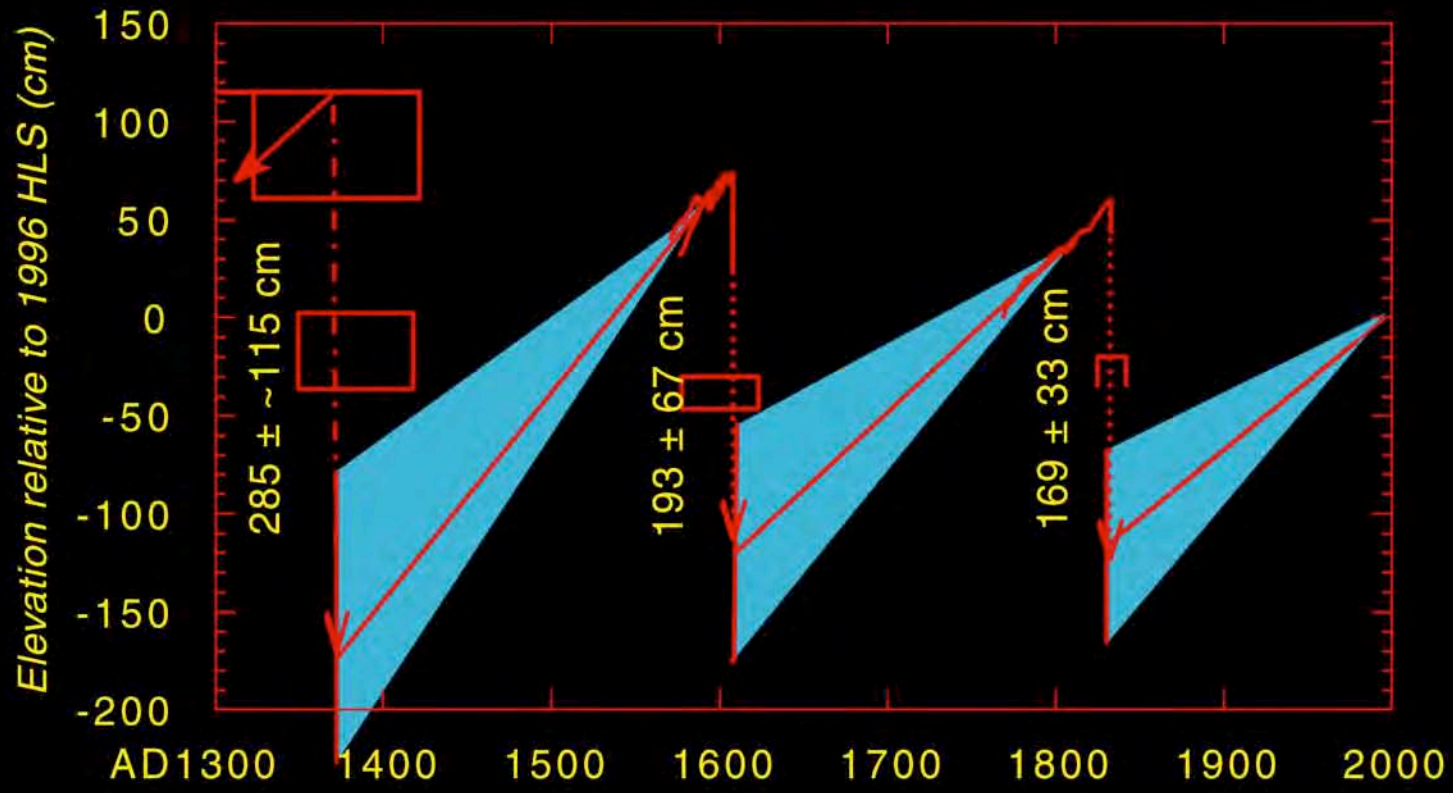
An example 96 km from the trench

Great and giant earthquakes have occurred in 1833, 1861, 1797 and the late 1600s.

This region is about 500 km from Singapore.



