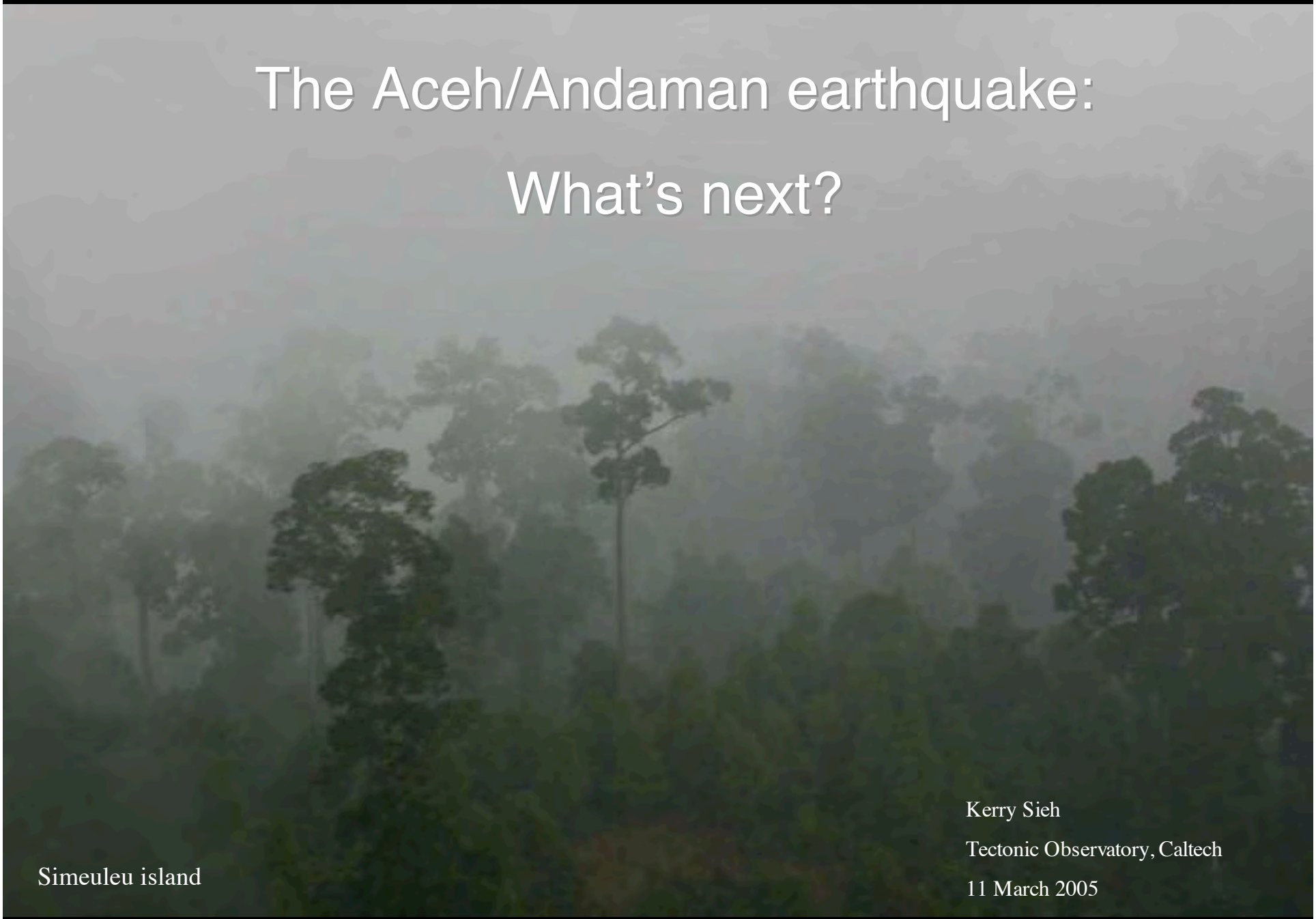
The Aceh/Andaman earthquake:

What's next?



Simeuleu island

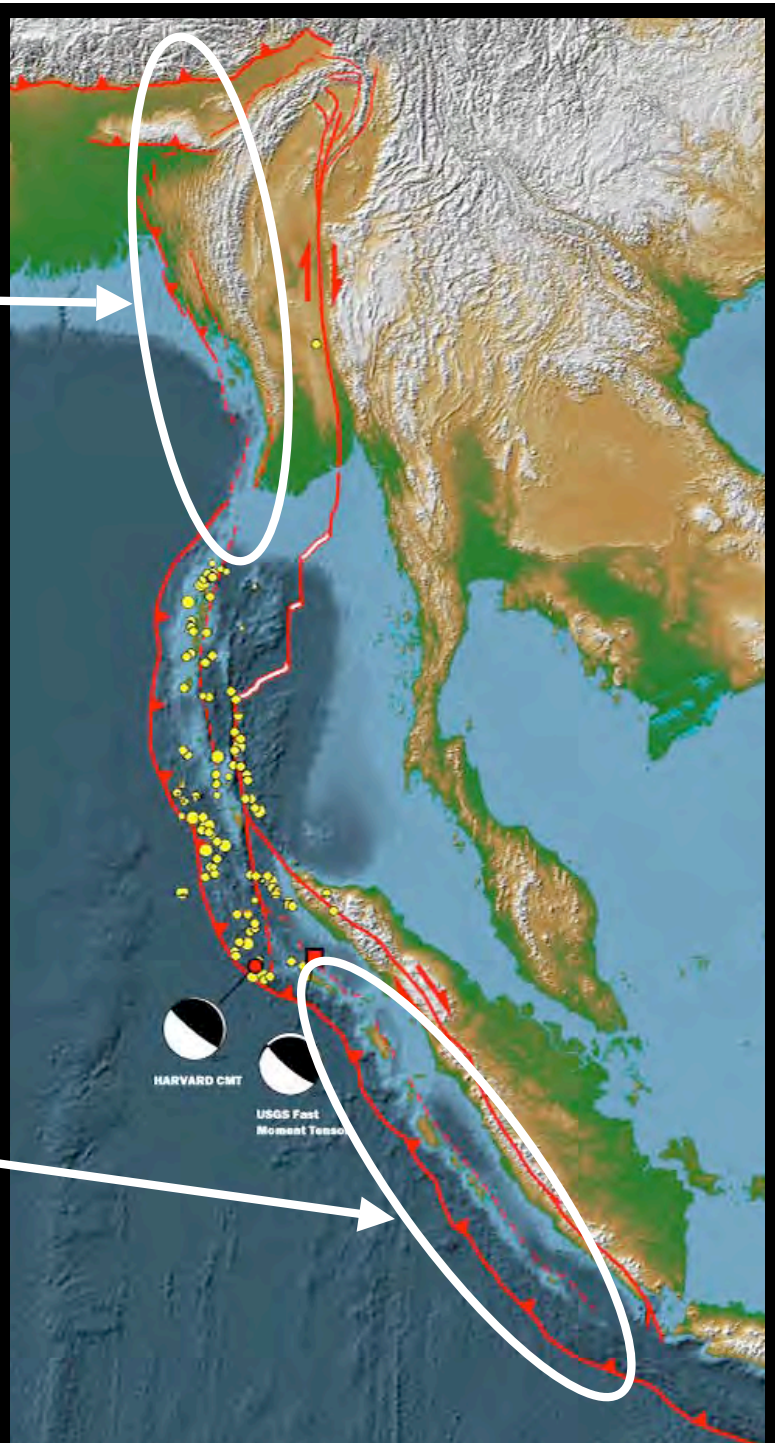
Kerry Sieh

Tectonic Observatory, Caltech

11 March 2005

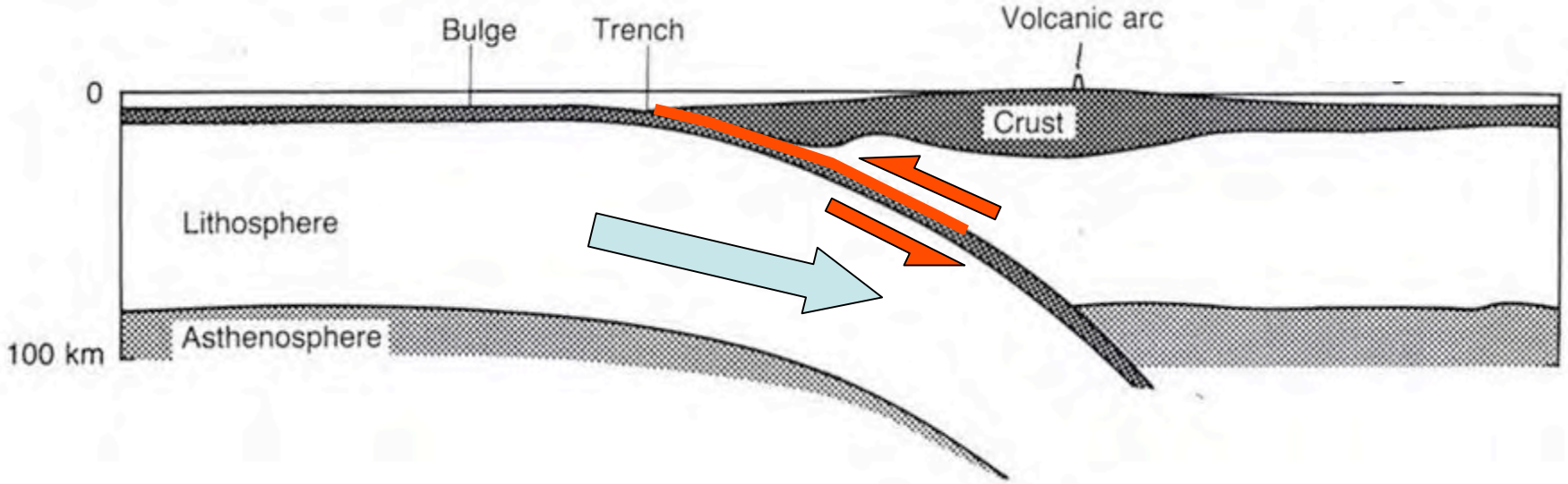
Indo-burman source(s)

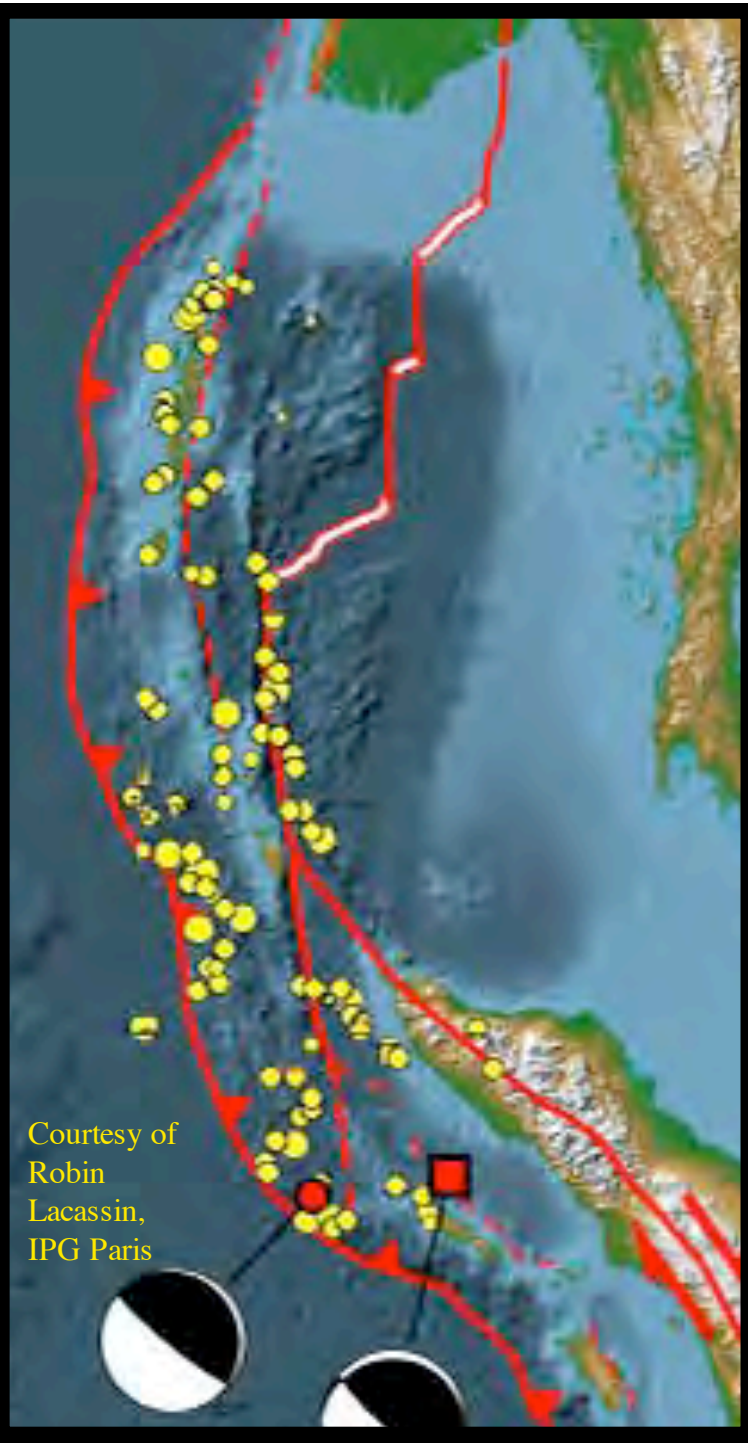
west Sumatran sources



Indian Ocean

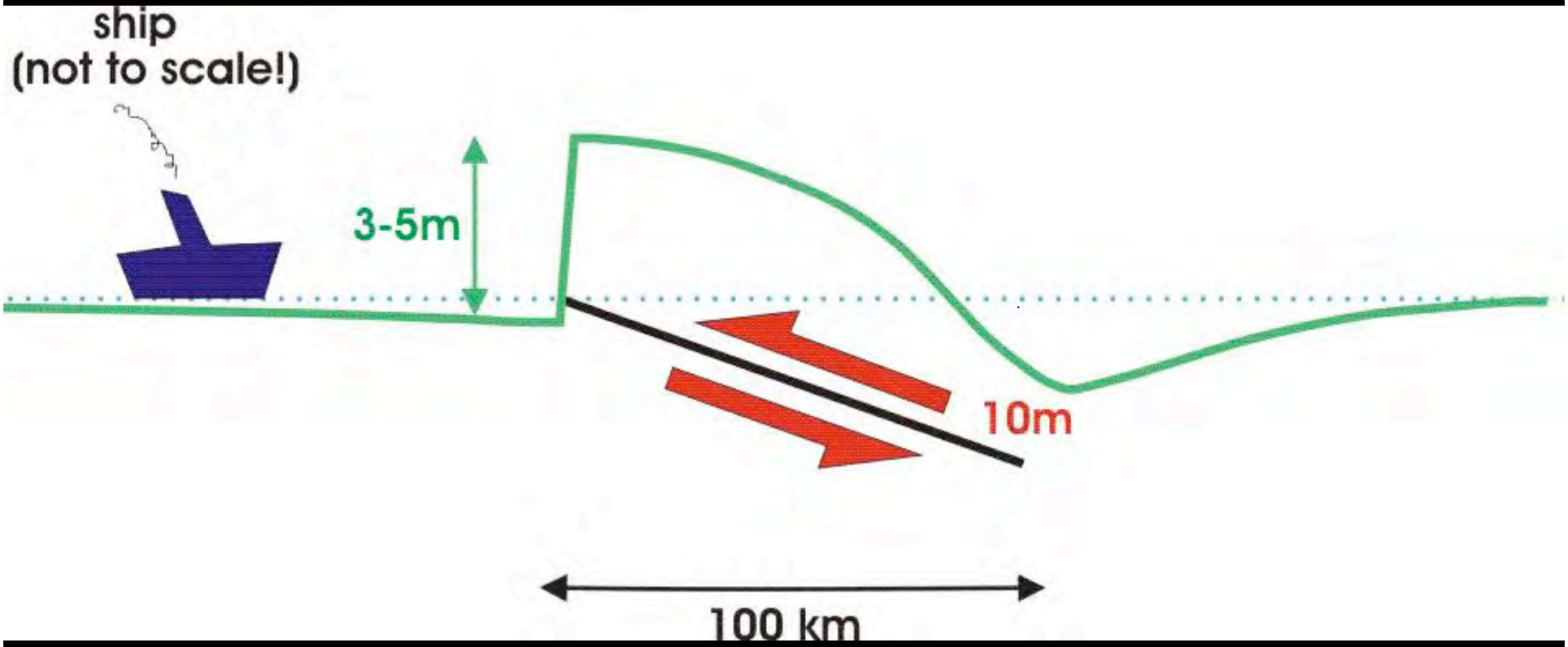
Sumatra





What do we know about the 2004 rupture?

WEST EAST



The pattern and magnitude of submergence and uplift constrain the rupture location and amount

Camorta island, Nicobars

Photo by Denis Giles

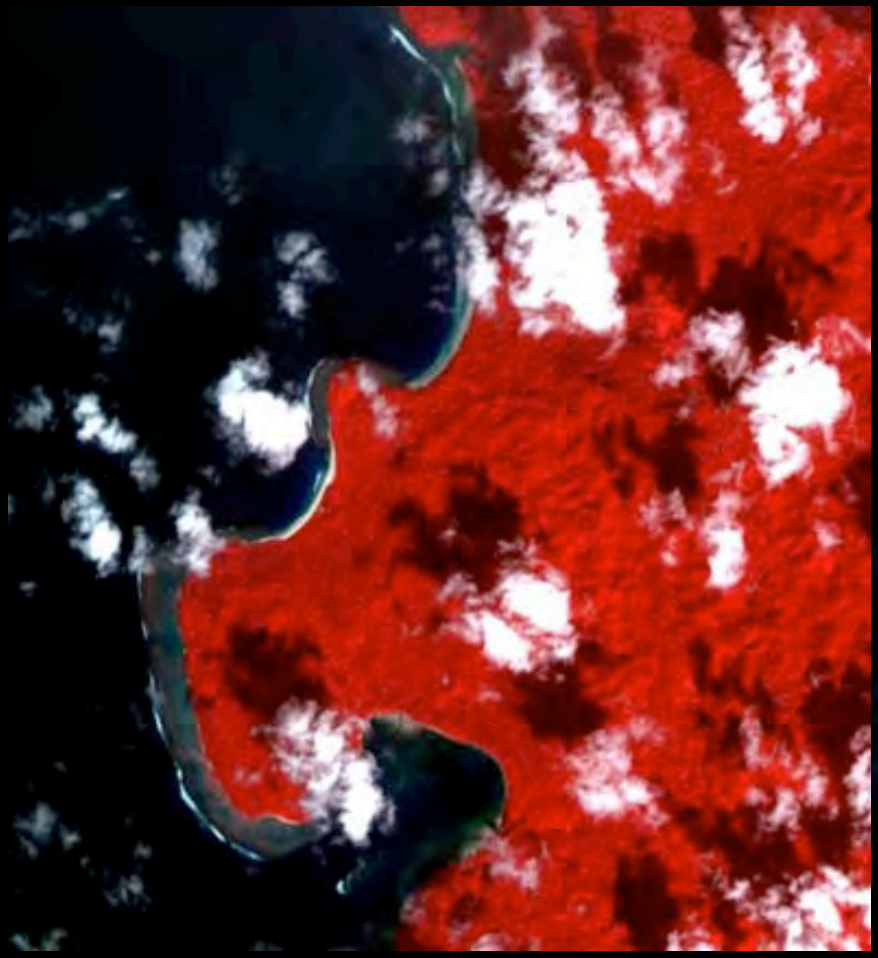
Banda Aceh

before

after

Great Nicobar island

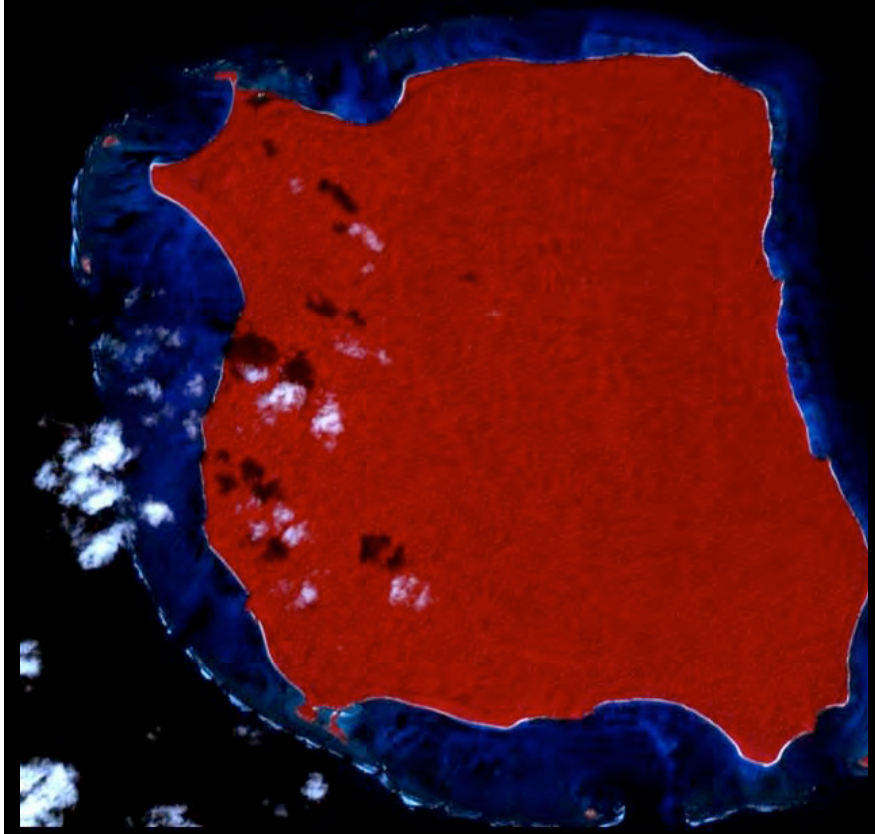
Courtesy of Aron Meltzner,
Tectonics Observatory,
Caltech



