Paleogeodesy of the Sumatran Subduction Zone:

Evidence of seismic and aseismic behavior
Some fundamental questions about active faults

• What determines whether a fault fails seismically or aseismically?
• Does fault behavior vary with time?
• How uniform are slip events?
  – In space?
  – In time?
Why go all the way to Sumatra to investigate fault behavior?
The Sumatran subduction zone is a large, isolated fault, unlikely to be influenced by its neighbors.
The Sumatran outer-arc ridge is largely above water ...
and coral “microatolls” are abundant on its fringing reefs
MICROATOLL NATURAL GAUGE

HLS (cm)

YEAR

Sea Level (HLS)

cm

0 1 2 3 4 5 6 7
MICROATOLL NATURAL GAUGE
A small emergence event
MICROATOLL NATURAL GAUGE

HLS (cm)

YEAR

cm

0 1 2 3 4 5 6 7
MICROATOLL NATURAL GAUGE

HLS (cm)

YEAR

Sea Level 3

cm

0

2

3
MICROATOLL NATURAL GAUGE

HLS (cm)

YEAR

Sea Level

CM
Submergence followed by emergence
The sampling operation
We have focused in two areas:

This region of smaller earthquakes.

And this region of very large earthquakes.
Bendera
Richest zone of Fossil Microatolls among litters of loose cobbles and small boulders

Legend:
- Yellow: Beach berm
- Blue: Intertidal Reef Flat
- Light brown: Zone of fossil heads
- Dark brown: Zone of large living heads
- Green: Mangroves, swamps, forests
- Orange: Observed loose cobbles and boulders
- Black: GPS control points

Some tilted fossil heads
Non-tilted fossil heads
Drowned, dead trees
The microatoll “graveyard” in the intertidal zone
Record of 1935 emergence

85 cm

2000 Sea level

Tb97A1

Tb00A1
Pattern during seismic rupture
Basic pattern during interseismic period
Pre-1935

Distance from Trench axis (km)

Baseline = 2 mm/y
1935 - 1962

Distance from Trench axis (km)

Depth (km)

Uplift (mm/y)

Slip = 5.4 cm/y
Slip = 1.4 cm/y
Slip = 4.0 cm/y
Baseline = 1 mm/y

95.3 (16.9)
125 (27)
1962 Submergence

Distance from Trench axis (km)

Slip = 1.66 meters

Slip = 1.15 meters
Modern Rate (1962 - 2000)
1962 - 2000

Distance from Trench axis (km)

Depth (km)  Uplift (mm/y)

Slip = 3.7 cm/y
Slip = 1.7 cm/y
Slip = 4.0 cm/y
Baseline = 1 mm/y

108.5 (21.1)  125 (27)
What about longer-term behavior?
High seismic rate, very large events

Low seismic rate, moderate events

Why?
Hypothesis of the eastward moving of the subducting IFZ (Investigator Fracture Ridge) along the Sumatran subduction. The plate vector is ~7 degree eastward from the axis of the IFZ. Thus, the IFZ moves toward east about 7 mm/yr. The IFZ moved about 70 km since 10 Ma or about 155 km along the trench axis. This subducting IFZ may have led to the intense faulting.
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Conclusions

• Behavior is localized geographically
  – One region is predominantly aseismic
  – An adjacent region is predominantly seismic
• These behavioral patterns persist over centuries
• Giant earthquakes occur in clusters with overlapping sources?
Work in progress

- Paleogeodetic studies south of the Equator:
  - modern rate variations along strike, rapid aseismic geodetic events, giant earthquakes
  - 5 cycles of steady aseismic submergence and uplift during large earthquakes
6 permanent GPS stations are now up and running.