These giant earthquake sequences appear to occur about every two centuries

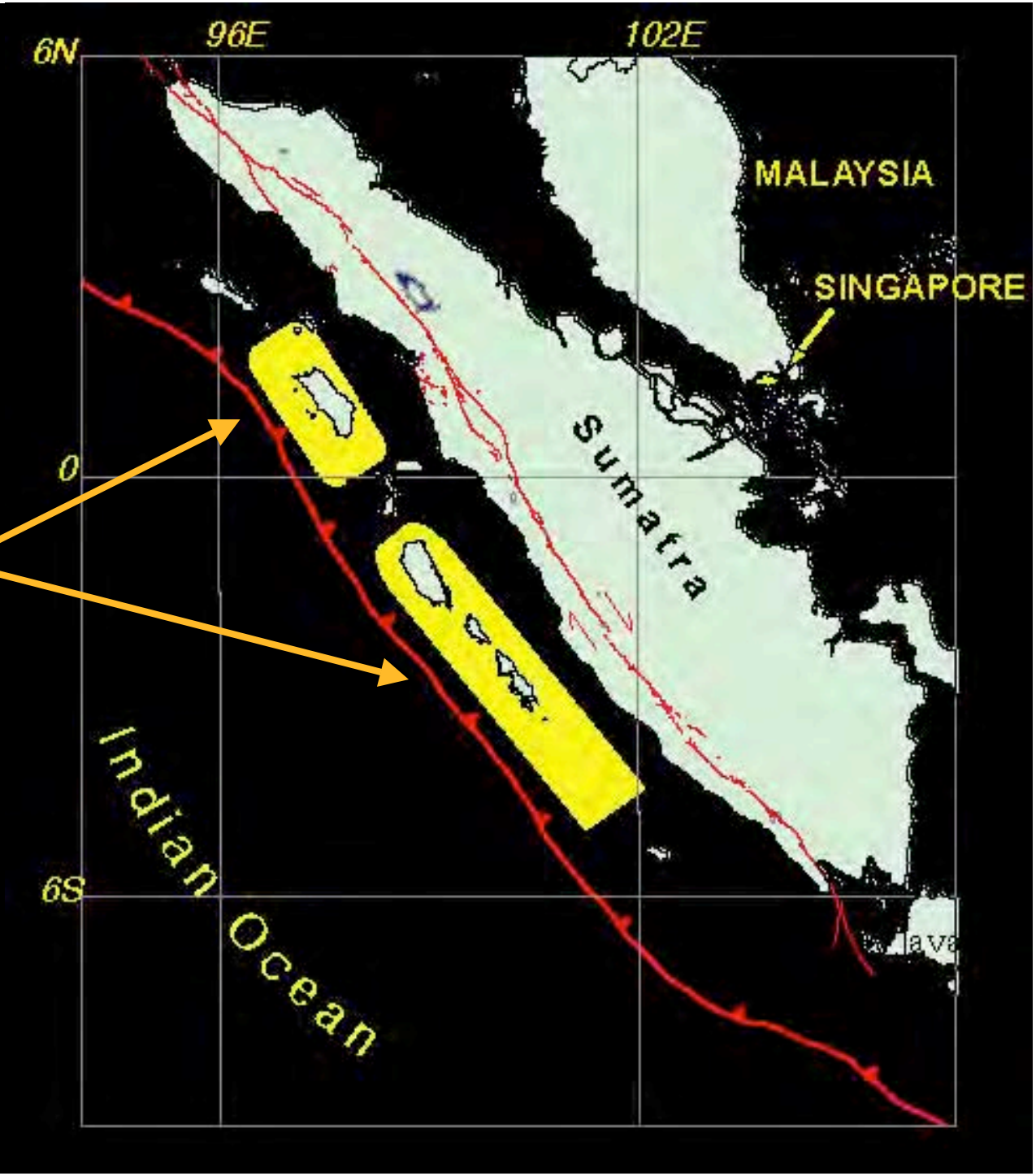


Thus, it would be prudent to anticipate that a repetition similar to the 1600s, 1797, 1833, 1861 cluster to begin within the next few decades

What earthquakes can Singapore expect within the next century?