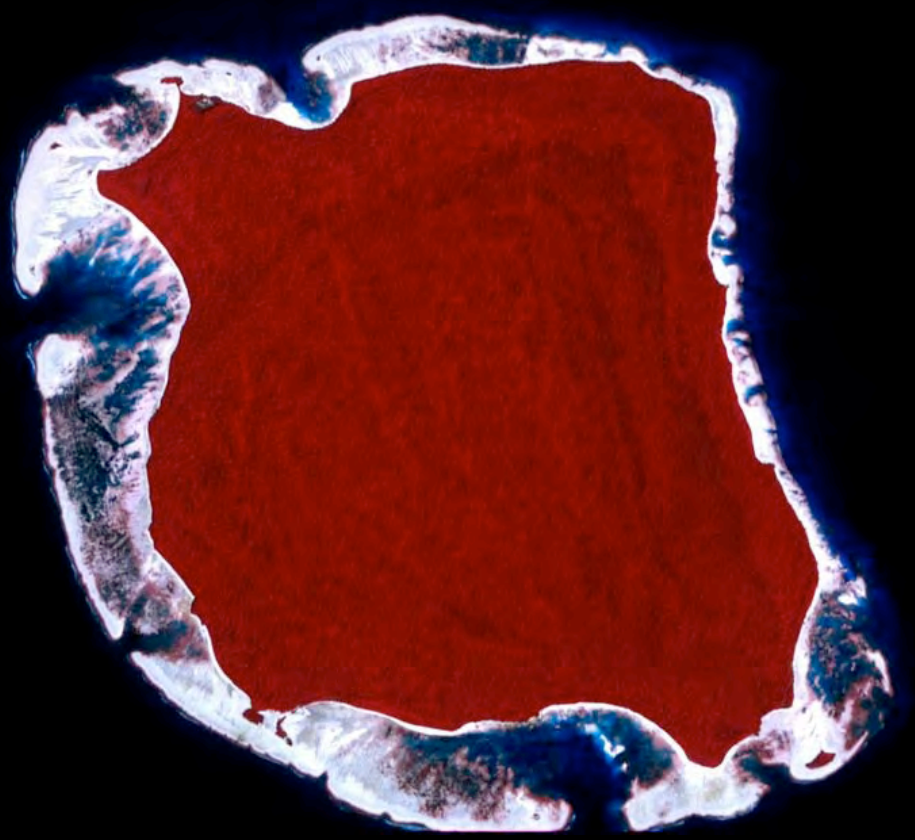
before

after

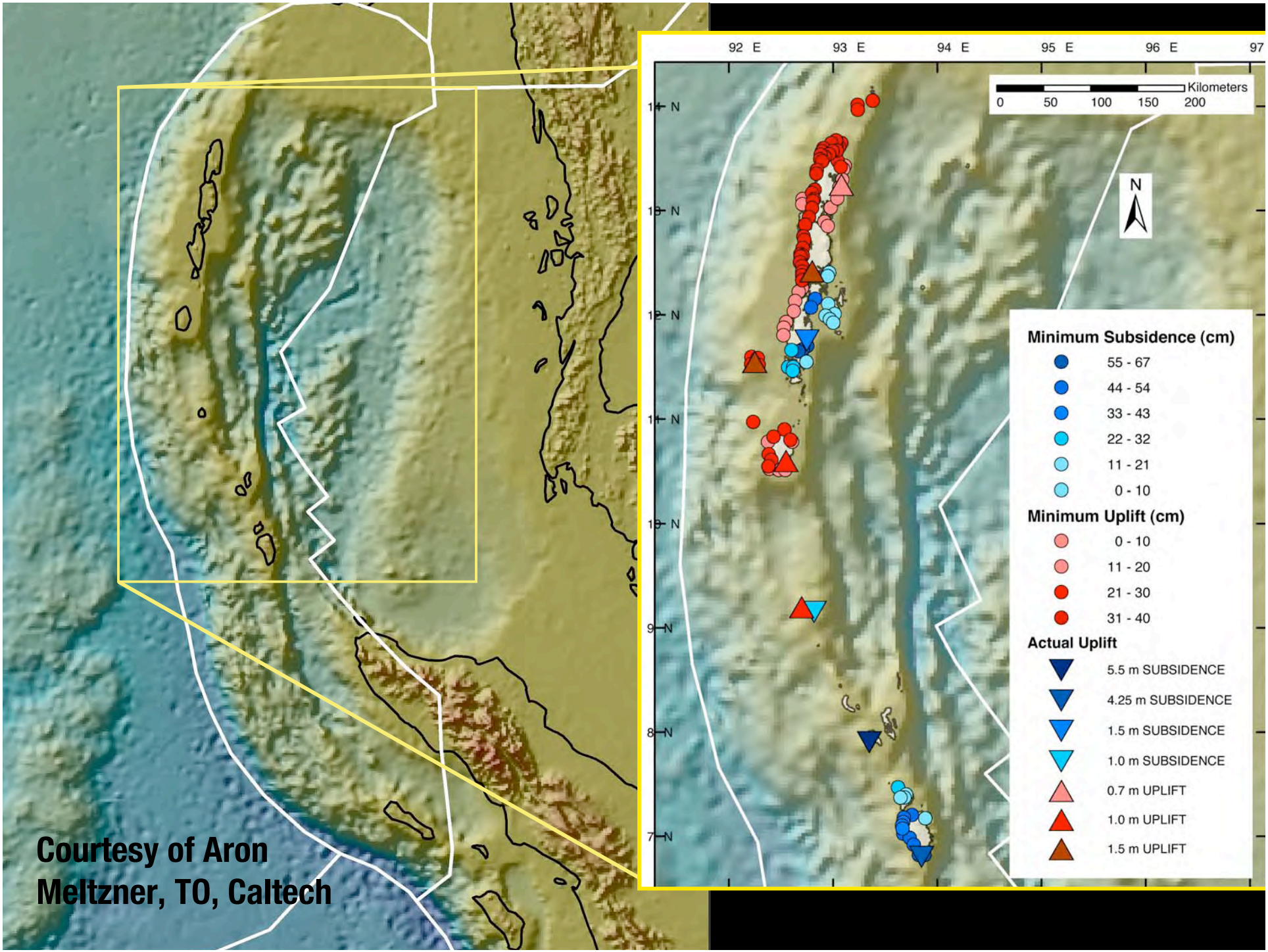
North Sentinel island, Andaman island group

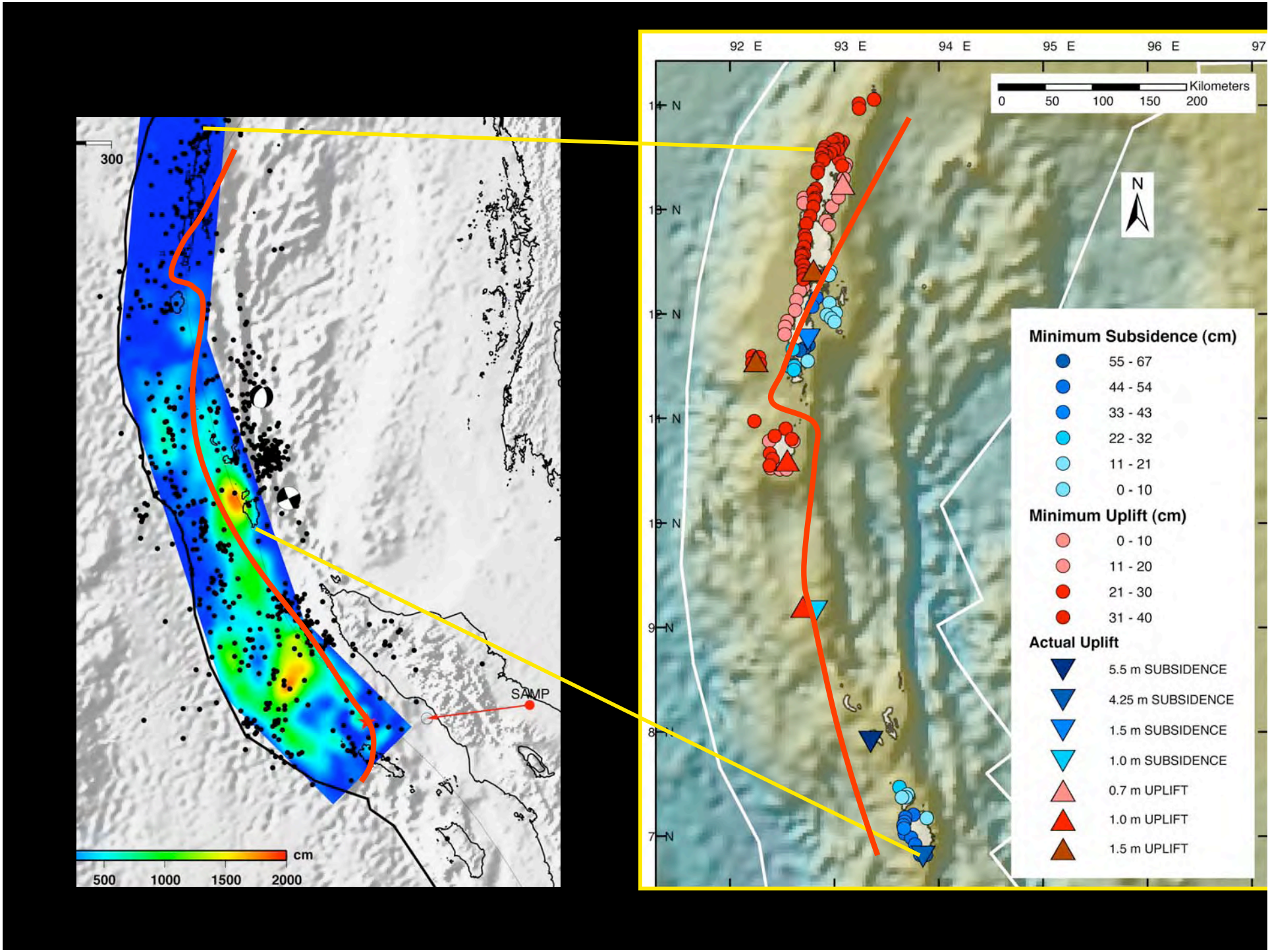


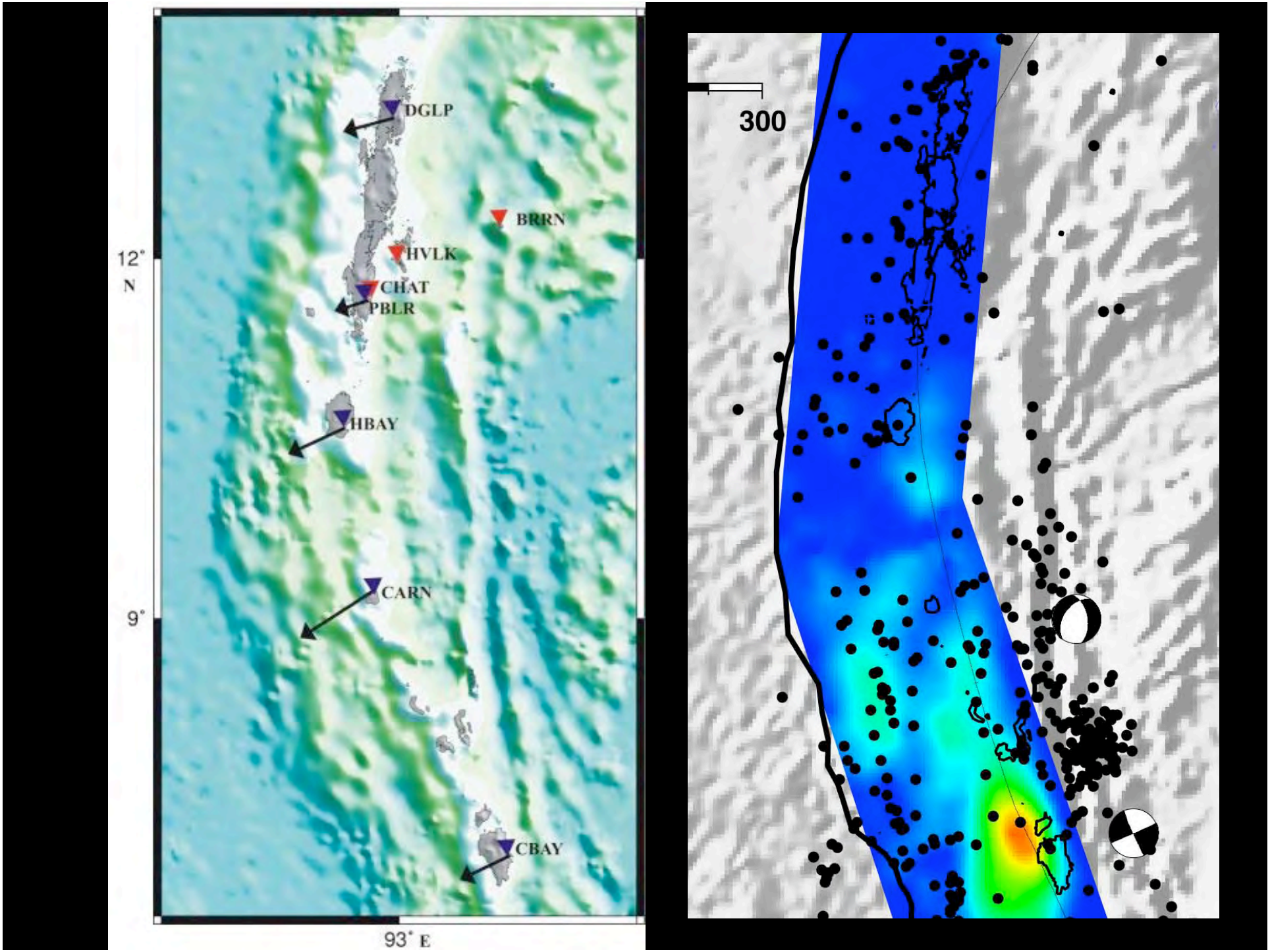
before

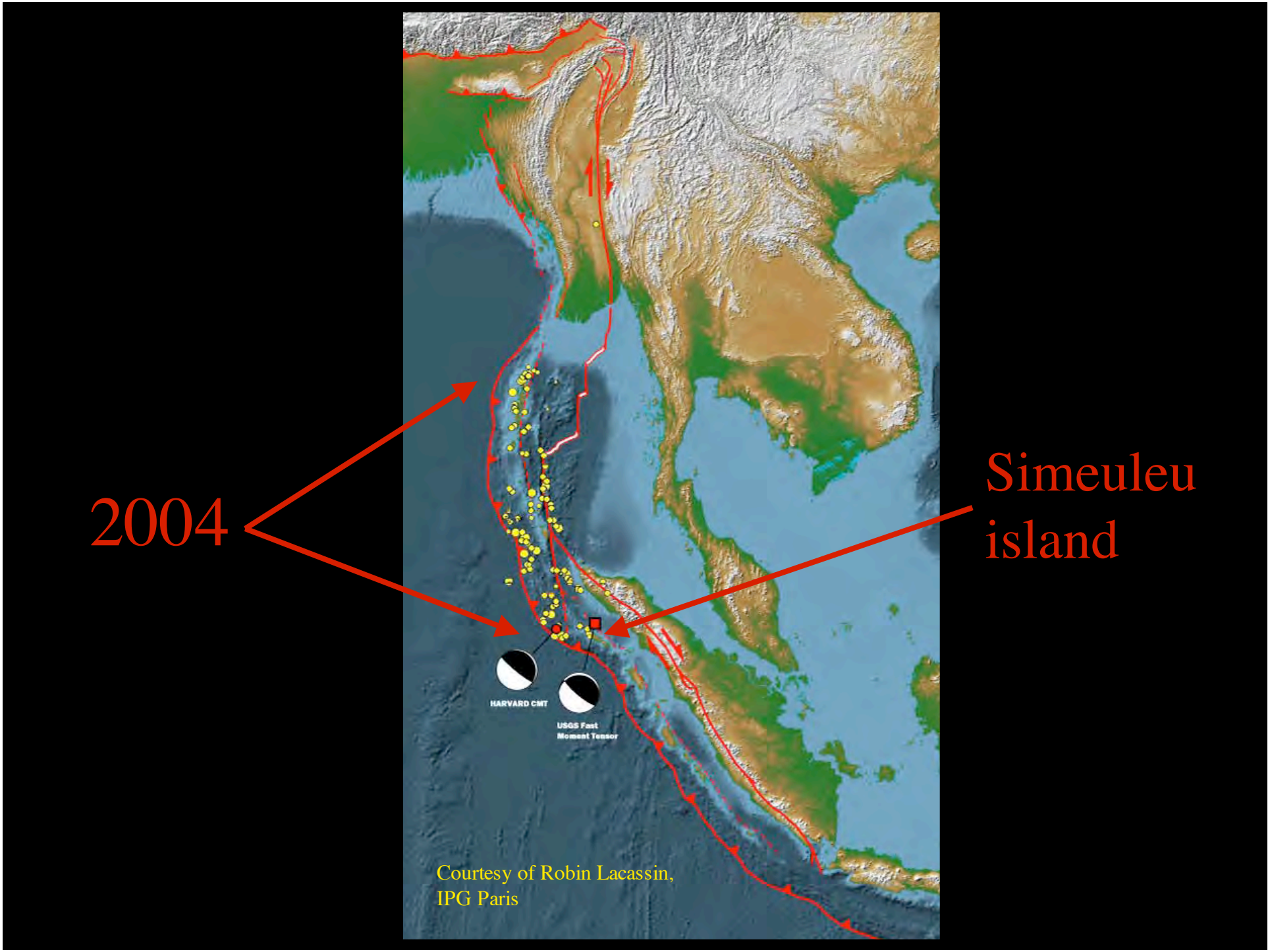


after


92 E
93 E
94 E
95 E
96 E
97
Kilometers
0 50 100 150 200
N
Minimum Subsidence (cm)
55 - 67
44 - 54
33 - 43
22 - 32
11 - 21
0 - 10
Minimum Uplift (cm)
0 - 10
11 - 20
21 - 30
31 - 40
Actual Uplift
5.5 m SUBSIDENCE
4.25 m SUBSIDENCE
1.5 m SUBSIDENCE
1.0 m SUBSIDENCE
0.7 m UPLIFT
1.0 m UPLIFT
1.5 m UPLIFT
Courtesy of Aron Meltzner, TO, Caltech


300
SAMP
cm
500
1000
1500
2000
92 E
93 E
94 E
95 E
96 E
97
Kilometers
0
50
100
150
200
N
Minimum Subsidence (cm)
55 - 67
44 - 54
33 - 43
22 - 32
11 - 21
0 - 10
Minimum Uplift (cm)
0 - 10
11 - 20
21 - 30
31 - 40
Actual Uplift
5.5 m SUBSIDENCE
4.25 m SUBSIDENCE
1.5 m SUBSIDENCE
1.0 m SUBSIDENCE
0.7 m UPLIFT
1.0 m UPLIFT
1.5 m UPLIFT