Most significantly,

M 8 to 9 events produced by the Sumatran subduction zone, >=500 km away



A Proposed Agenda

- For the earth scientist:
  - Figure out the details of past ruptures ("what has happened can happen")
  - Begin seismic and geodetic monitoring programs of the Sumatran plate boundary, with an eye toward forecasts
  - Prepare hazard maps for land use planning and development
- For the engineering seismologist:
  - Assess what the ground motions are likely in nearby urban areas (for example, Singapore, Jakarta, Kuala Lumpur)
- For the engineer:
  - Assess the potential impact on structures and devise improvements
- For governments of Malaysia, Indonesia, and Singapore:
  - Modifications to building codes
  - Better land use planning and land development
  - Support of scientific and engineering research

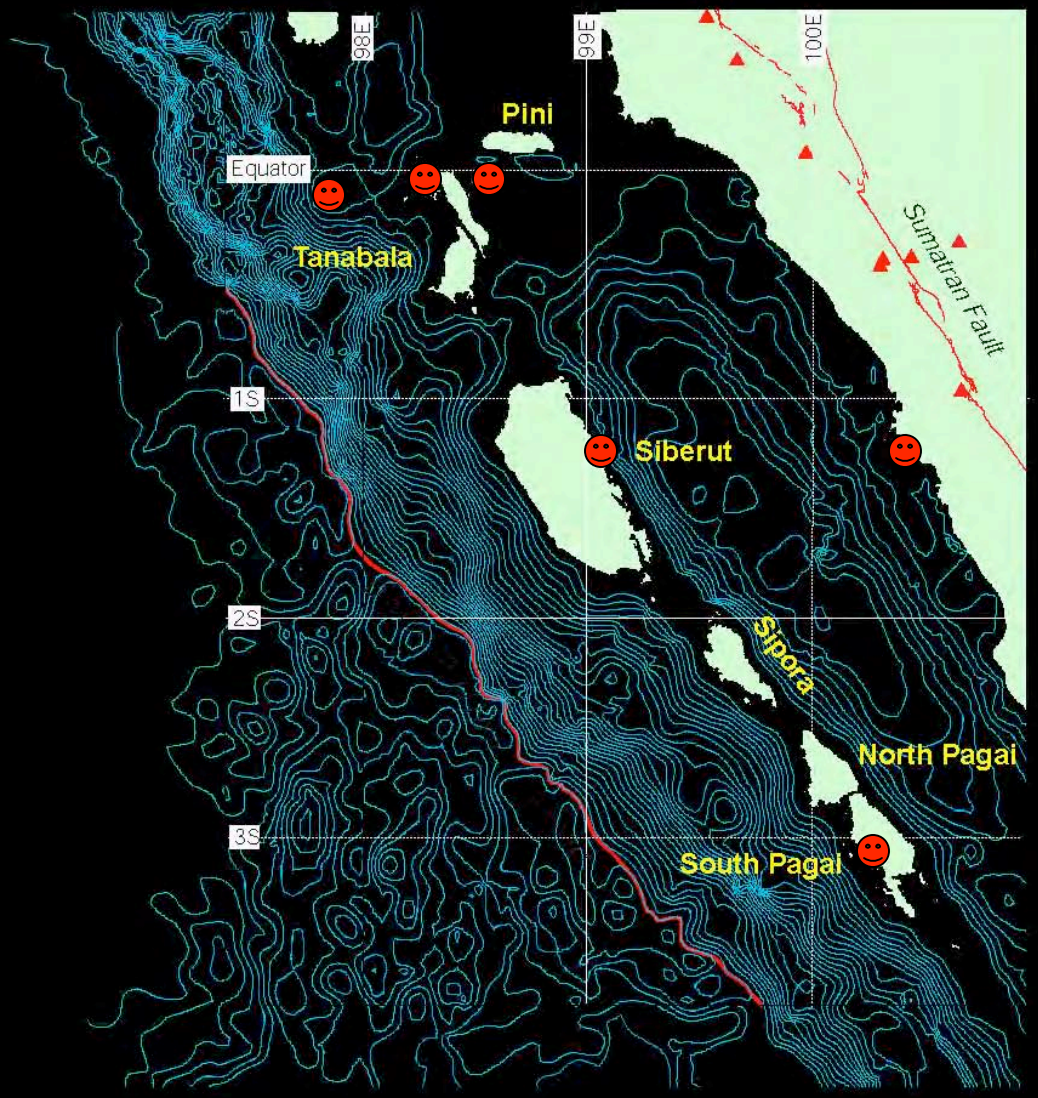
Crude geodetic measurements of the 1990s show, in fact, that the straining of western Sumatra is continuing at high rates.

These arrows show squeezing of western Sumatra at high rates.

But errors were large, and measurements discontinuous.

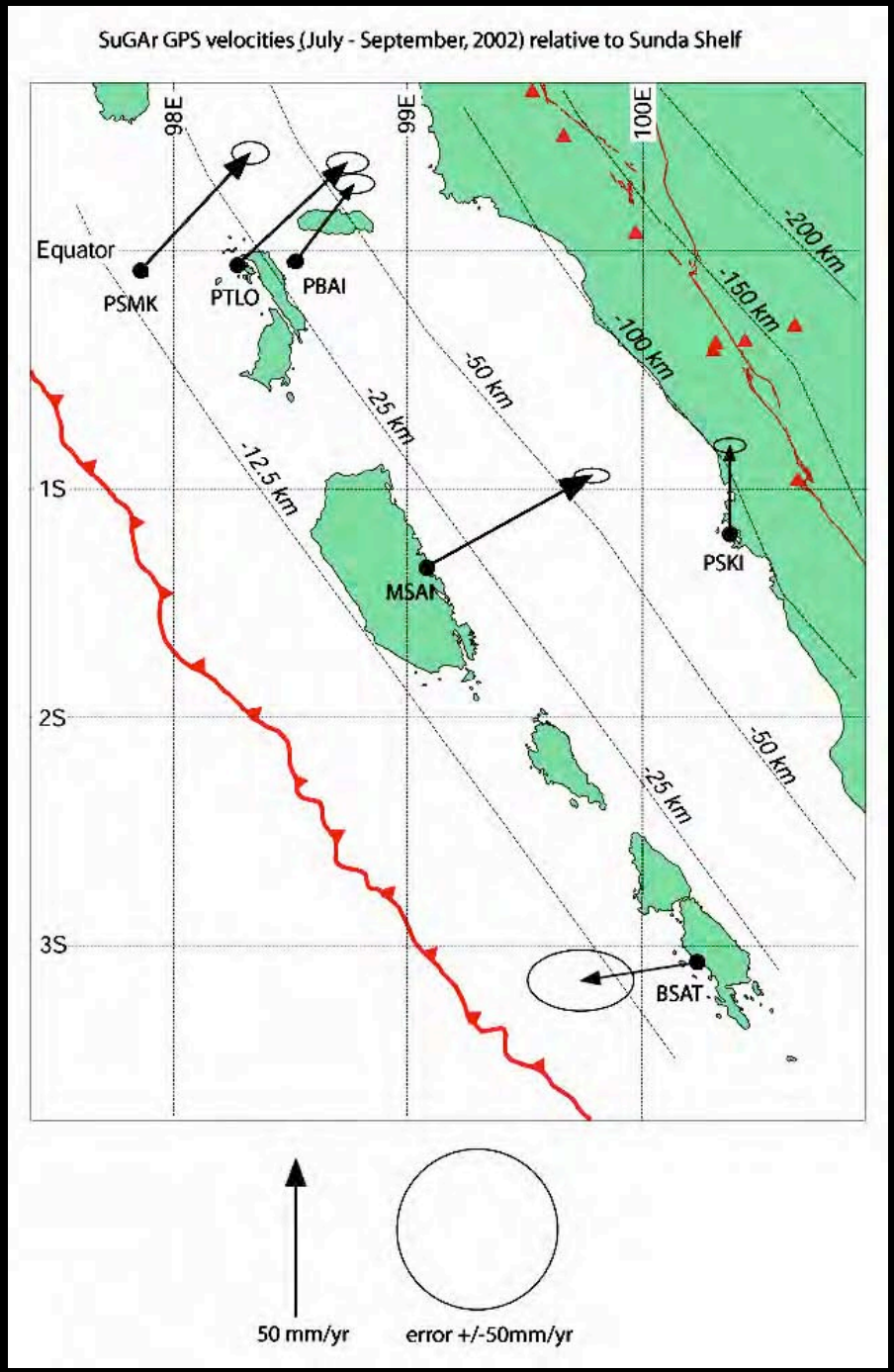
Caltech's TO is improving geodetic monitoring by establishing a continuously monitored network of GPS stations.