DGLP
BRRN
HVLK
CHAT
PBLR
HBAY
CARN
CBAY
12° N
9°
93° E
300

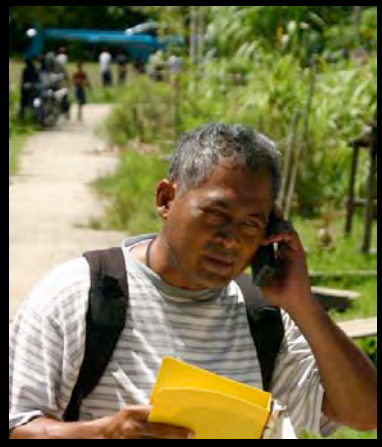

2004
Simeuleu
island
HARVARD CMT
USGS Fast
Moment Tensor
Courtesy of Robin Lacassin,
IPG Paris

Helicopter crew

Dayat

Samsir

Imam Suprihanto



Bambang Suwargadi

Science team

Me

Logistics and GPS

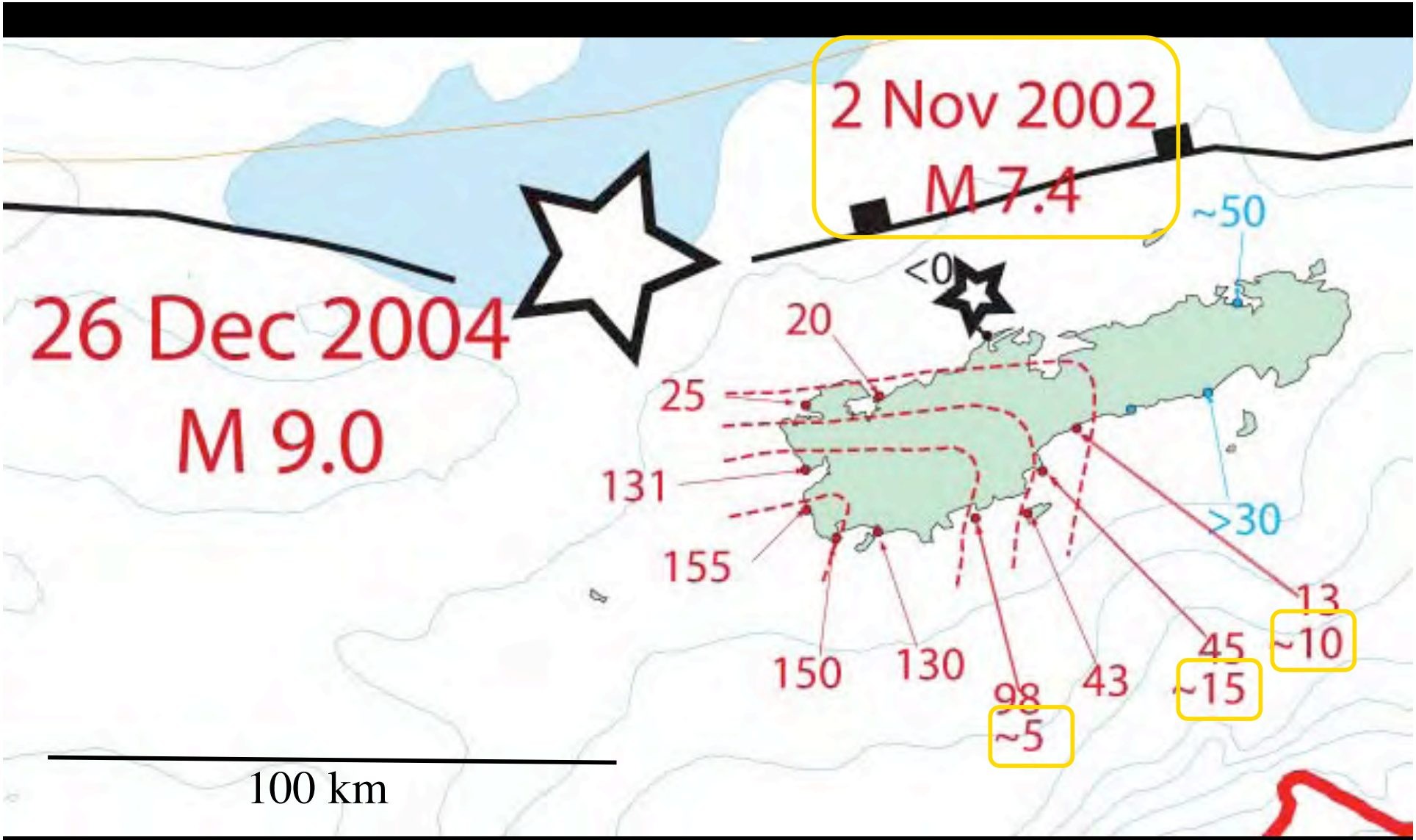
Danny Natawidjaja

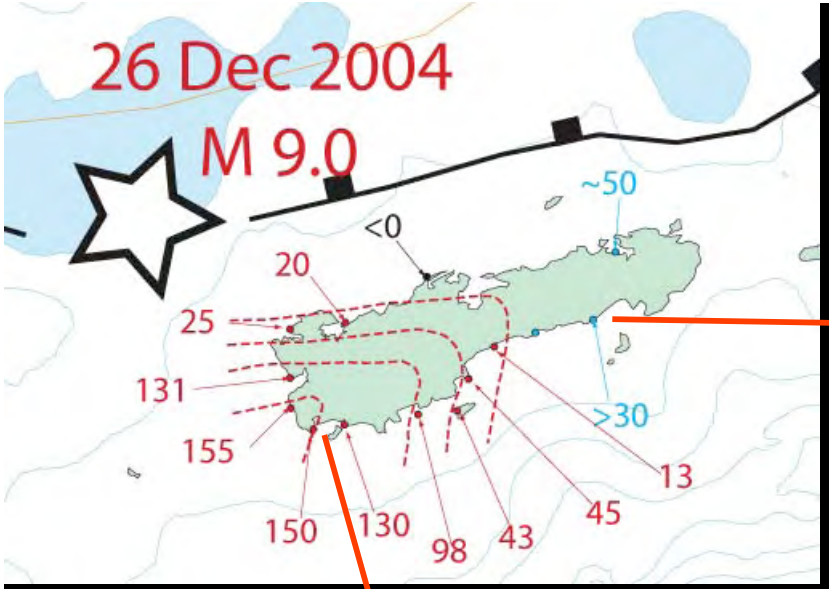
Mohamed Chlieh

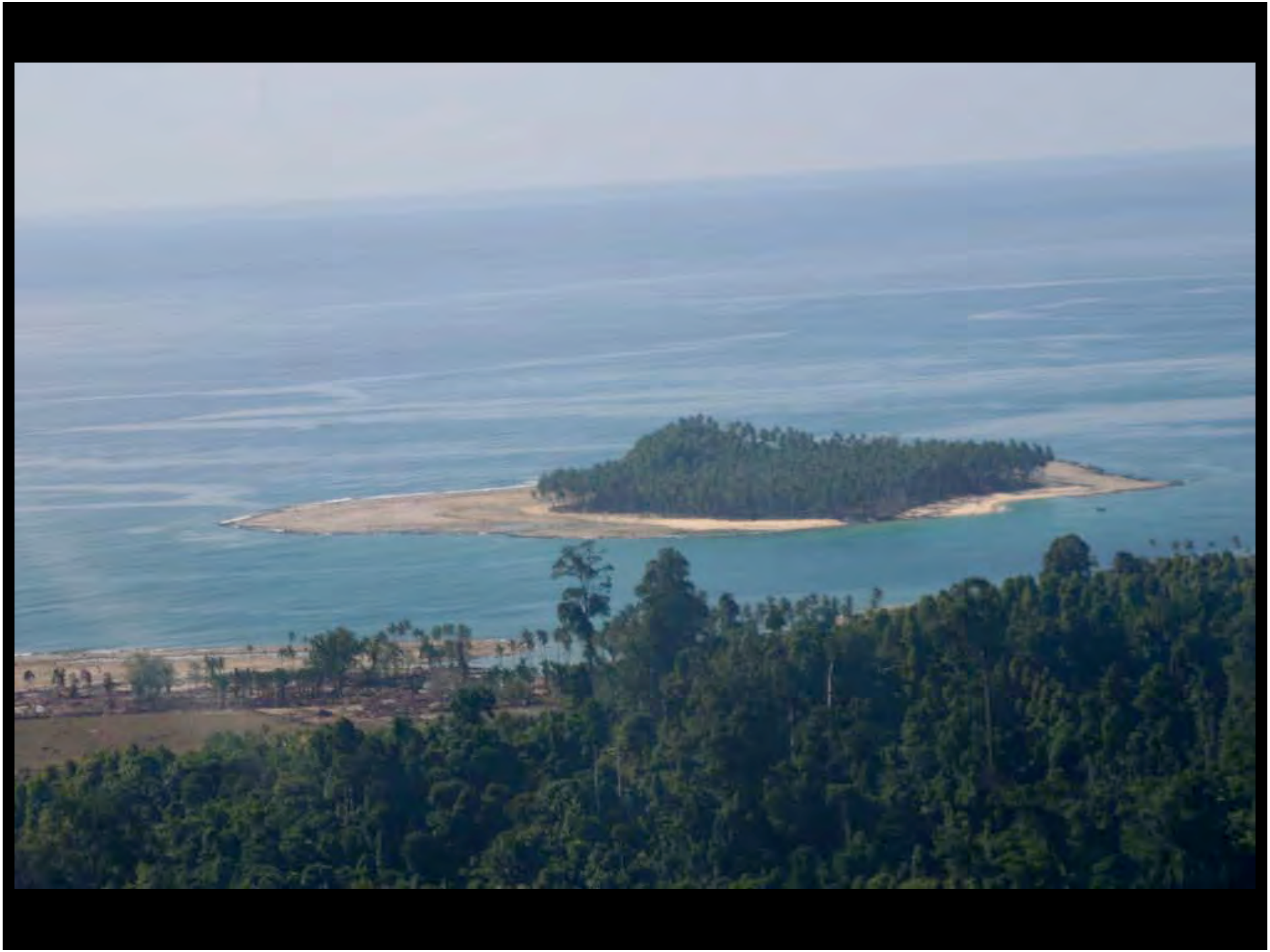
John Galetzka

Boat crew

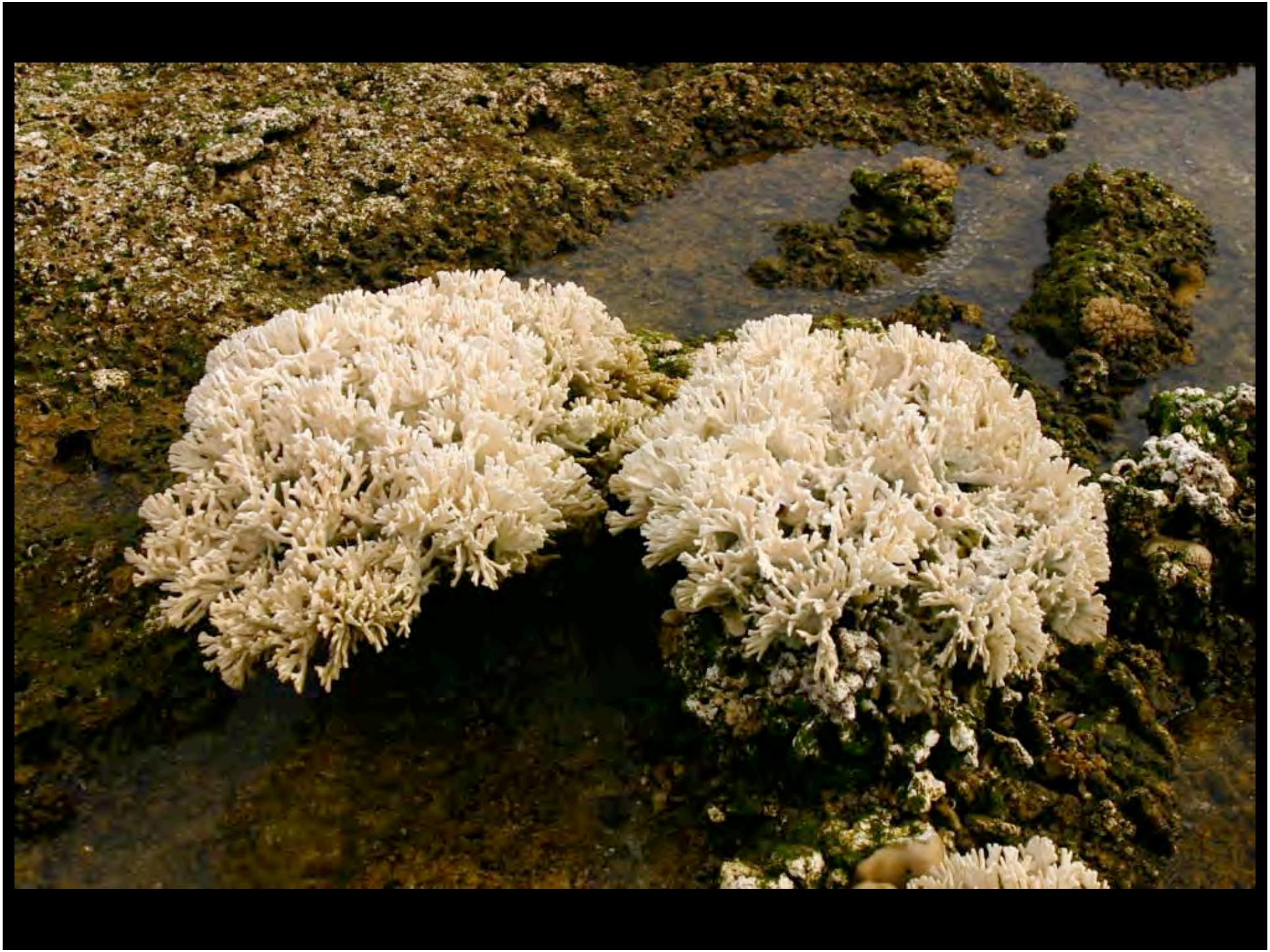
Man et al

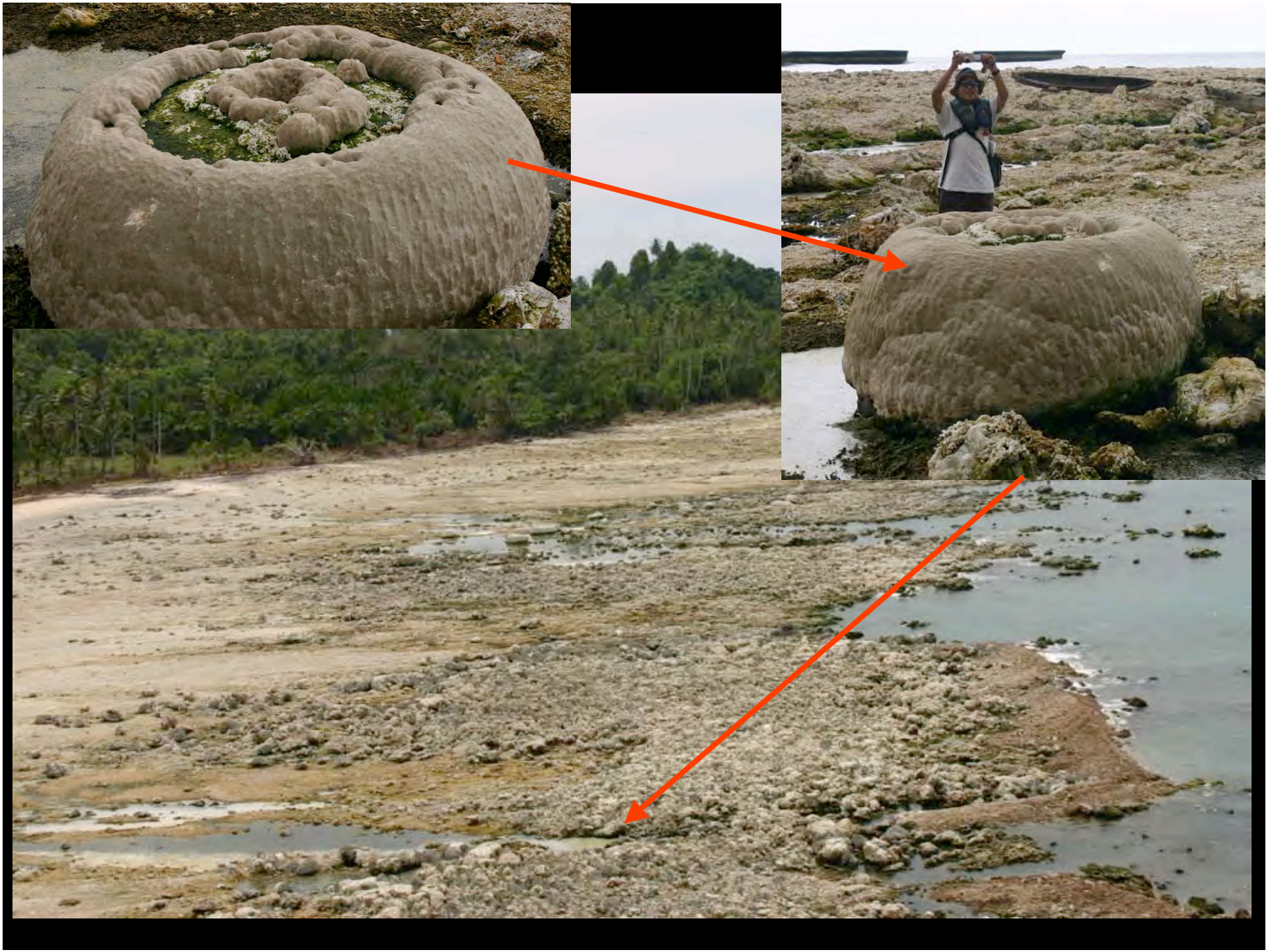

2 Nov 2002
M 7.4
26 Dec 2004
M 9.0
~50
<0
20
25
131
155
150
130
98
~5
43
45
~15
13
~10
>30
100 km


26 Dec 2004
M 9.0
~50
<0
20
25
131
155
>30
13
45
150
130
98
43



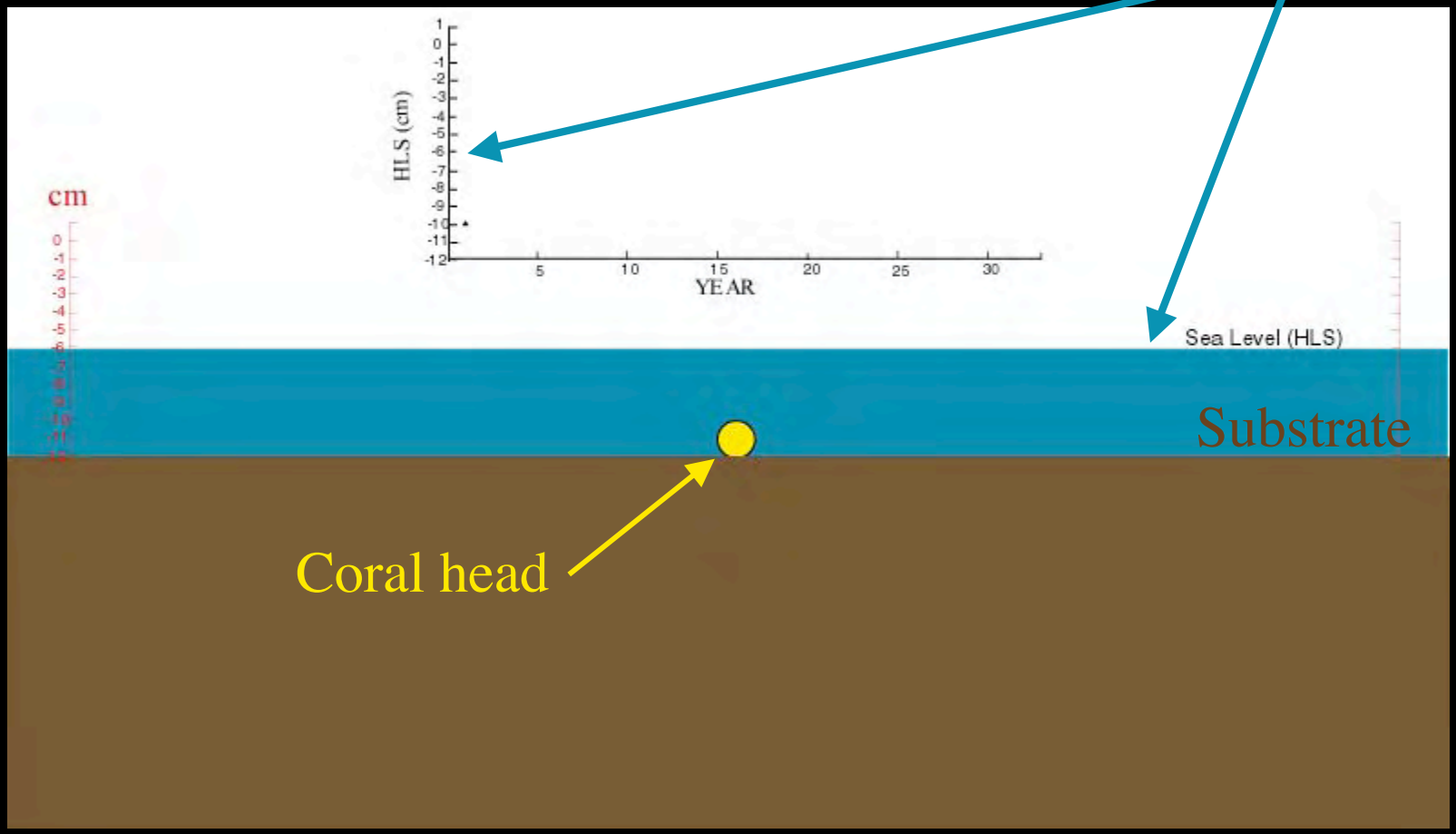
Simeulue island, Aceh, Sumatra

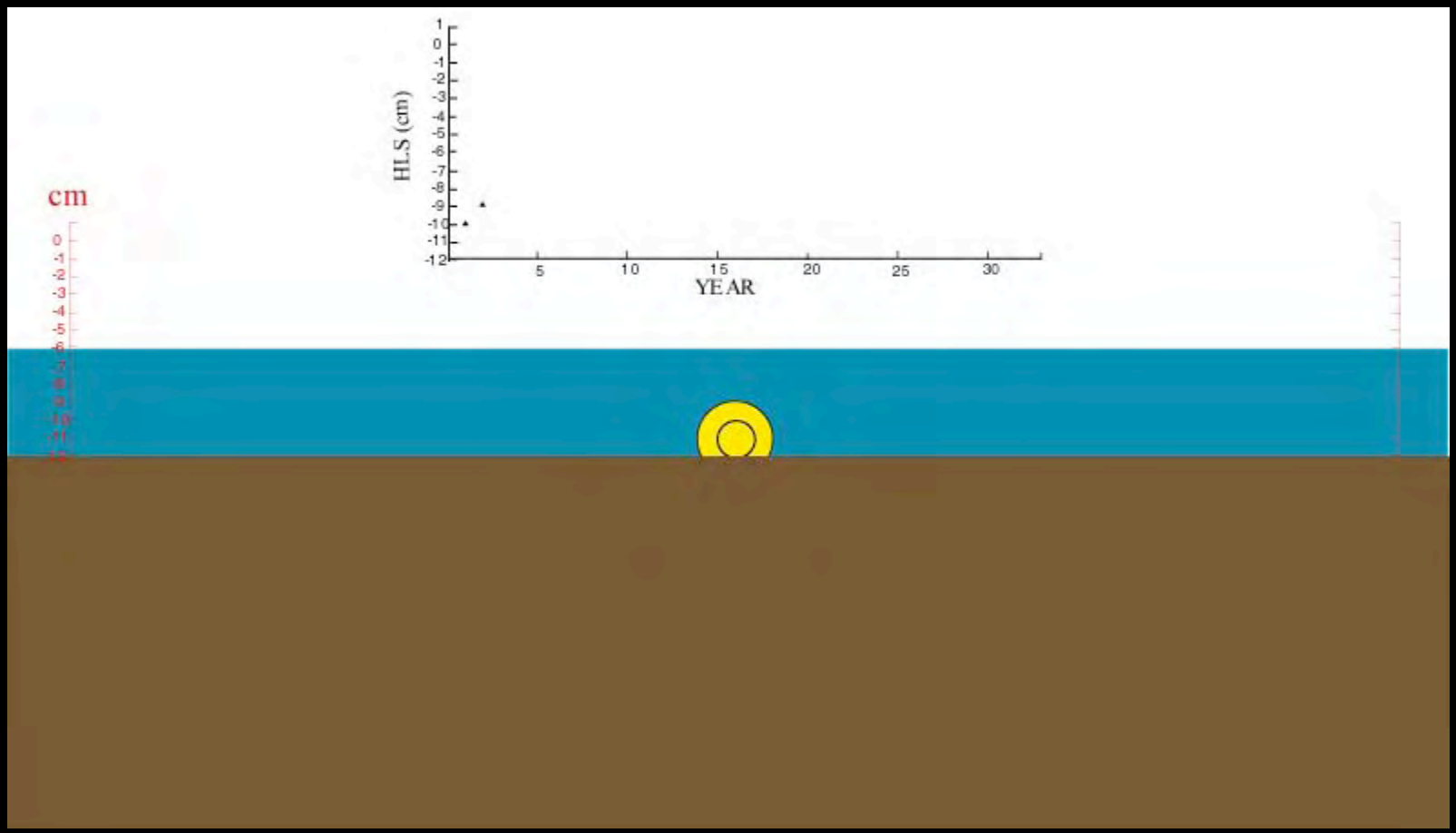


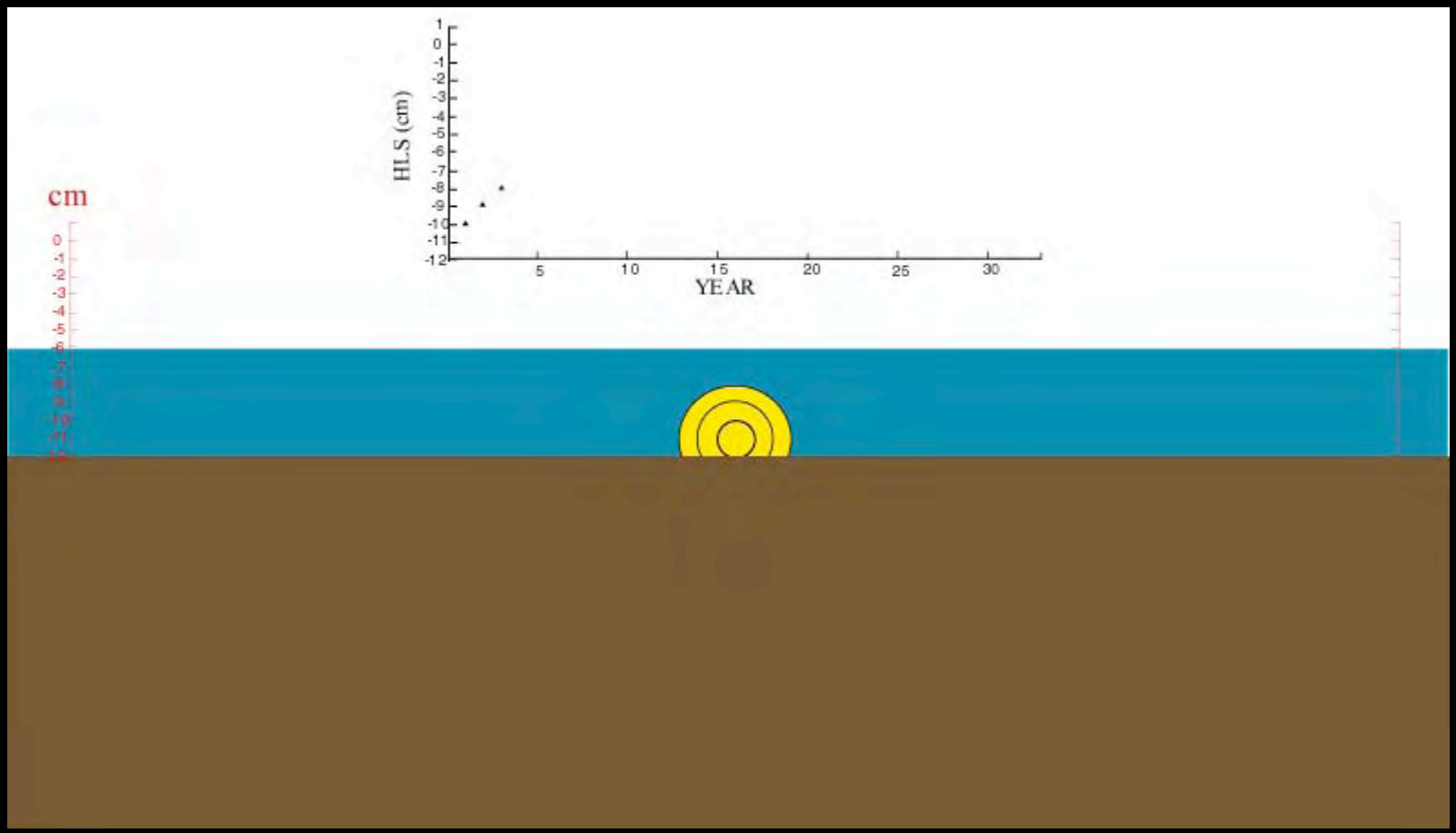


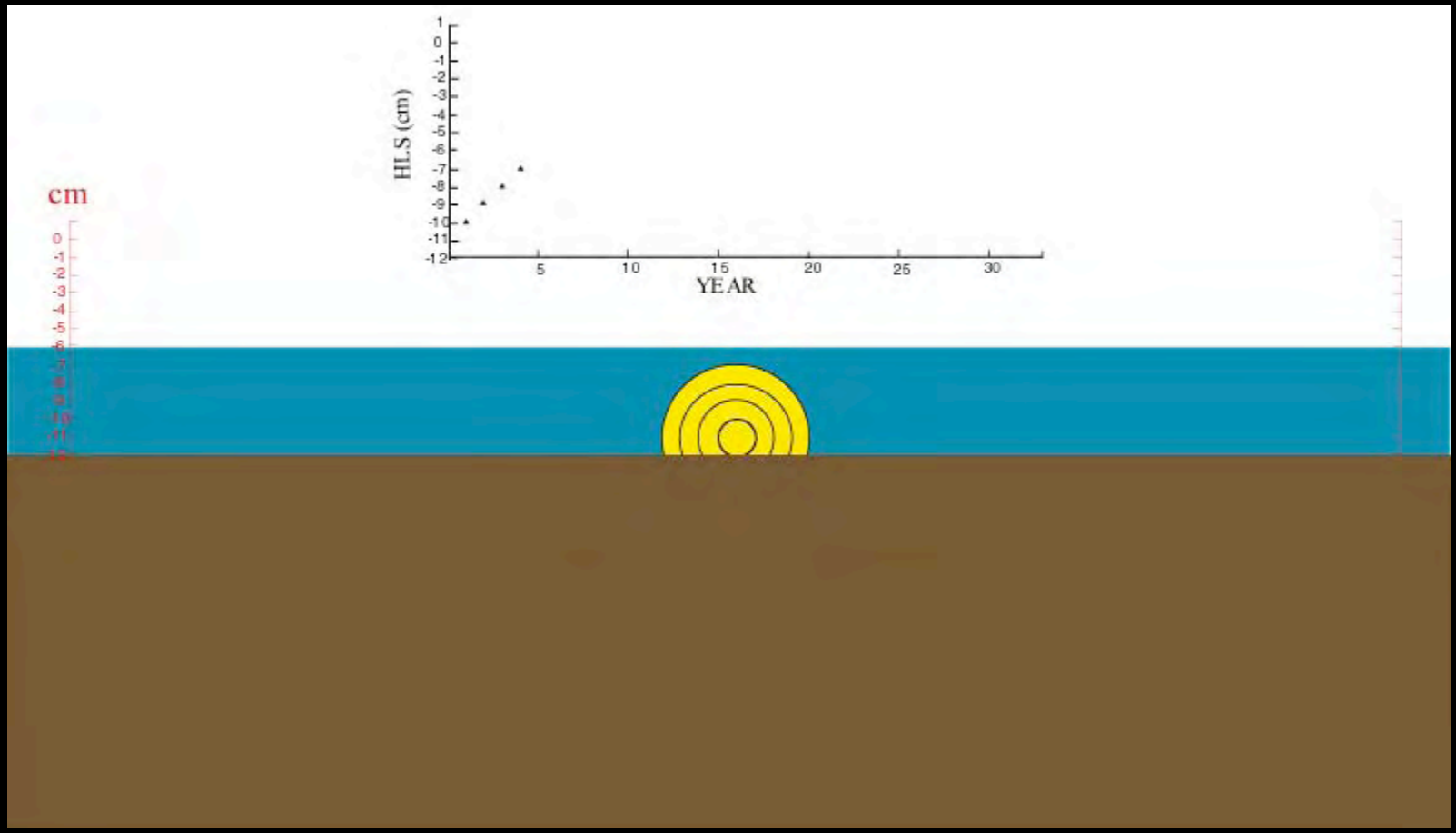
The coral “instrument”