An example of installation of a GPS station -- on a small island a kilometer off the west coast of Sumatra, August 2002



Caltech's interest is principally scientific. Therefore, we have begun a program of geodetic monitoring

Six Caltech permanent GPS stations are now up and running. We hope to install about 20 more stations in the next three years

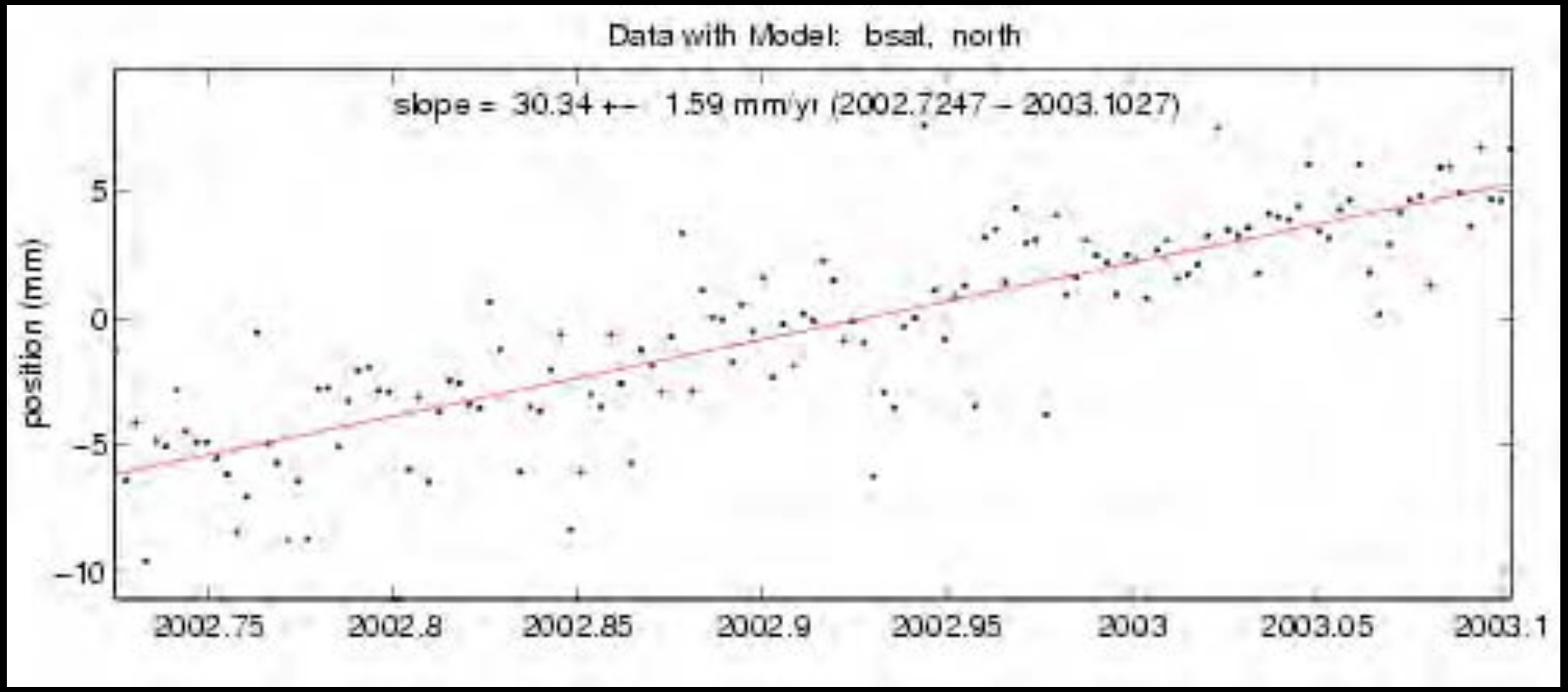


Our results after two months of data collection show strains accumulating at rates of about 50 mm/yr.

With continuous monitoring of stations, we expect to see fluctuations in rates of motion, associated with changes in the behavior of the subduction interface.