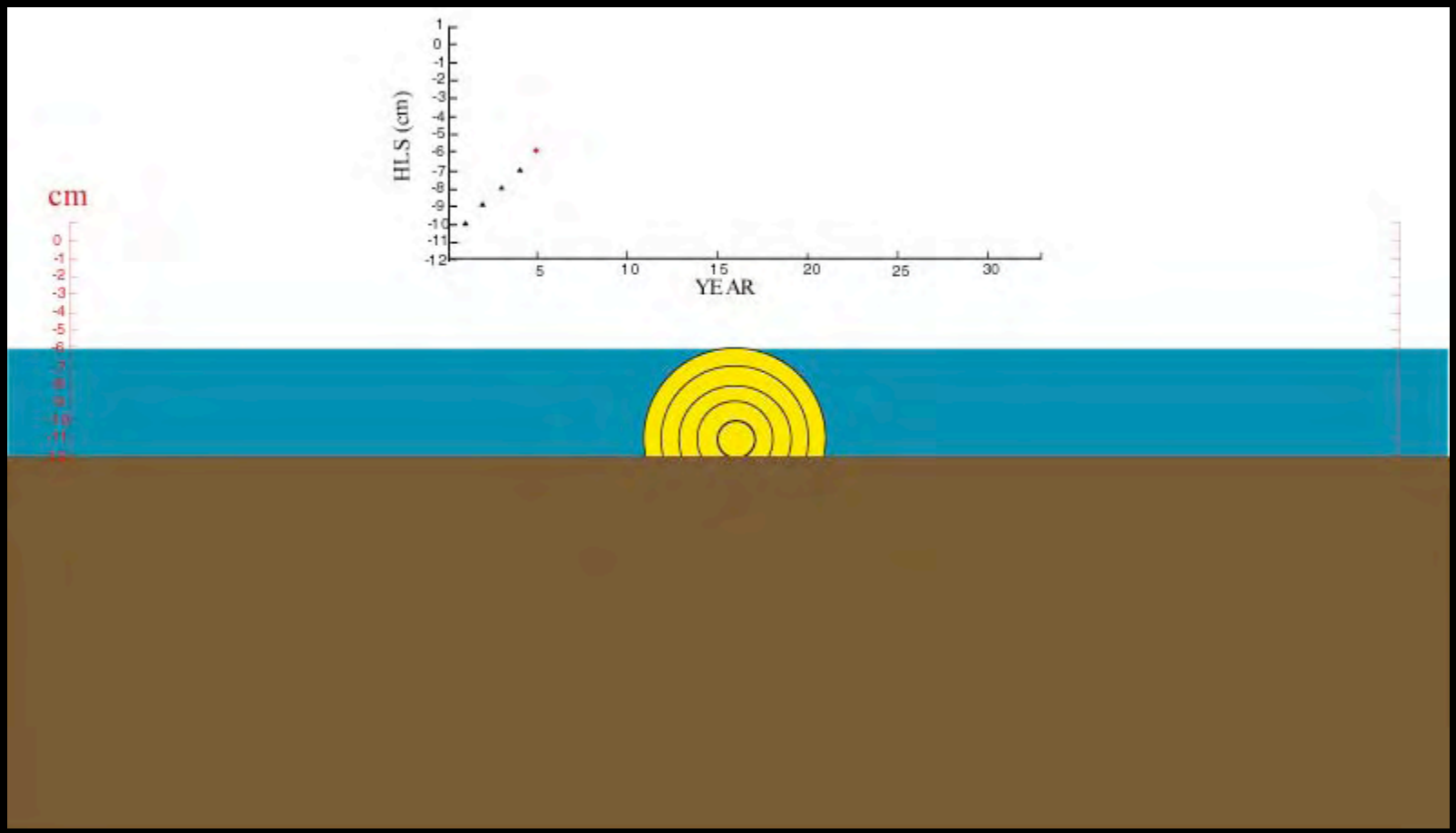
Annual lowest tide (“highest level of survival” or “HLS”)

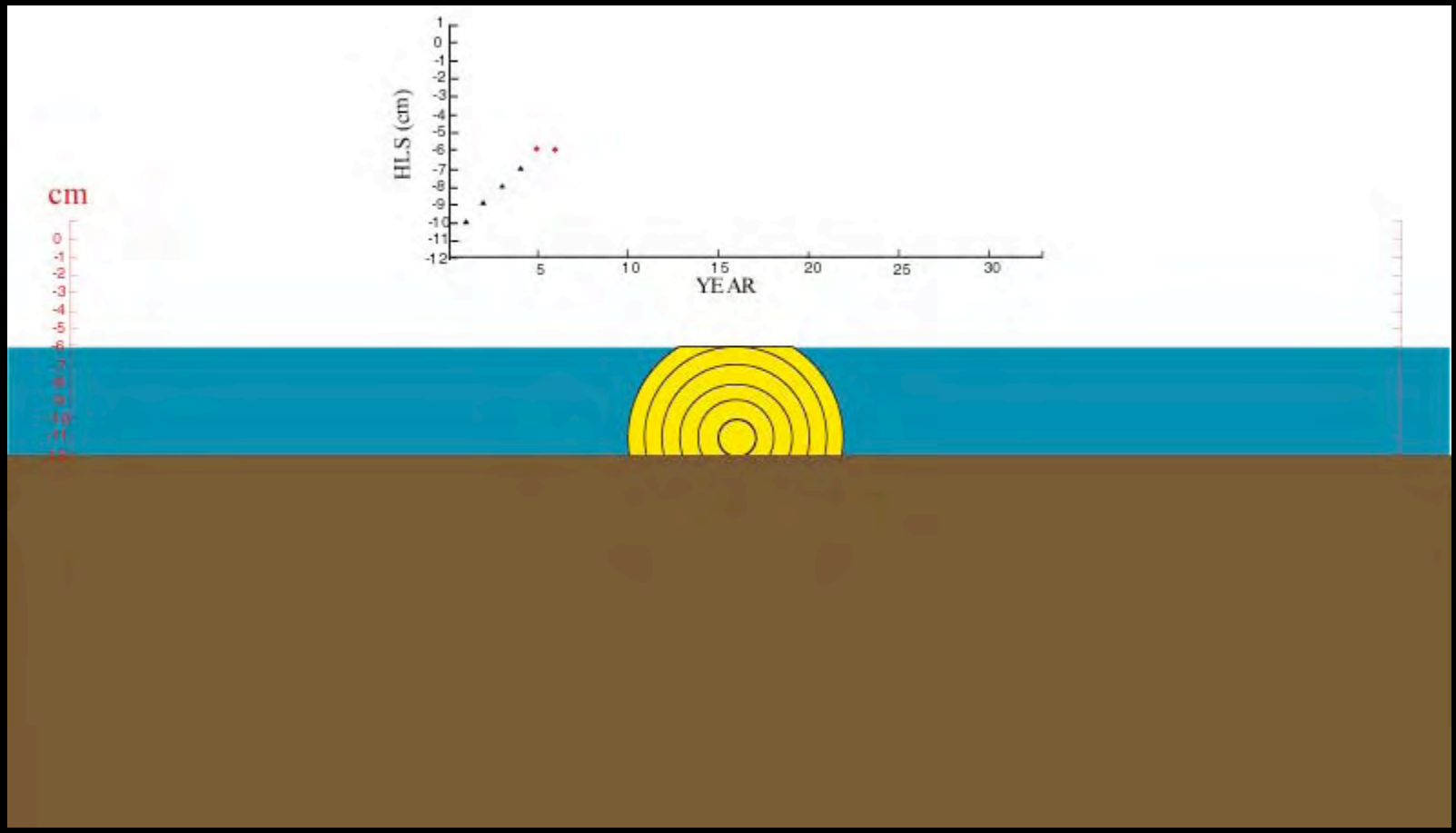


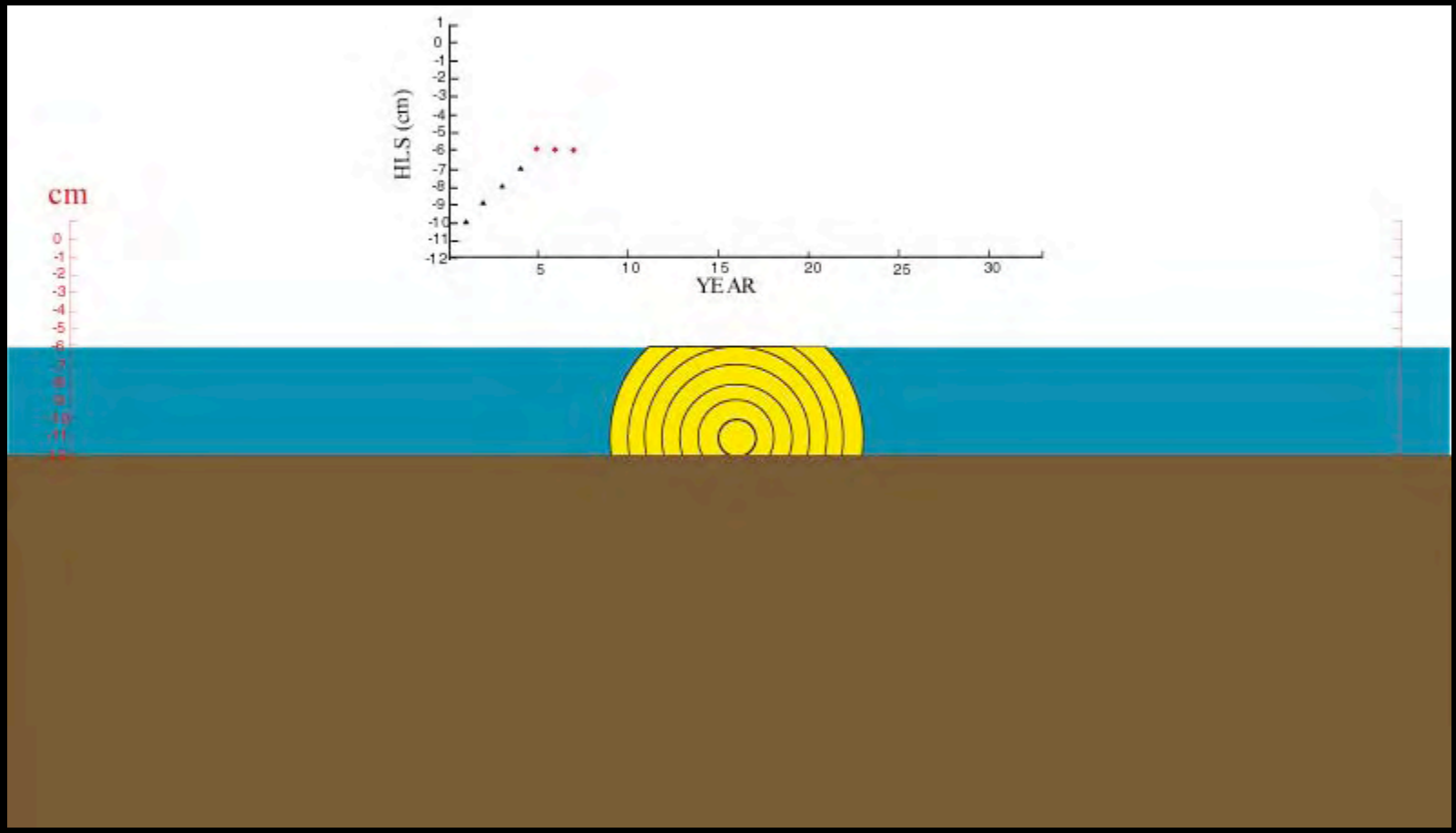

cm
HLS (cm)
YEAR
5
10
15
20
25
30

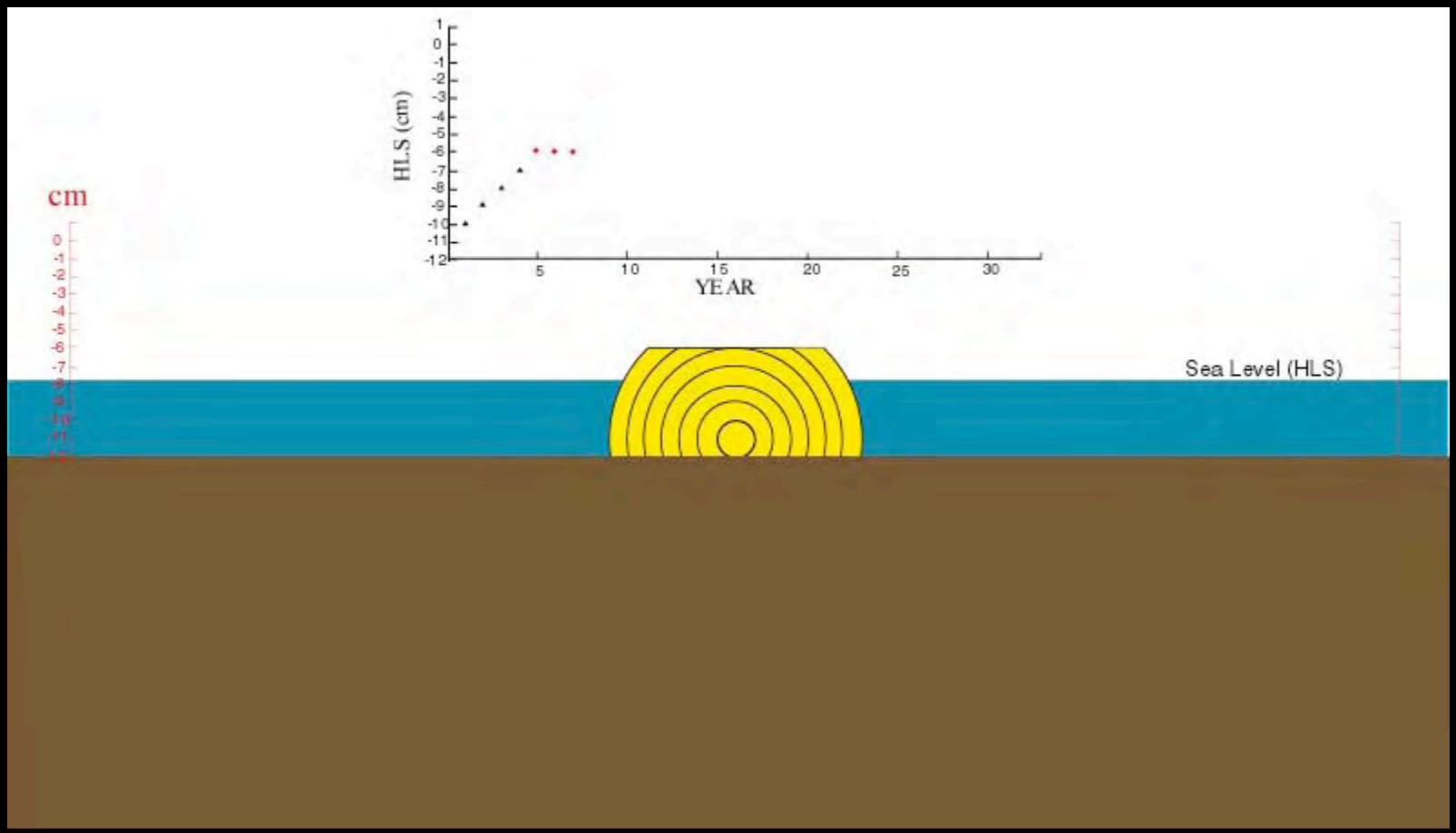

cm
HLS (cm)
YEAR
5
10
15
20
25
30

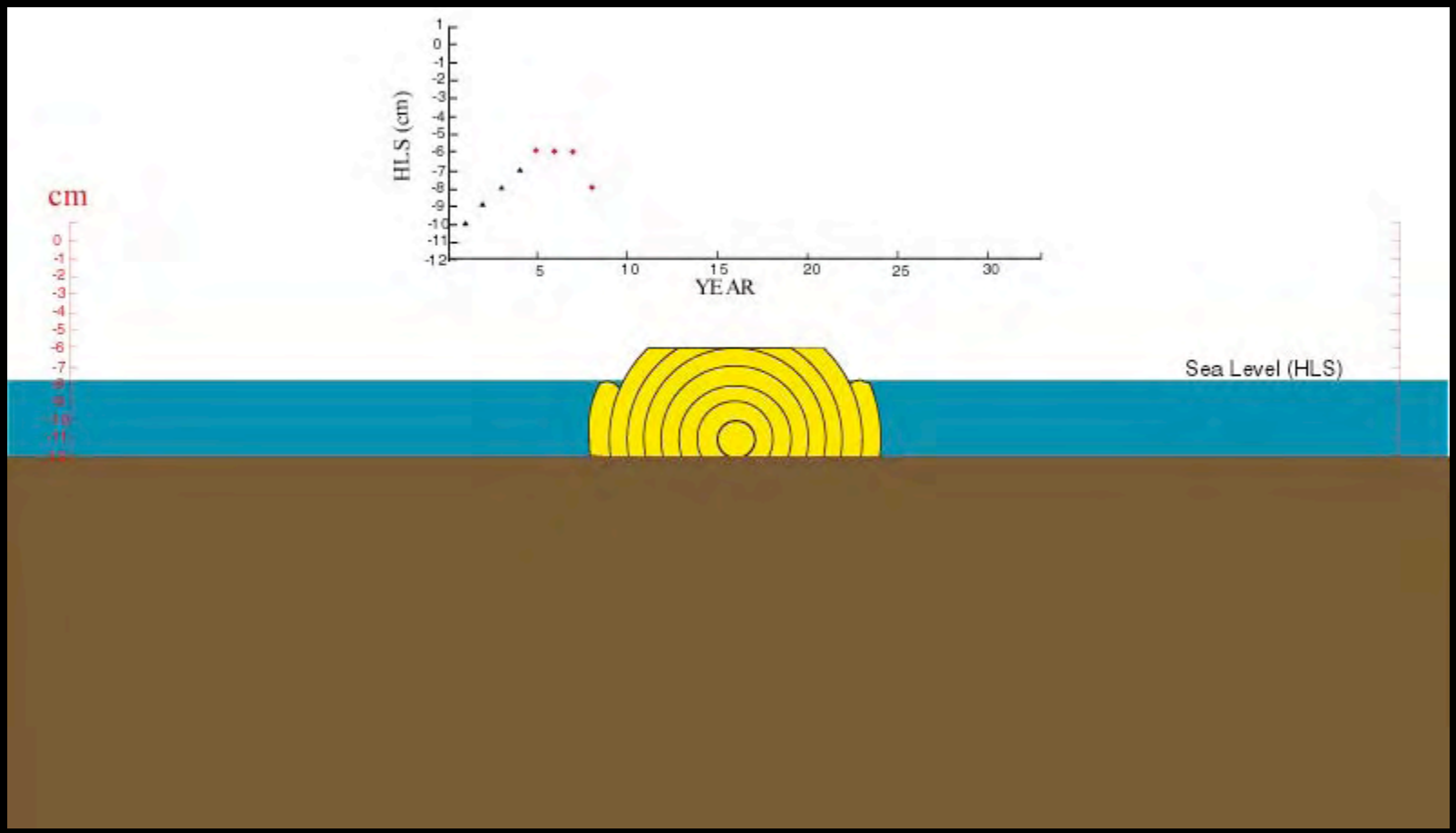

HLS (cm)
YEAR
cm

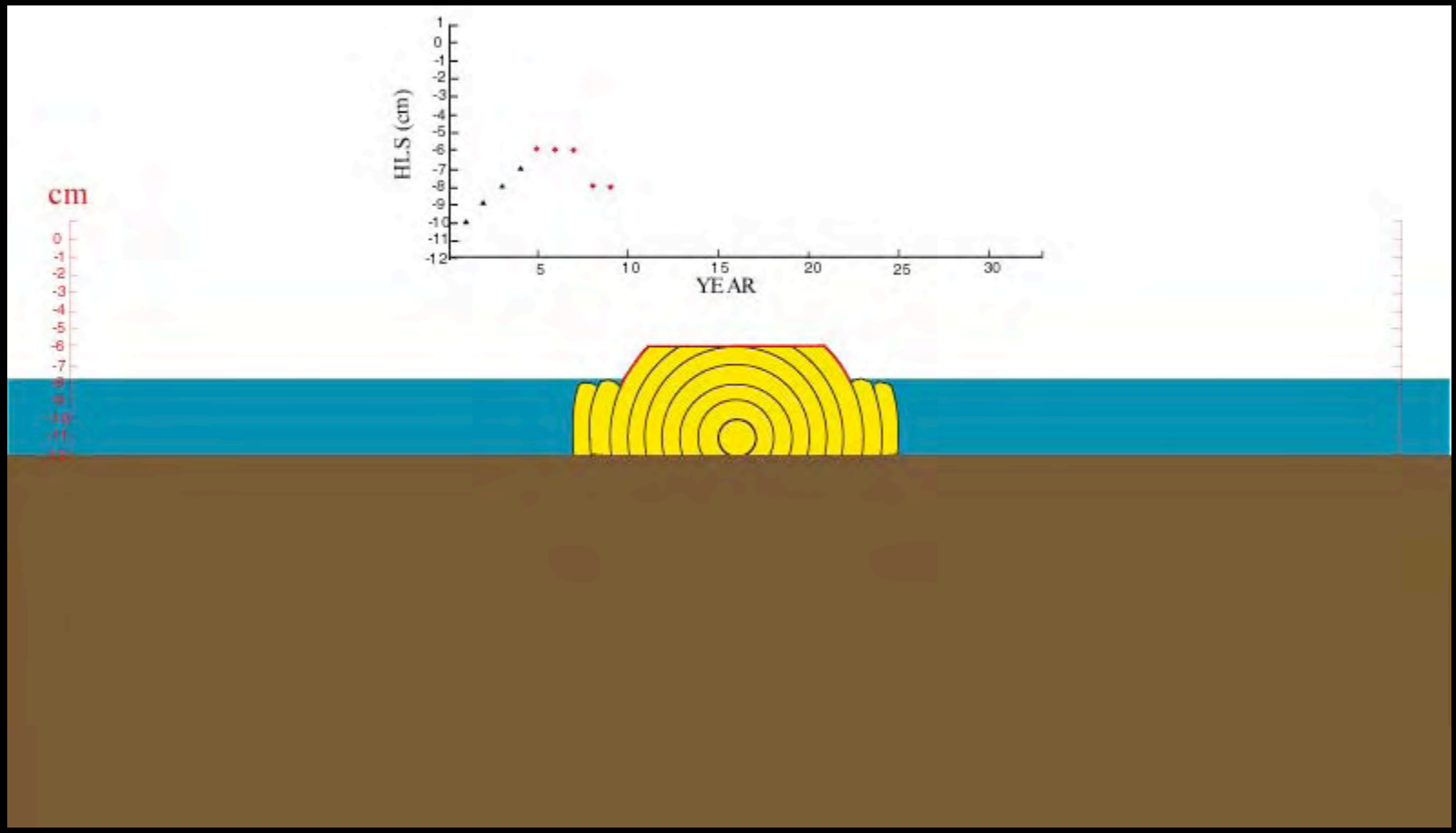

cm
HLS (cm)
YEAR
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
5
10
15
20
25
30

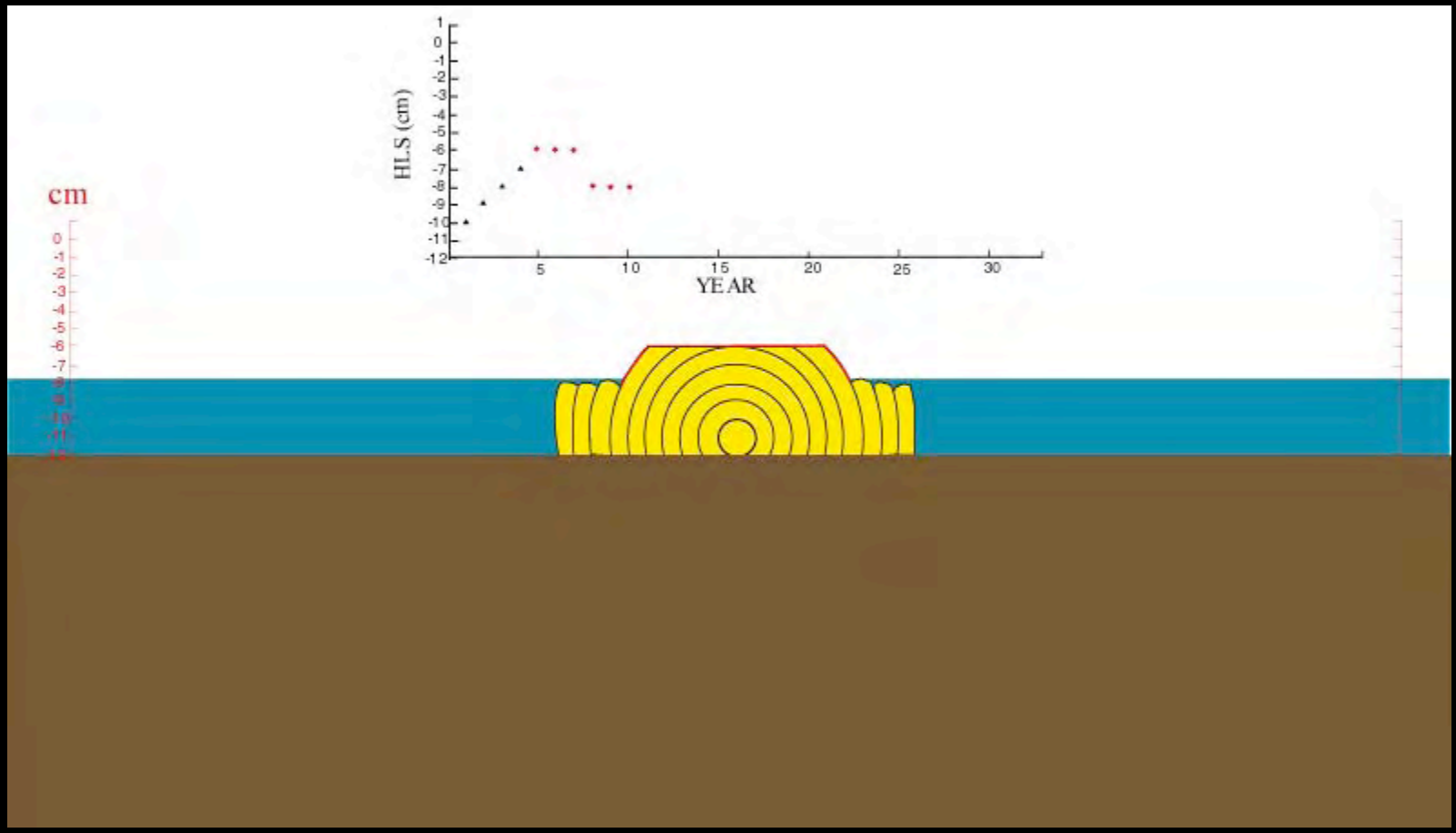

HLS (cm)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
5
10
15
20
25
30
YEAR
cm
0
-1
-2
-3
-4
-5
-6

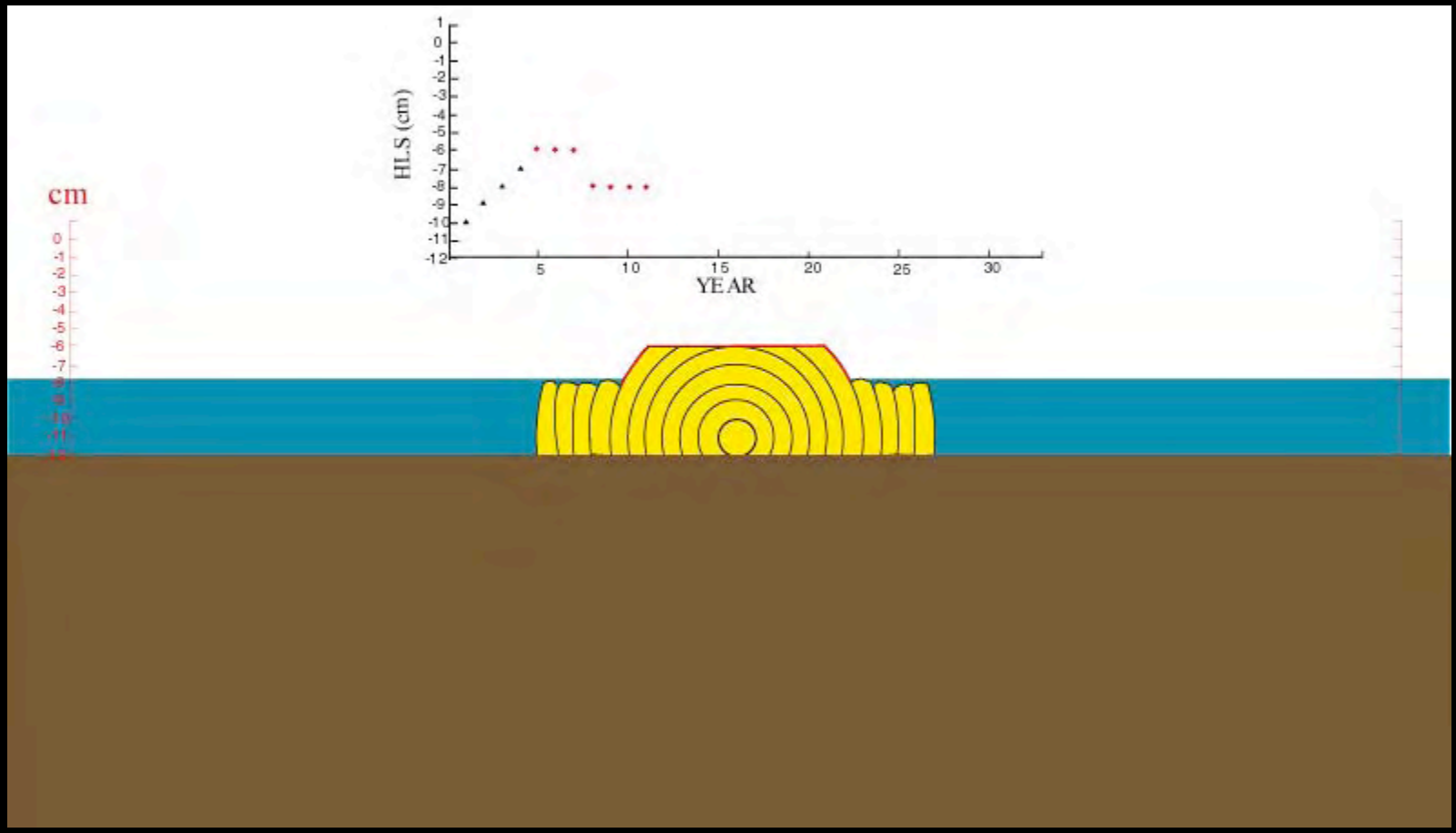

HLS (cm)
YEAR
cm

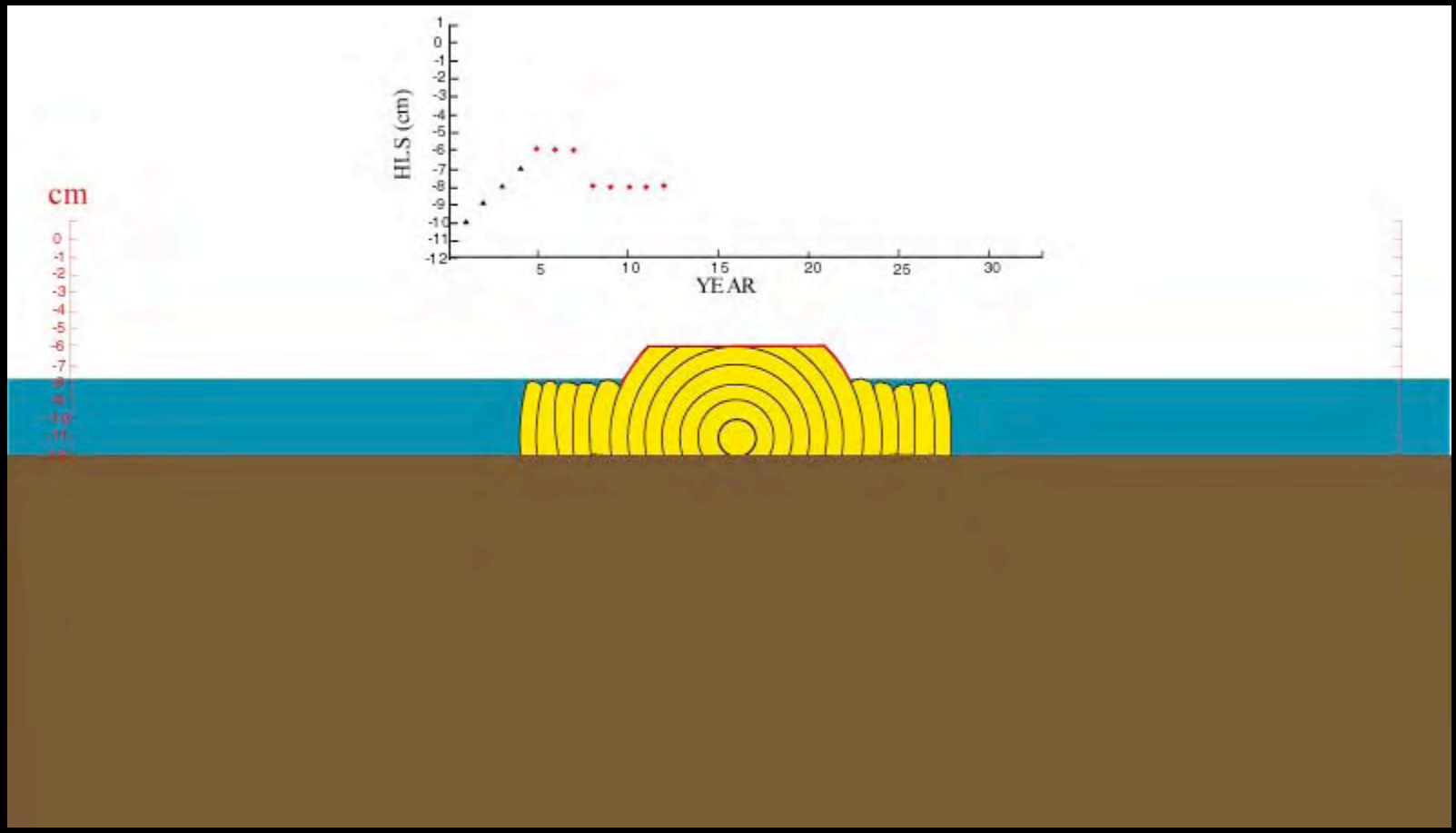

HLS (cm)
YEAR
cm
Sea Level (HLS)

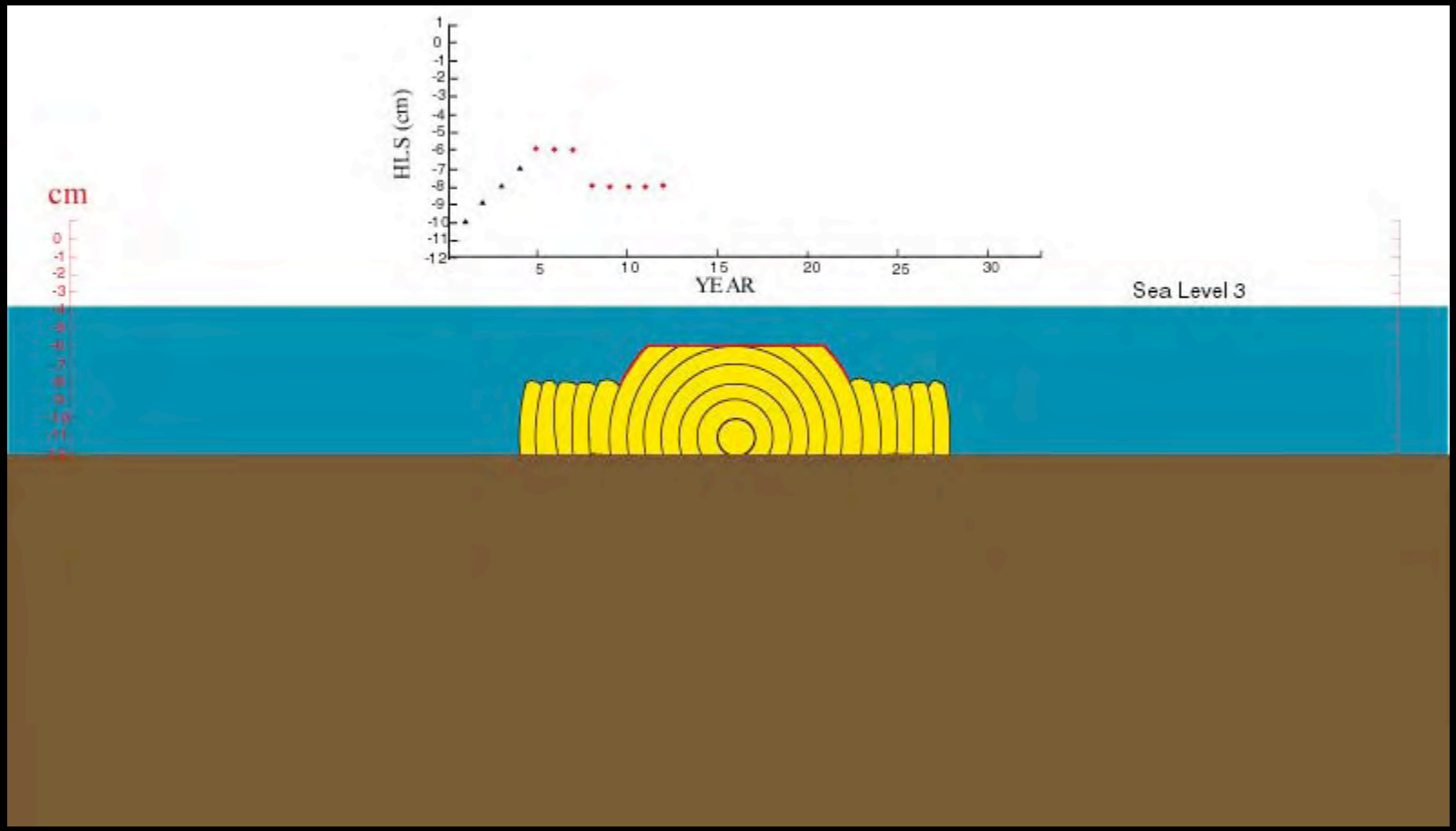

HLS (cm)
YEAR
cm
Sea Level (HLS)