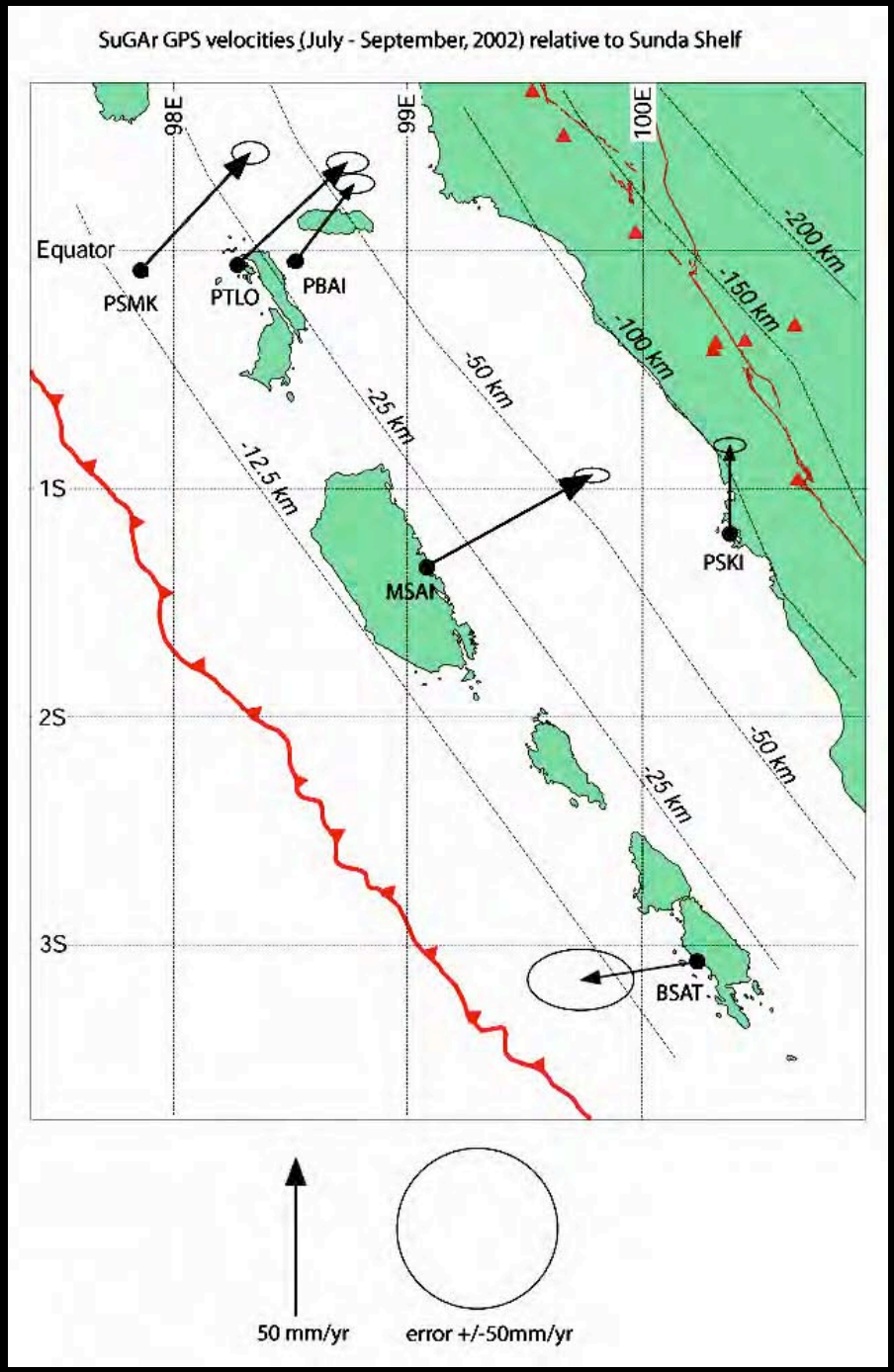
Specifically, we might be able to see precursors to great and giant earthquakes

With five months of data, the vectors are becoming more reliable.



Five months of data from one of the 6 initial sites:

The north component is averaging 30 mm/yr.



Our next steps are to install the remaining 20 or so stations, and to engineer the satellite-communications that will give us real-time access to the data.

Overall, Caltech expects to spend between US $1 and 2 million on this project over the next ten years.