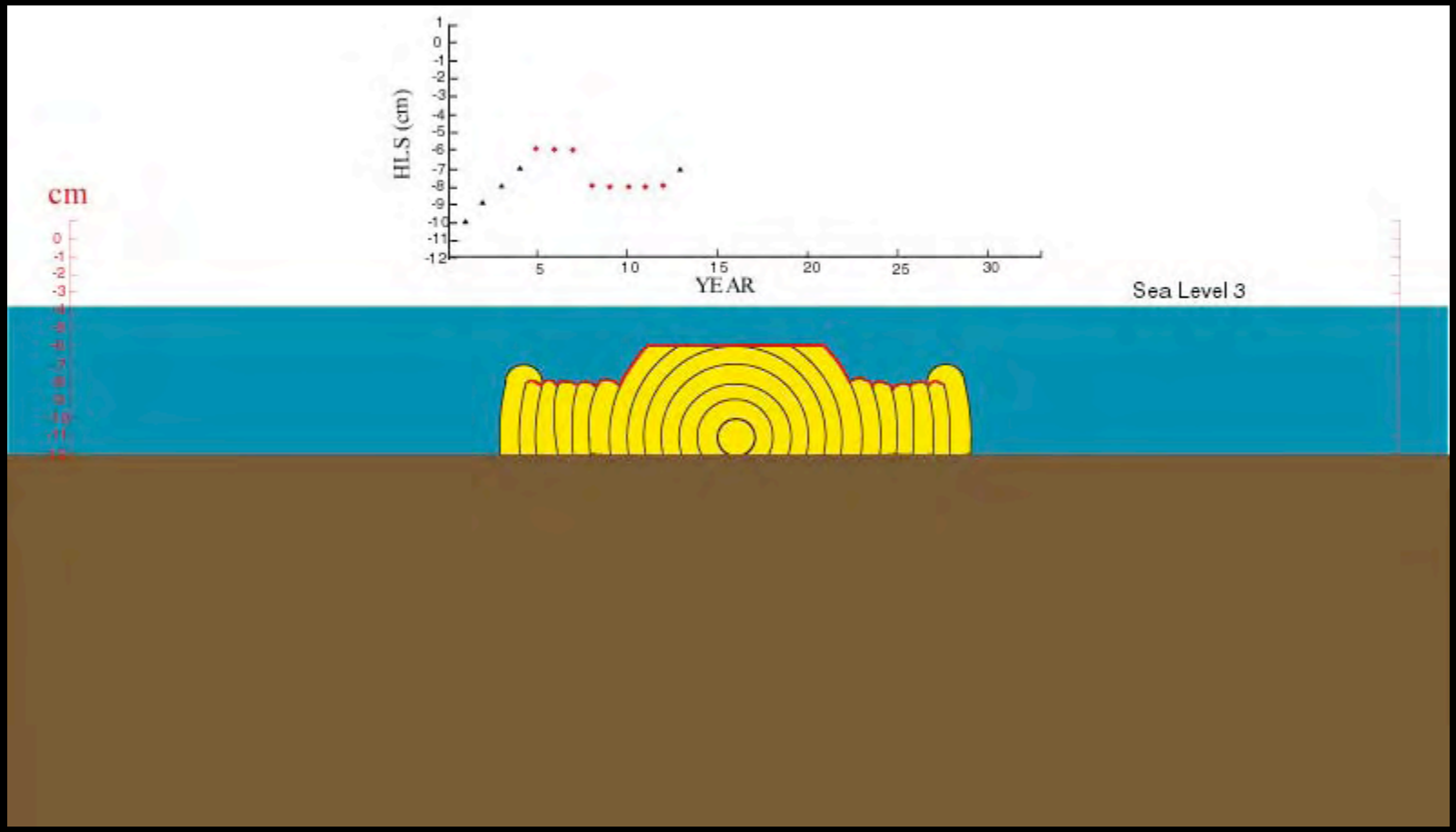

HLS (cm)
YEAR
cm

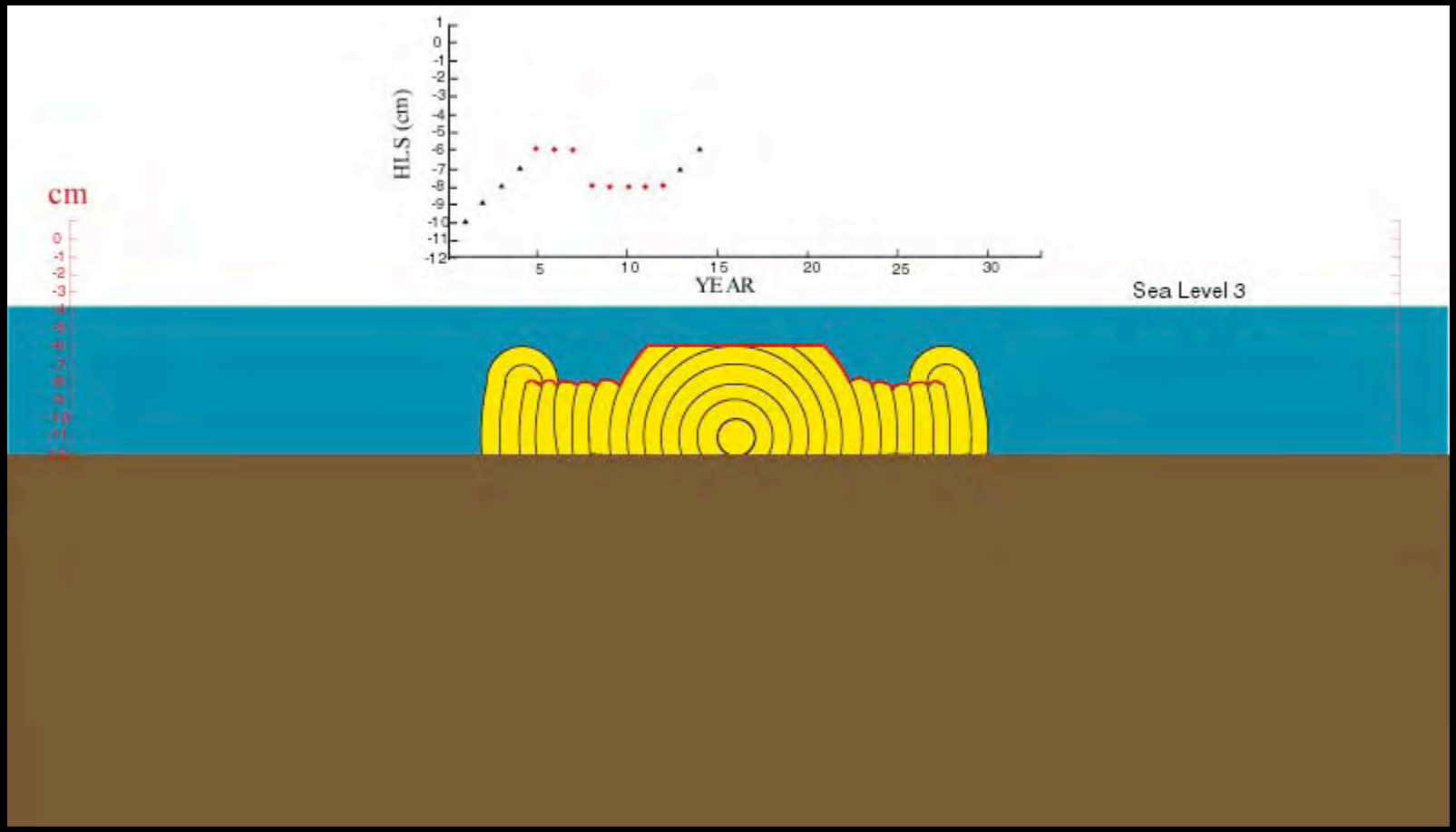

HLS (cm)
YEAR
cm

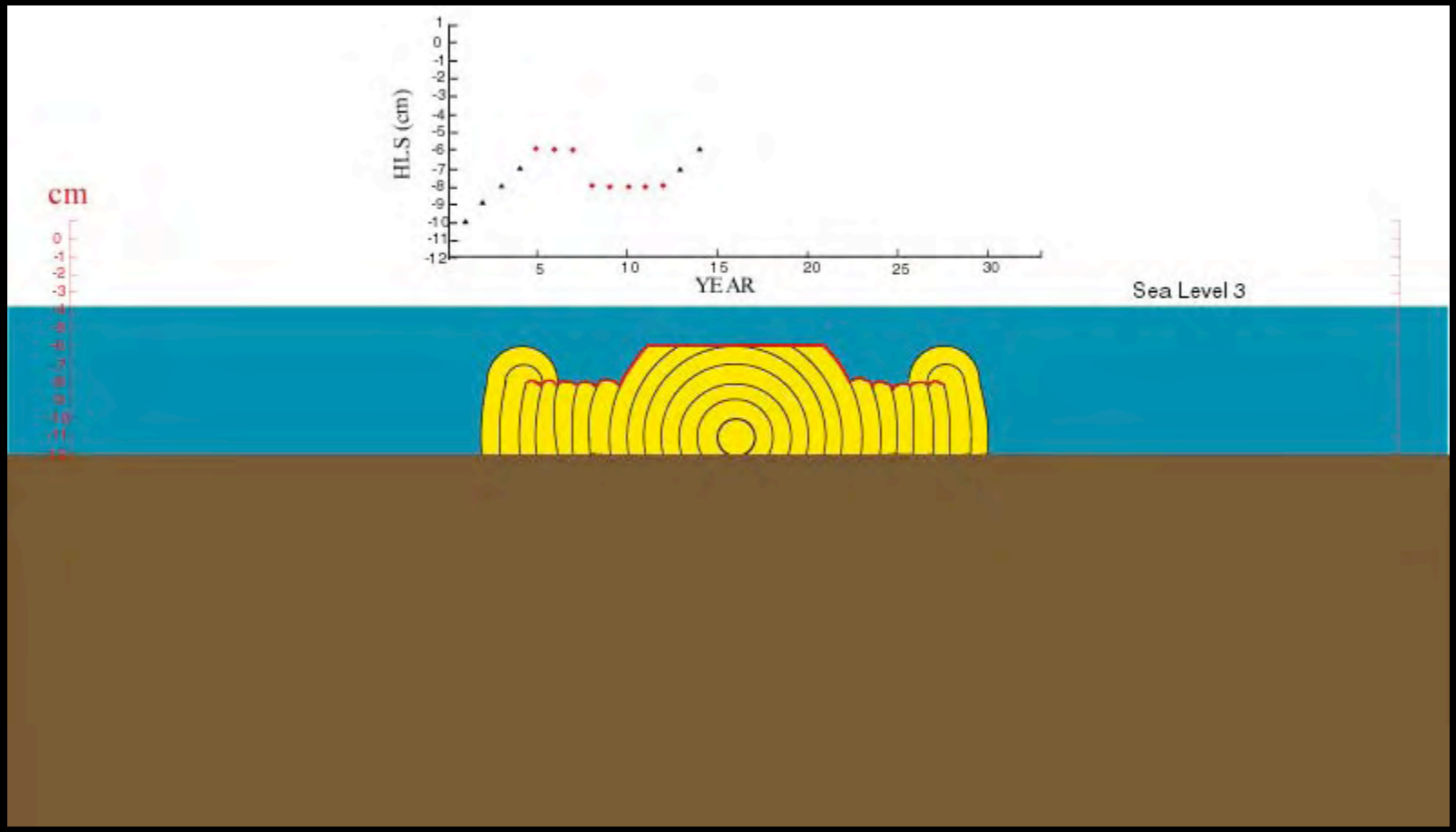

HLS (cm)
YEAR
cm

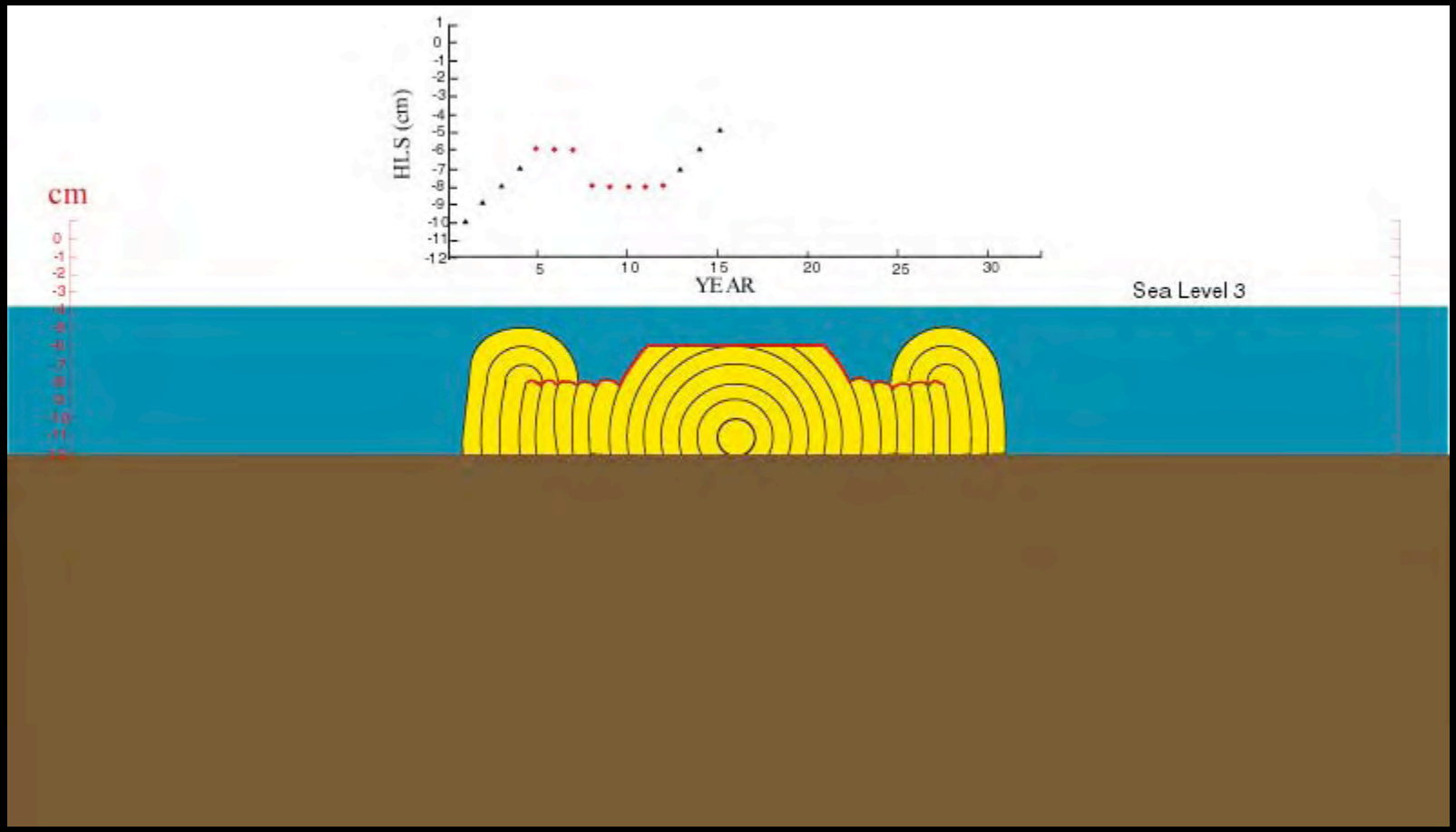

HLS (cm)
YEAR
cm

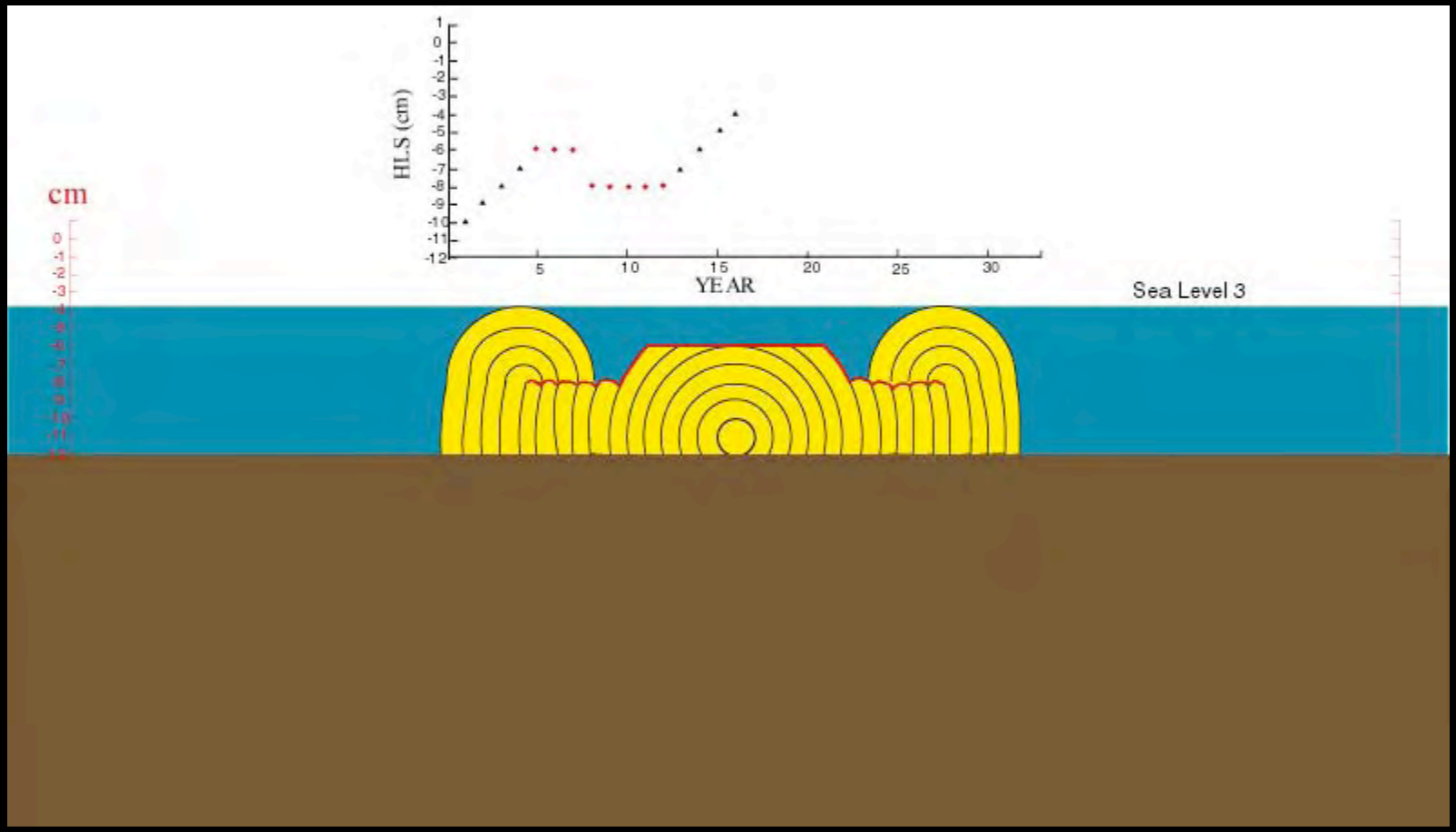

cm
HLS (cm)
YEAR
Sea Level 3


cm
HLS (cm)
YEAR
Sea Level 3


cm
HLS (cm)
YEAR
Sea Level 3


cm
HLS (cm)
YEAR
Sea Level 3

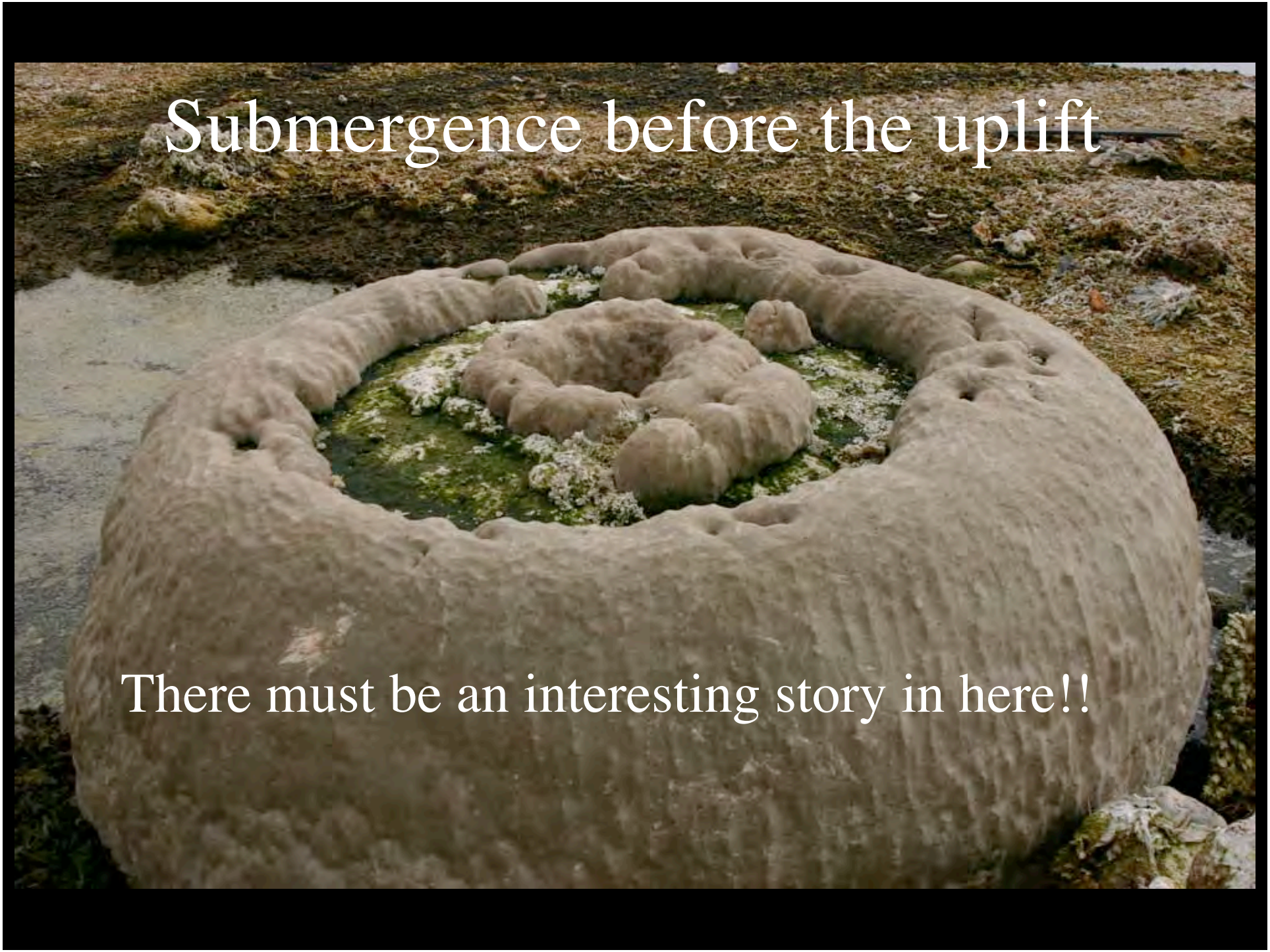

HLS (cm)
YEAR
cm
Sea Level 3

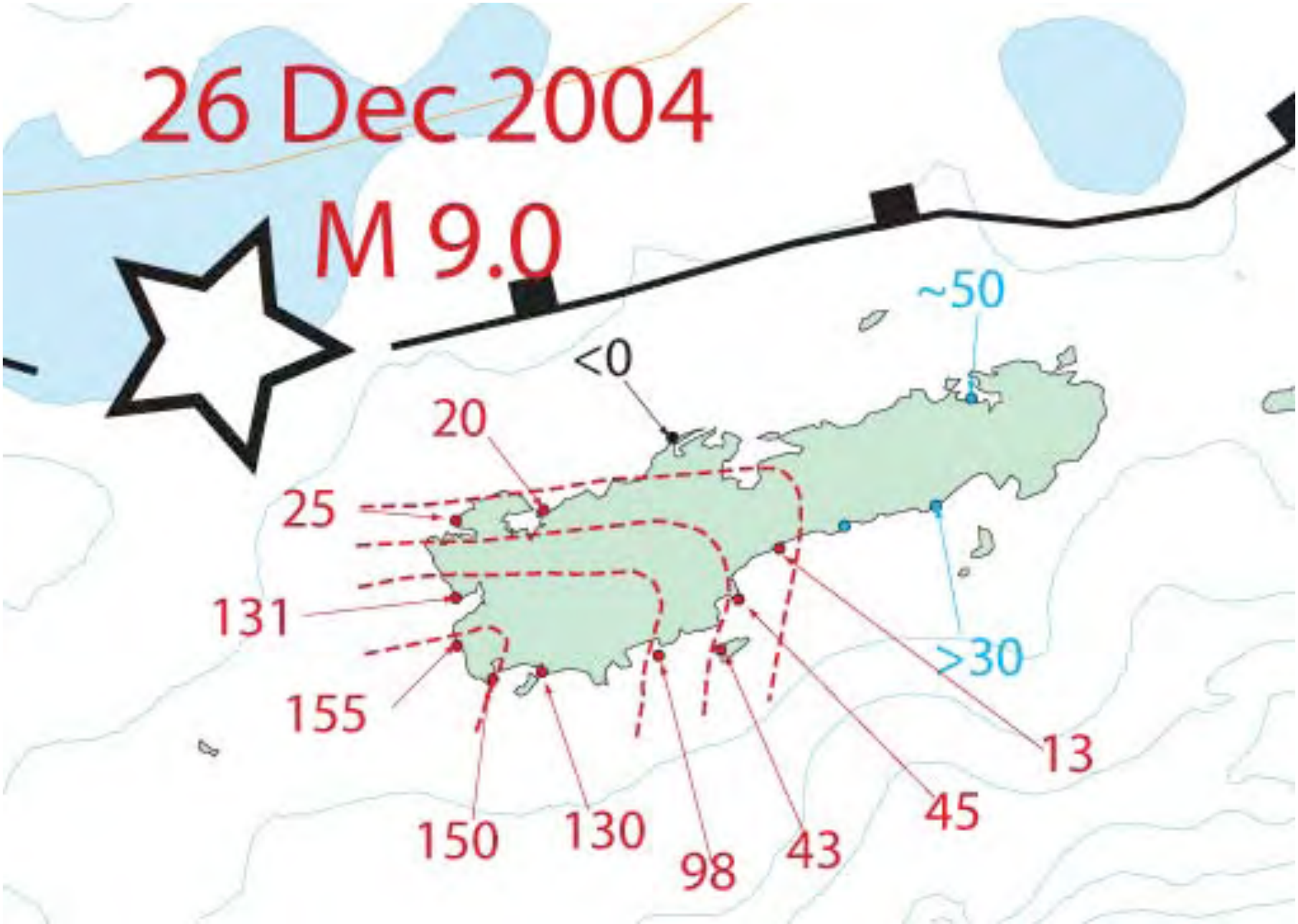

HLS (cm)
YEAR
cm
Sea Level 3

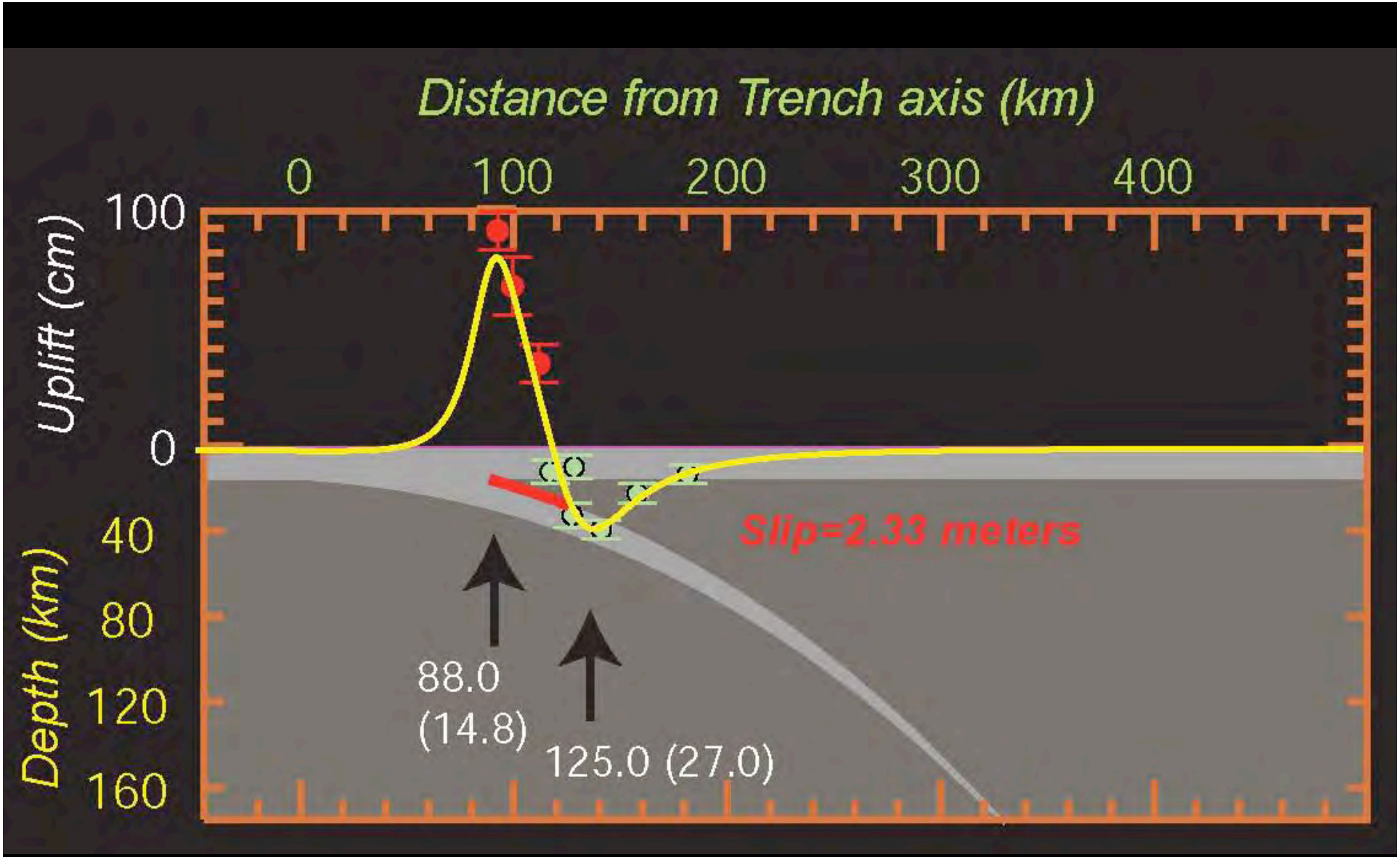

130 cm


130 cm

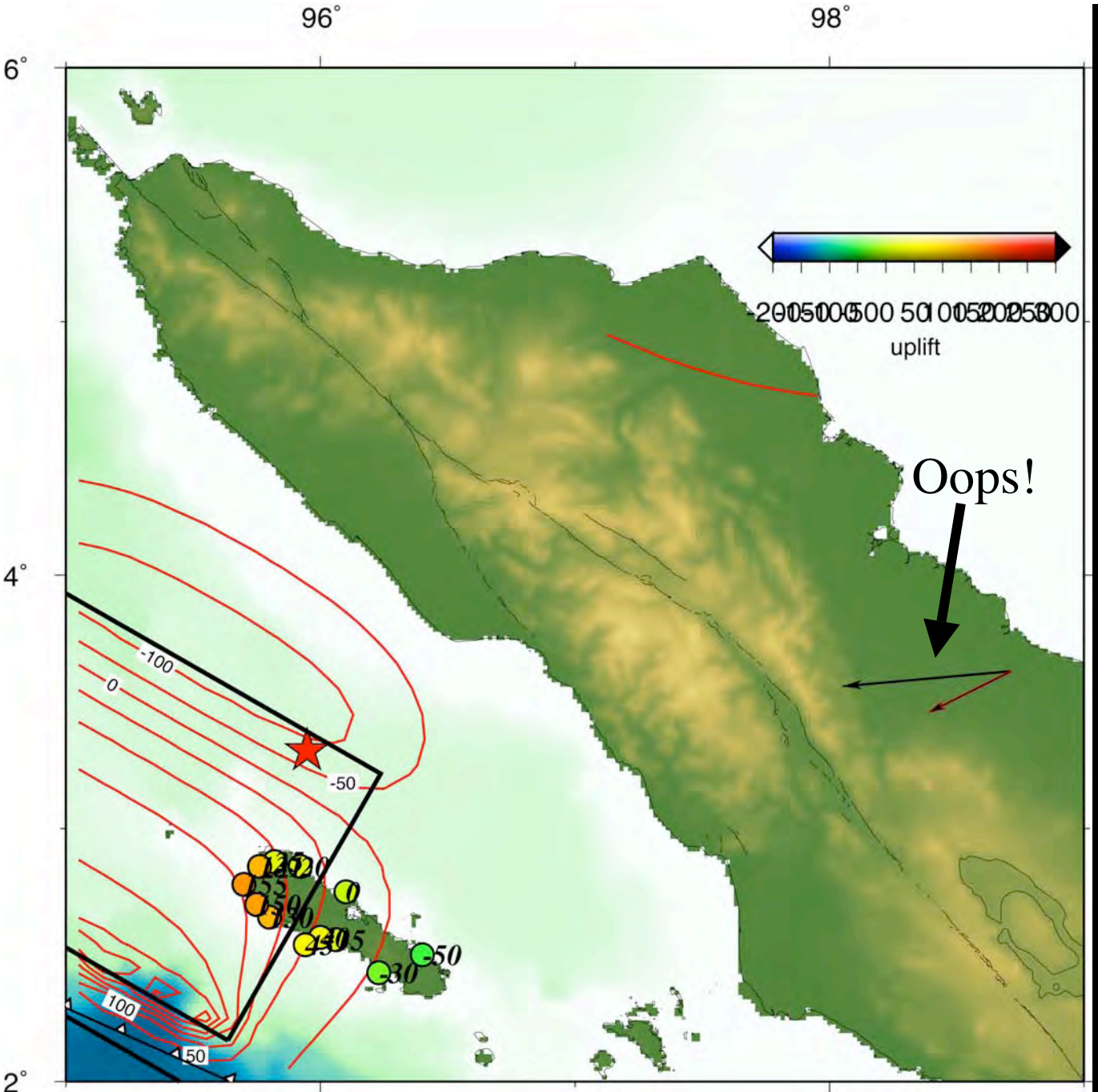

155 cm


Submergence before the uplift
There must be an interesting story in here!!


26 Dec 2004
M 9.0
~50
<0
20
25
131
155
150
130
98
43
45
13
>30



From Danny Natawidjaja's Ph.D. thesis,
Tectonic Observatory, Caltech, 2003

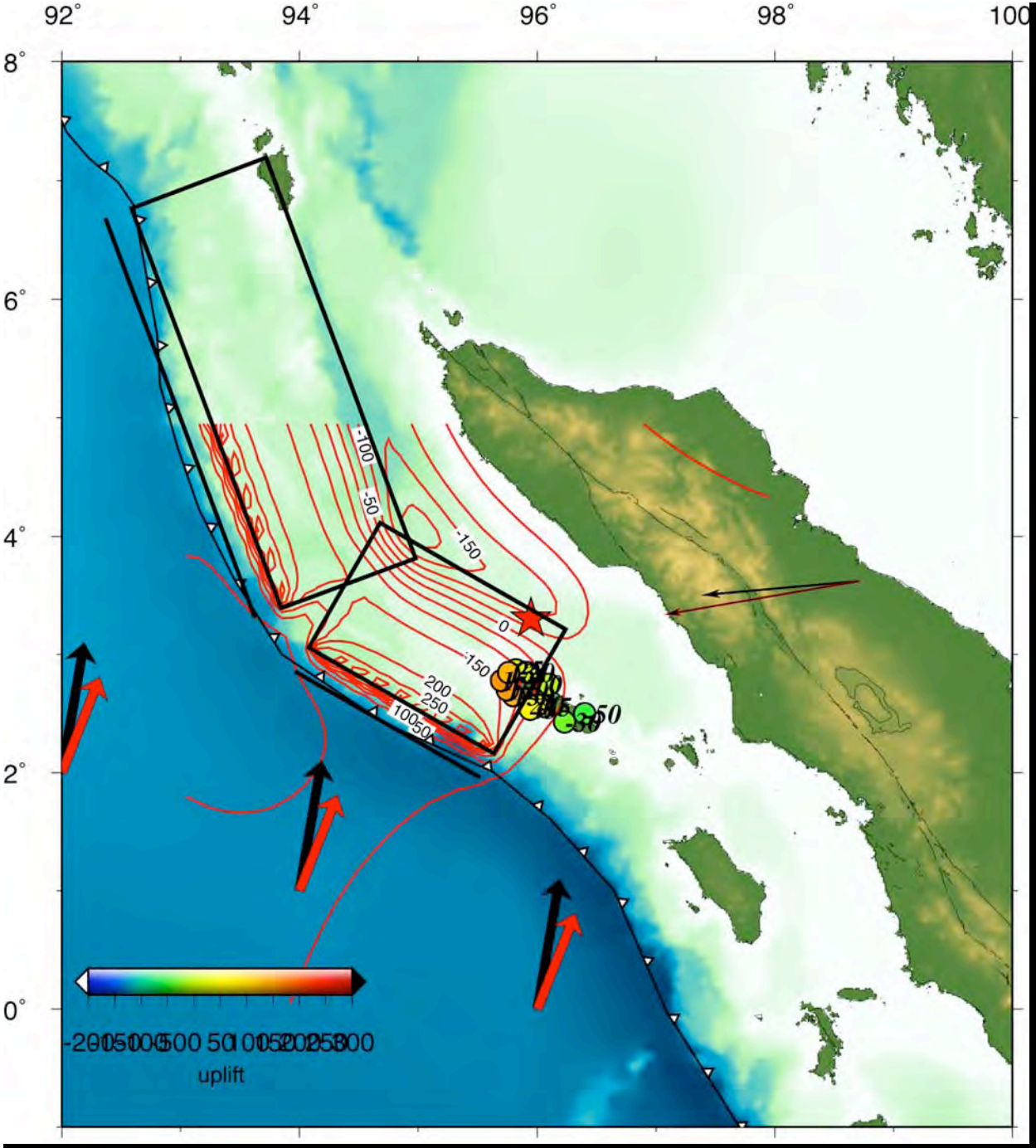


8 meters

15˚ dip

Trench to 43 km depth

First attempt to model the uplift, Mohamed Chlieh, Tectonics Observatory, Caltech

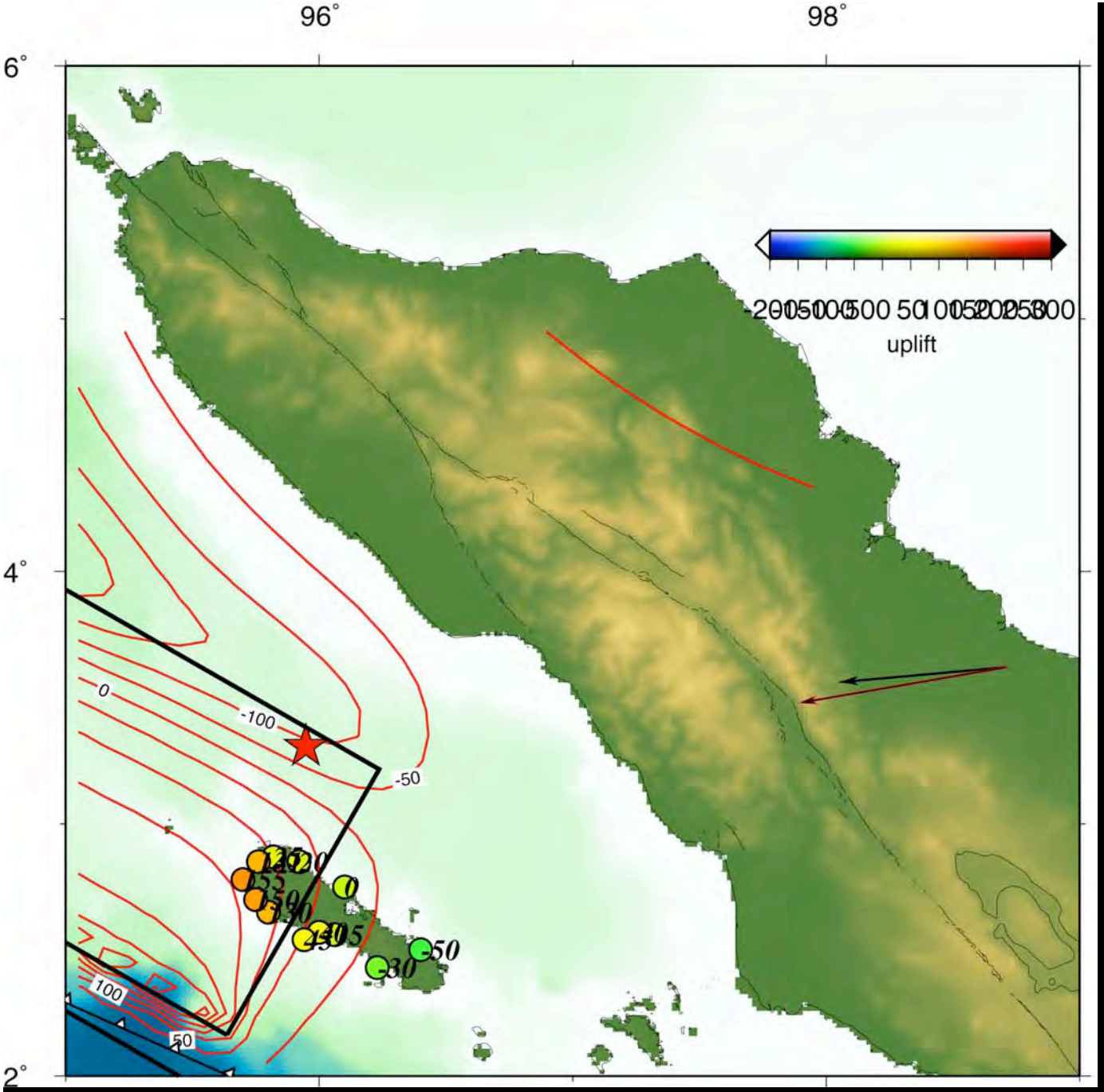


8 meters

15˚ dip

Trench to 43 km depth

2 segments

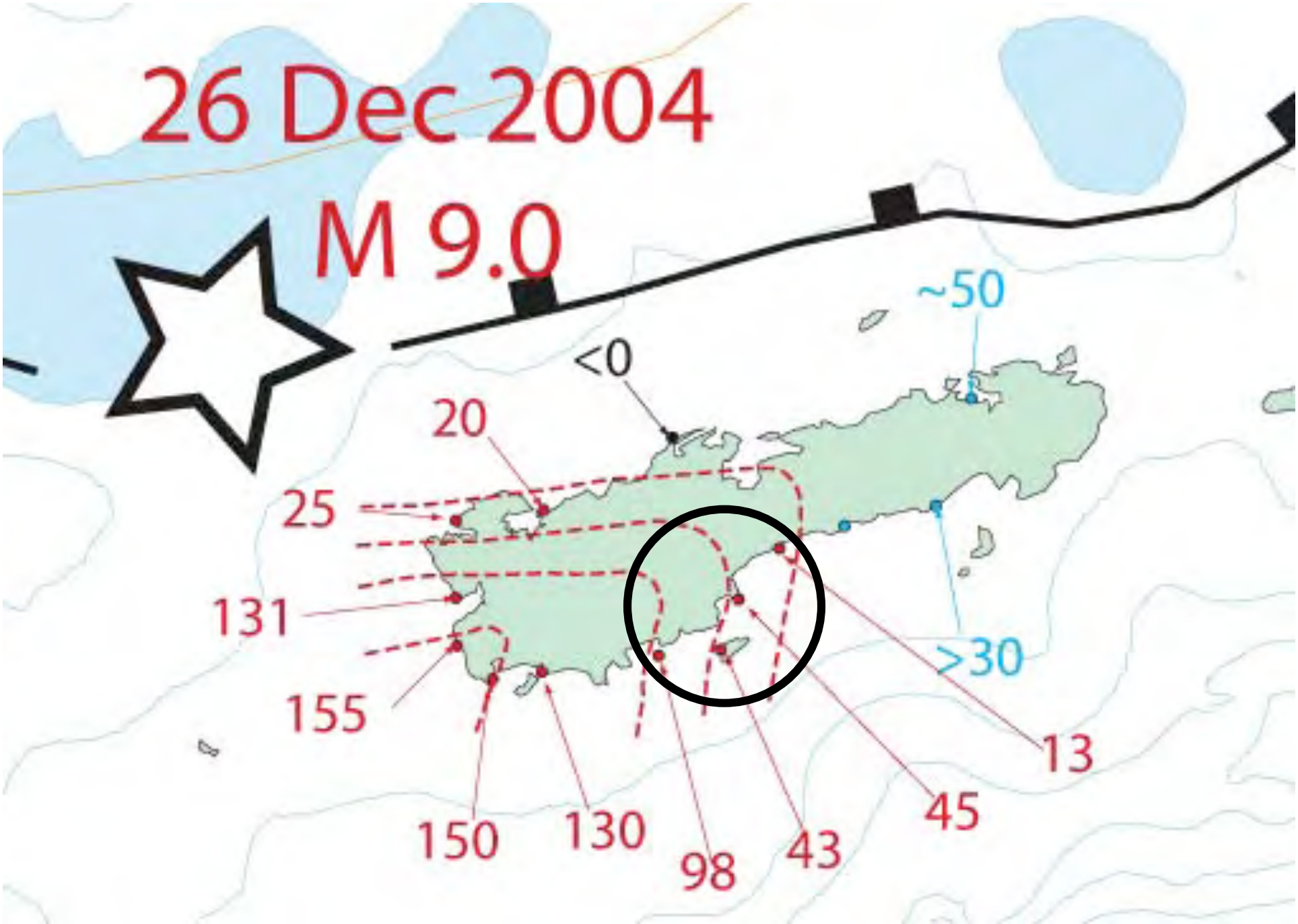


8 meters

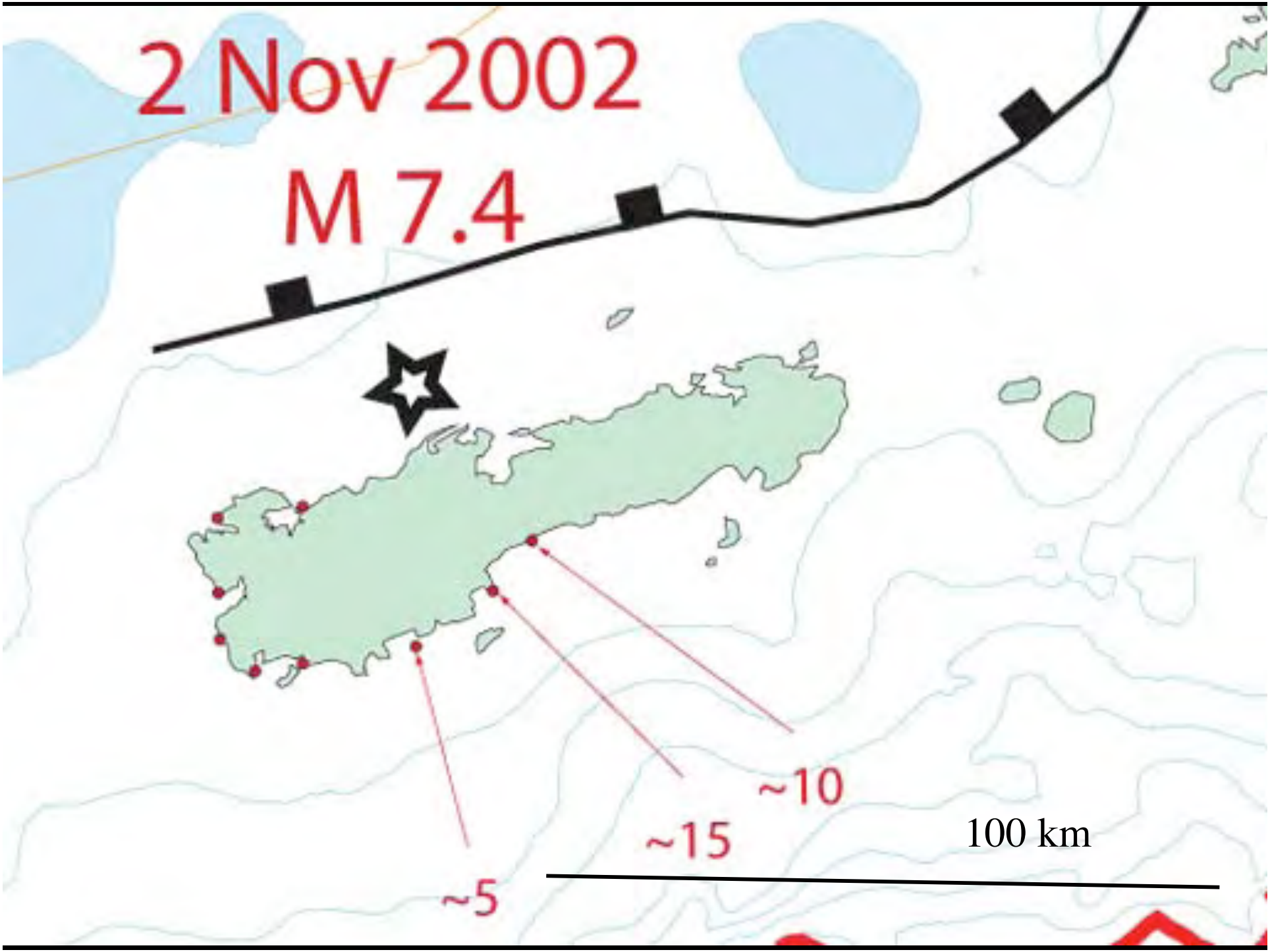
15˚ dip

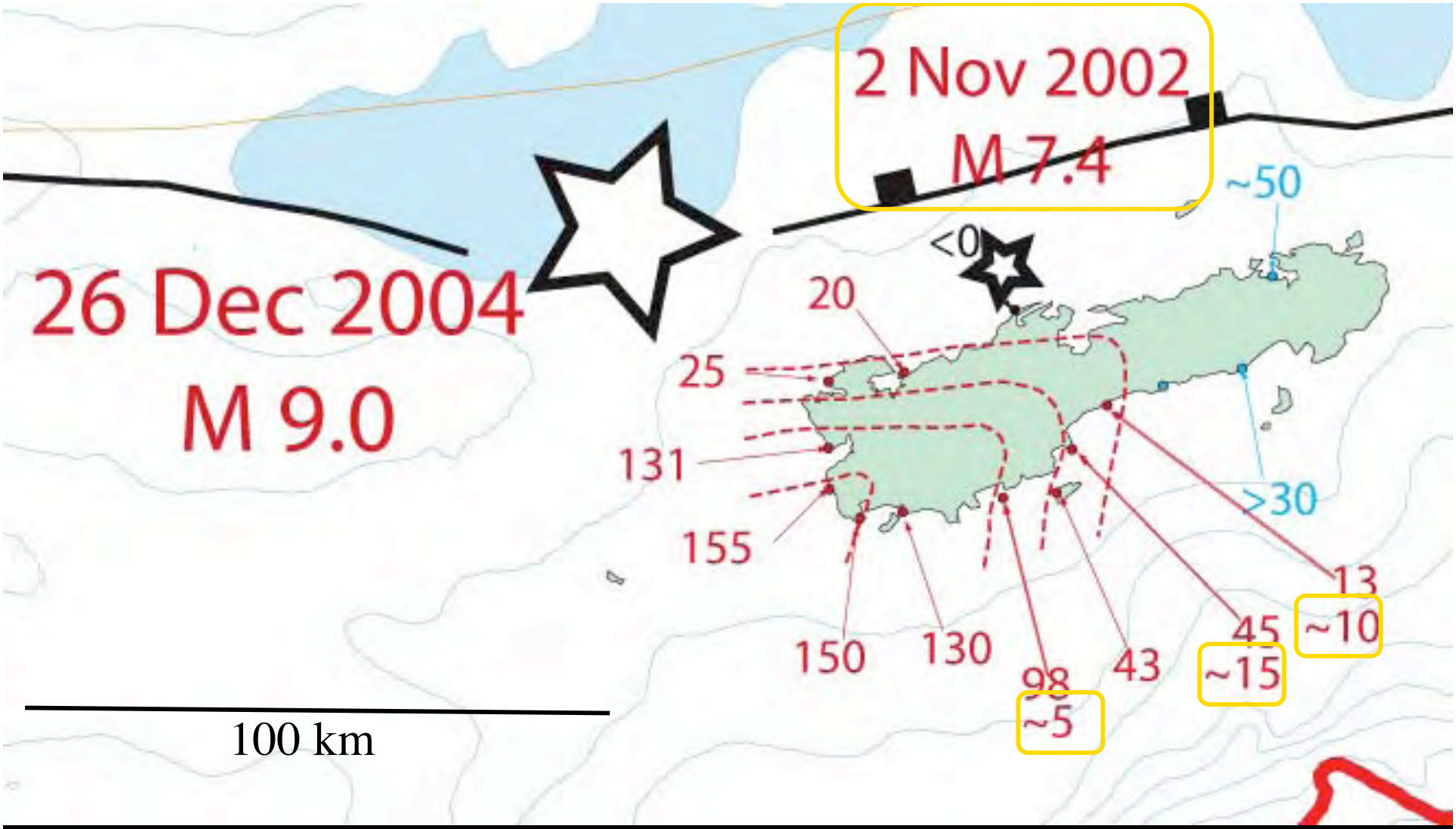
Trench to 43 km depth

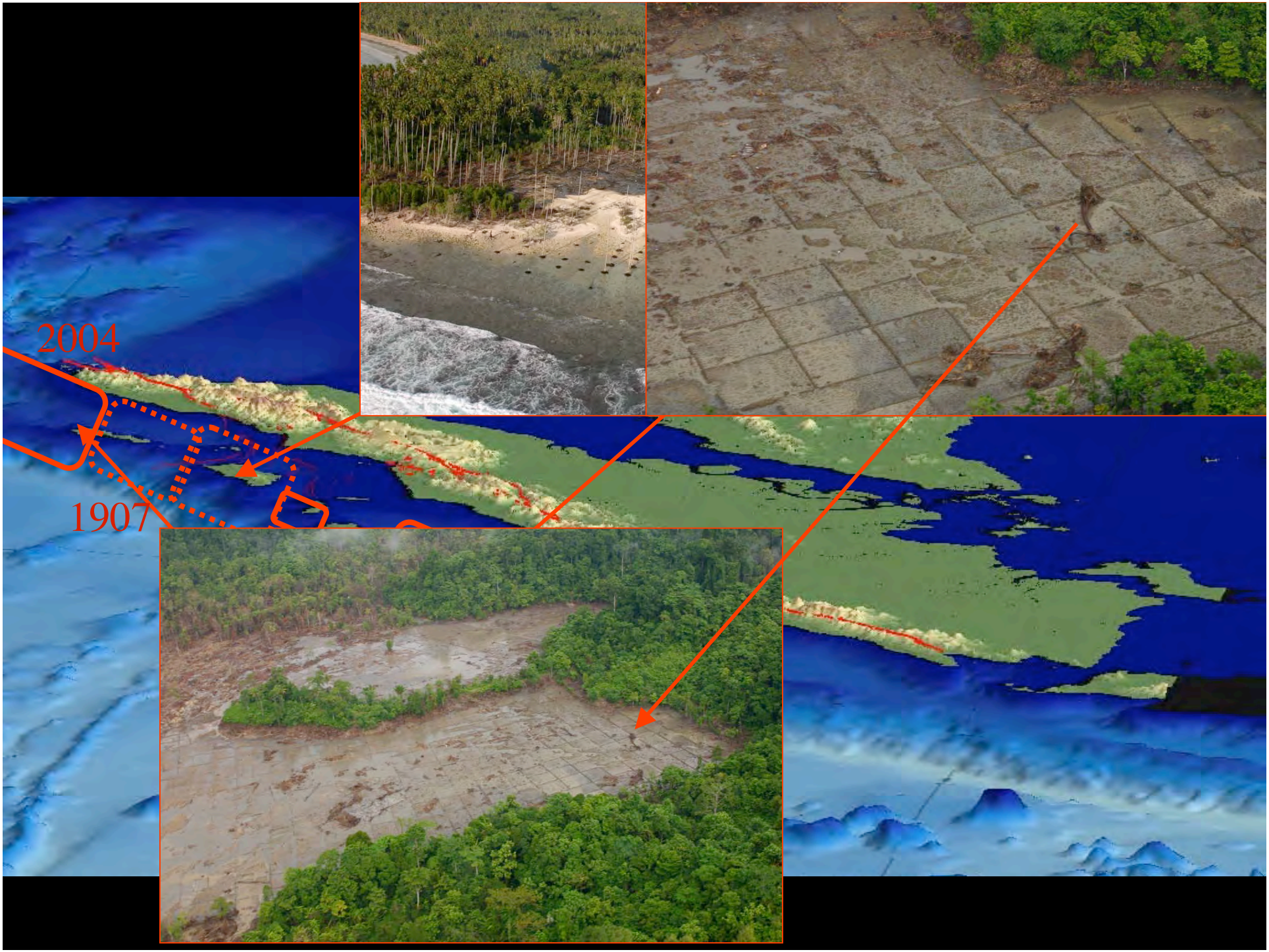
2 segments

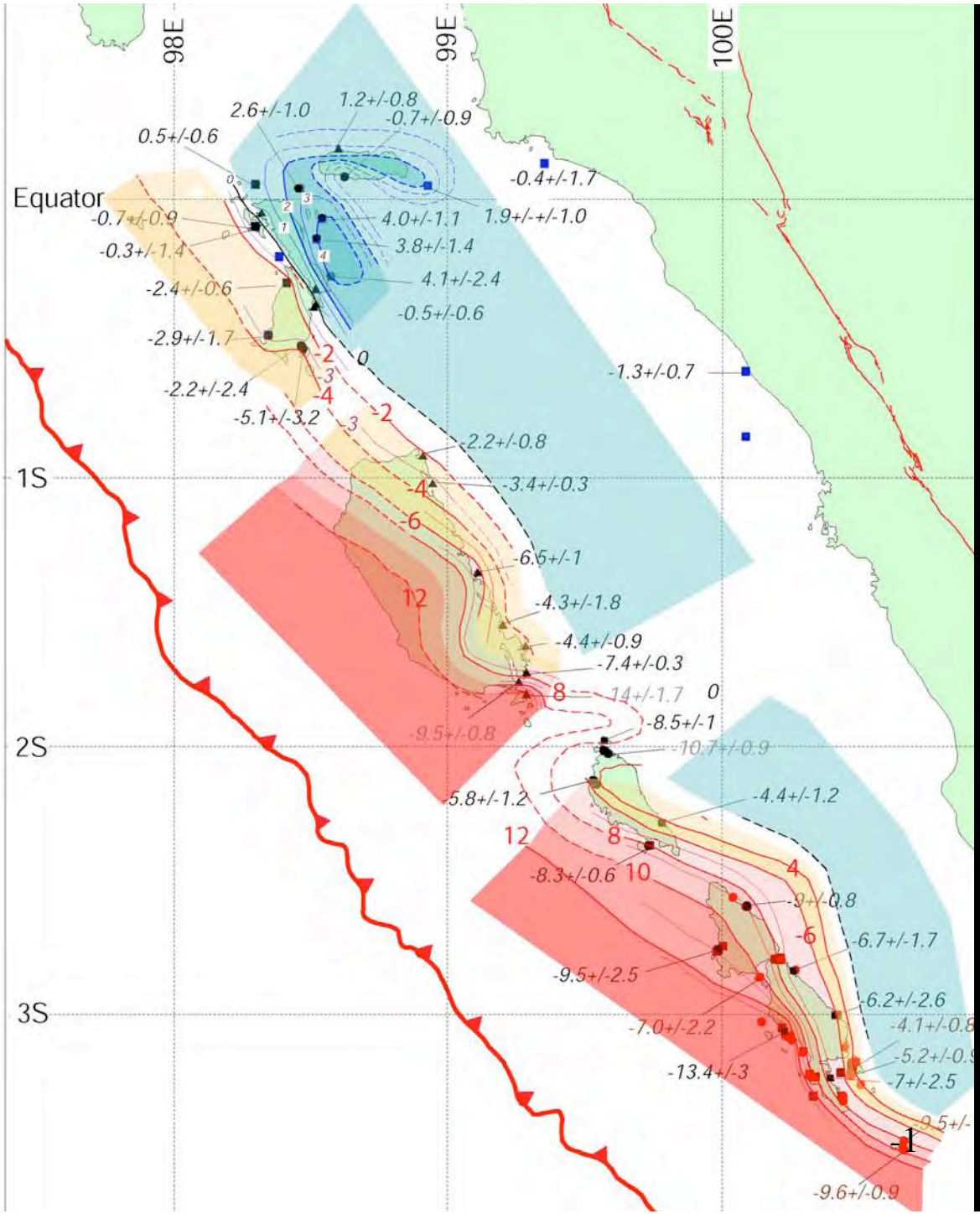

26 Dec 2004
M 9.0
~50
<0
20
25
131
155
150
130
98
43
45
13
>30


98 cm, 2004
5 cm, 2002

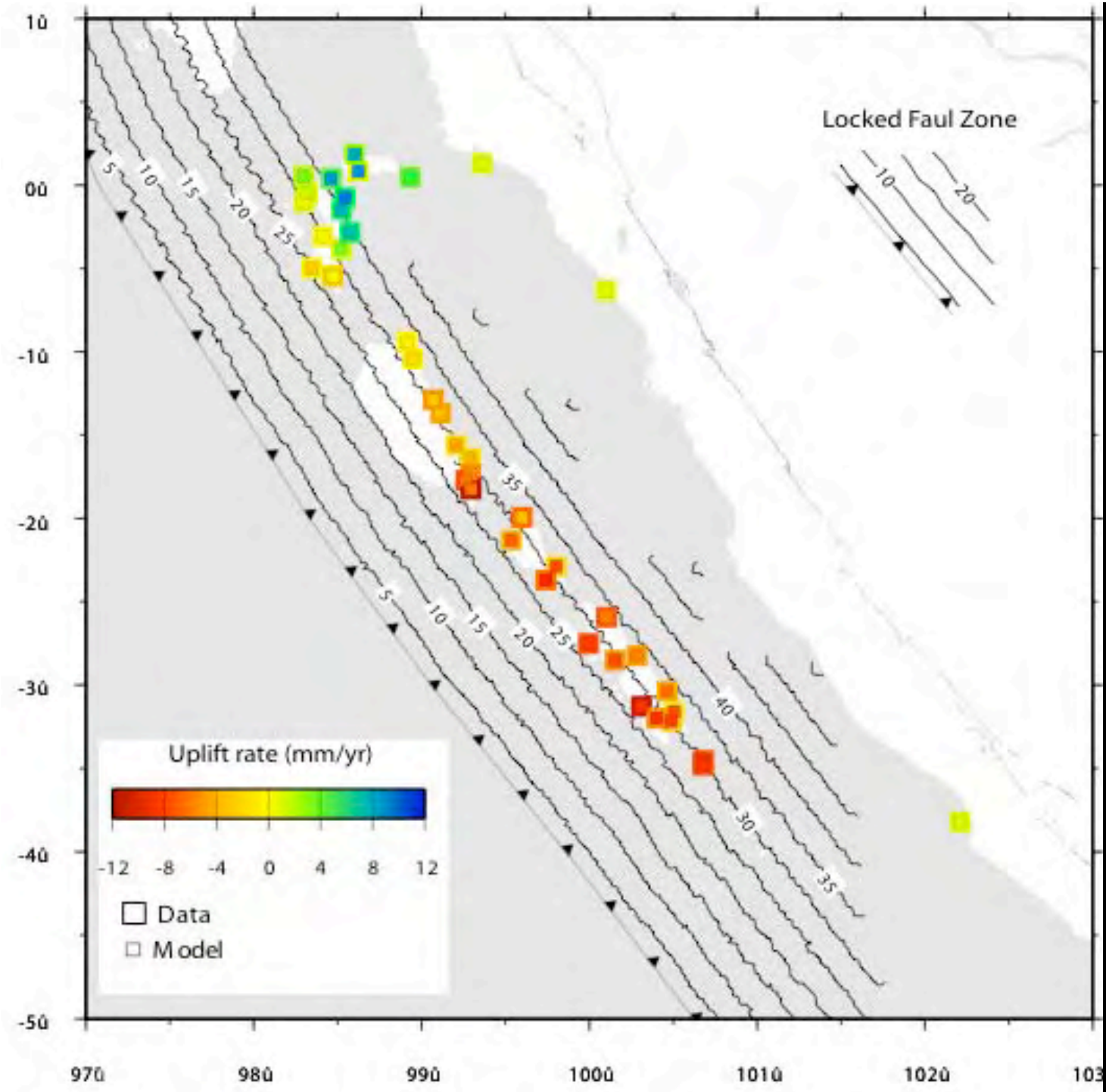

2 Nov 2002
M 7.4
~10
~15
~5
100 km


2 Nov 2002
M 7.4
26 Dec 2004
M 9.0
~50
<0
20
25
131
155
150
130
98
~5
43
45
~15
13
~10
>30
100 km


2004
1907



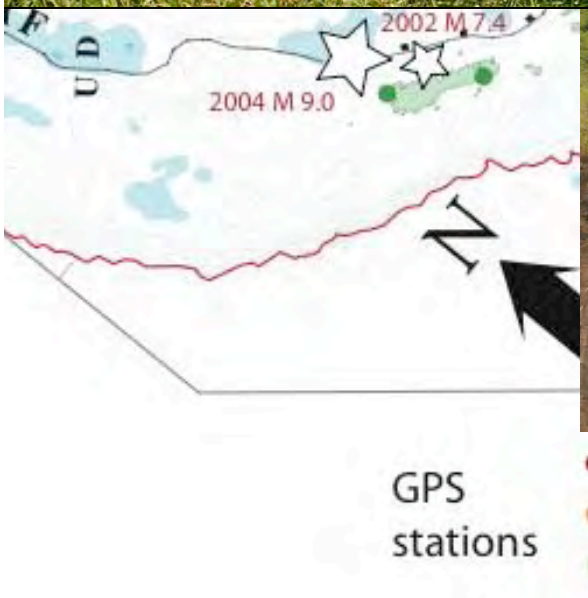
Submergence rates of the past 50 years …

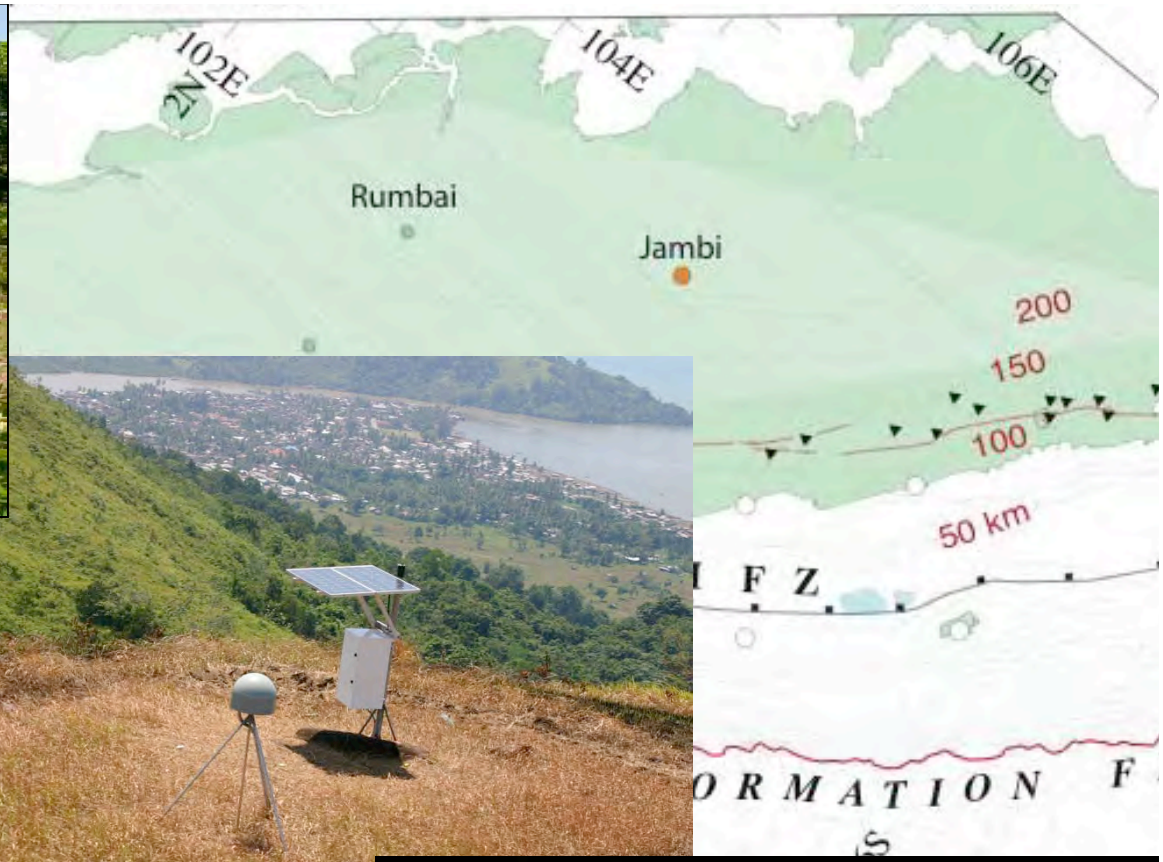


… suggest that the depth of locking of the subduction interface varies along strike

The wider the patch, the bigger the potential earthquake?

From Mohamed Chlieh, TO, Caltech

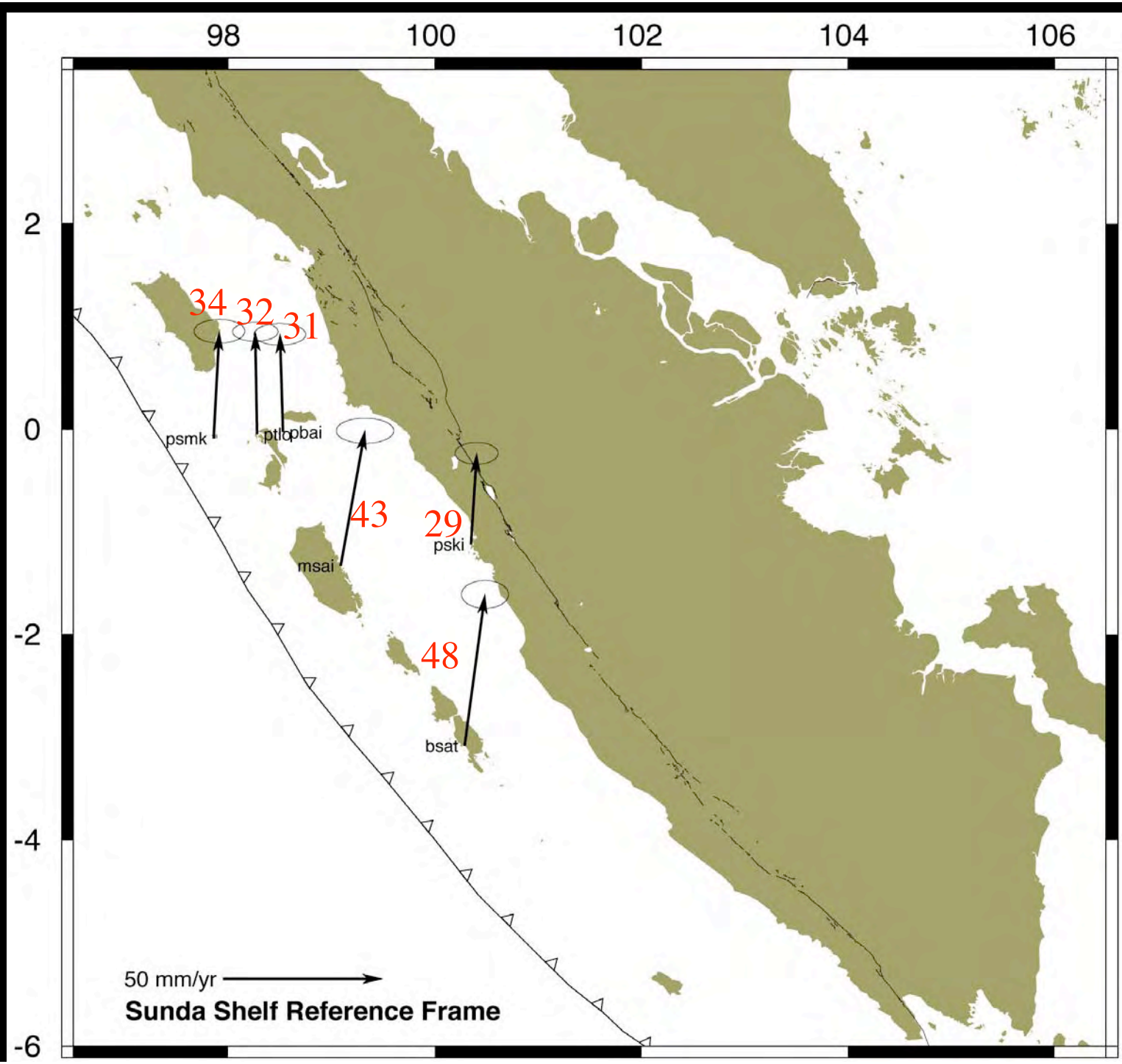


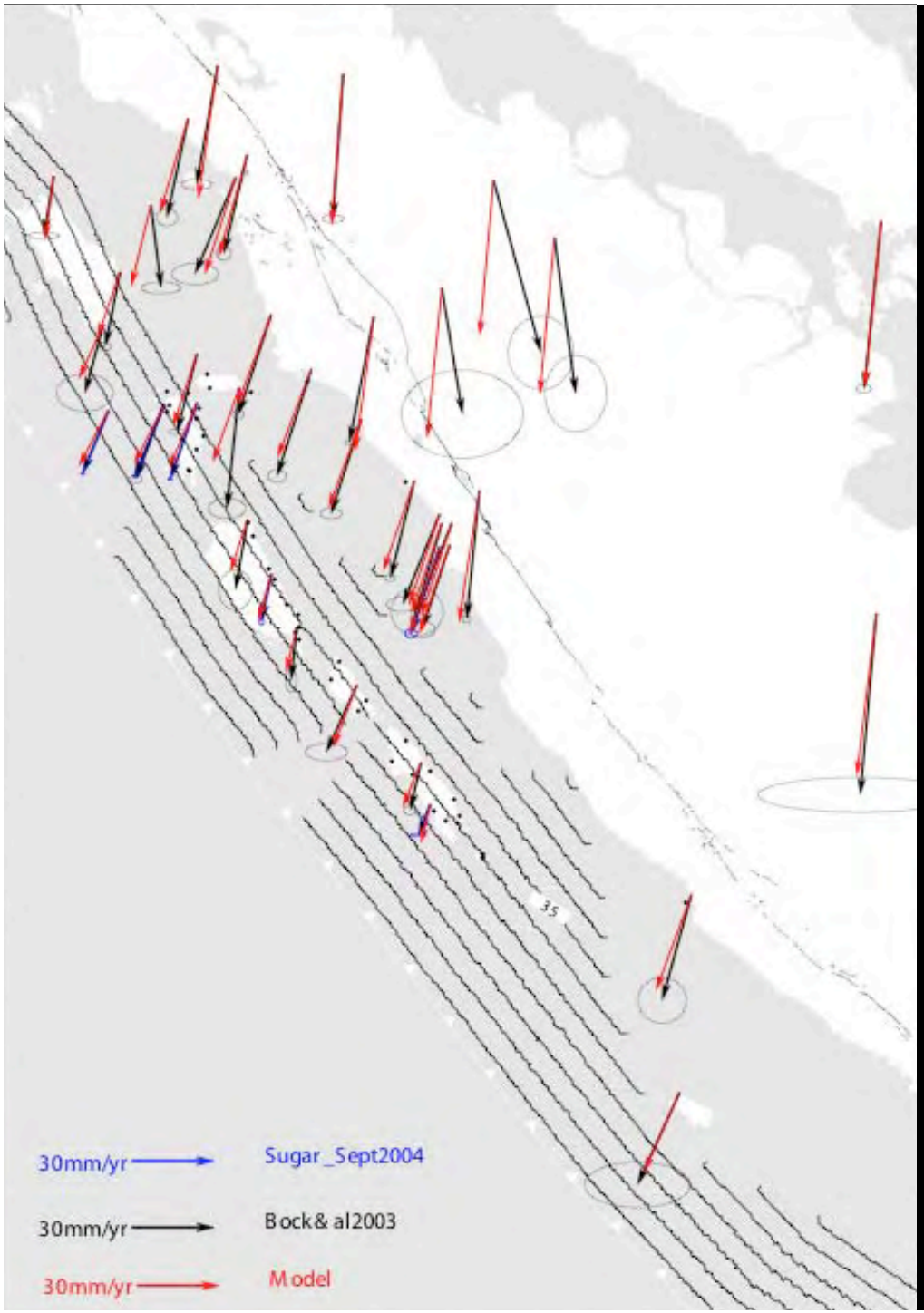


GPS stations

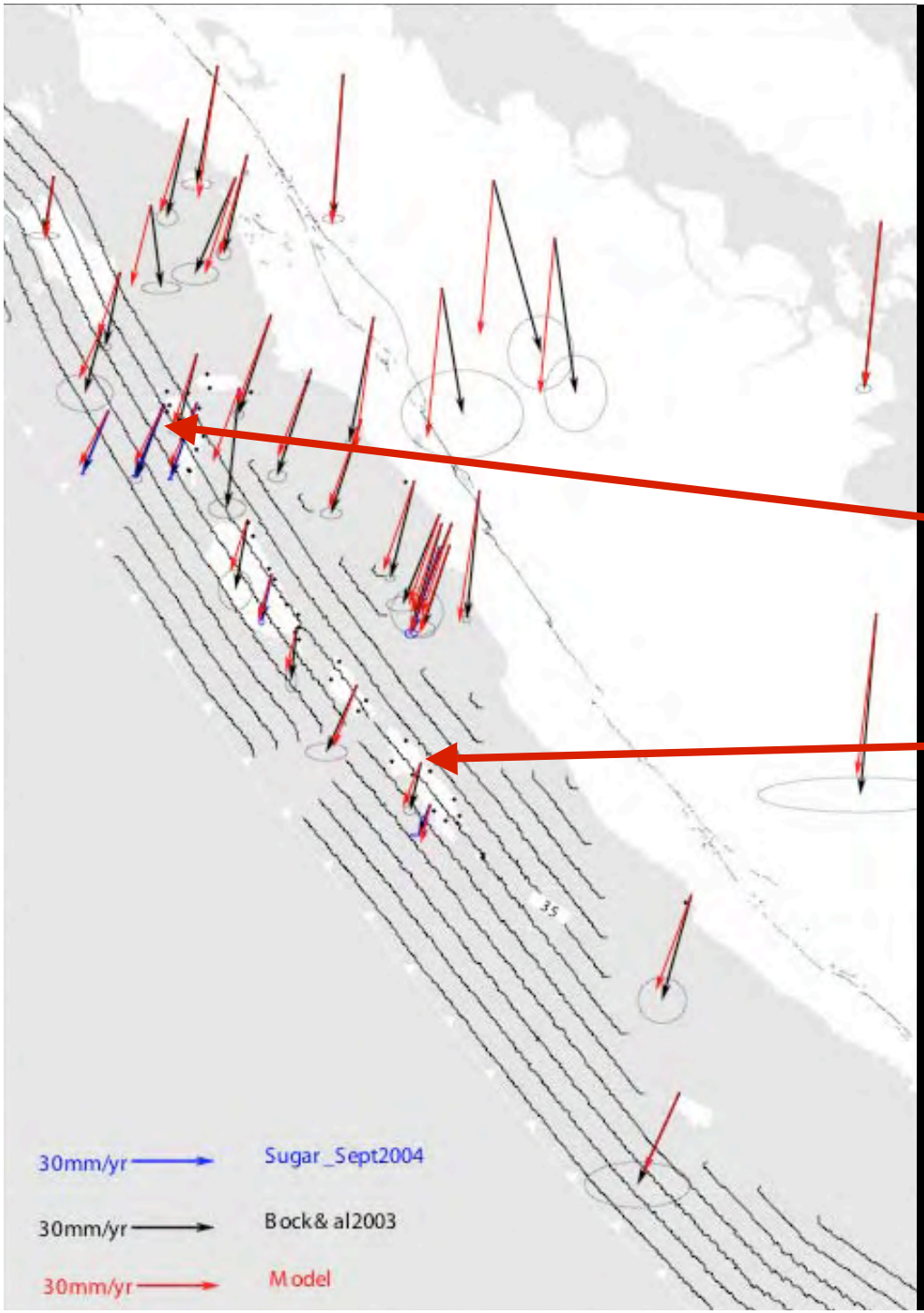
- 6 installed Sept 2002
- 8 installed Aug 2004
- 4 installed Feb 2005

To improve our measurements of deformation, we began installing the Sumatran GPS Array (SuGAr) in 2002


98
100
102
104
106
2
0
-2
-4
-6
34
32
31
psmk
ptlo
pbai
43
msai
29
pski
48
bsat
50 mm/yr
Sunda Shelf Reference Frame



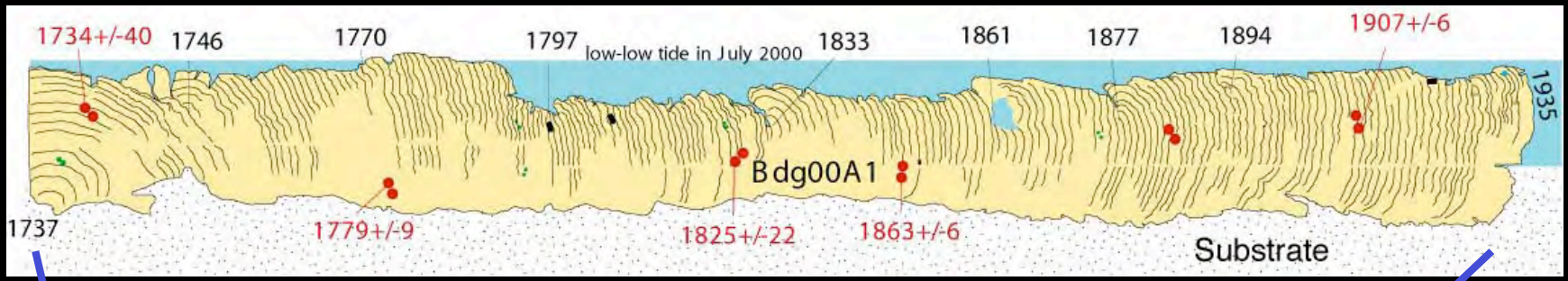
Modeling of campaign and continuous GPS velocity vectors also suggests that the depth of locking varies widely along strike

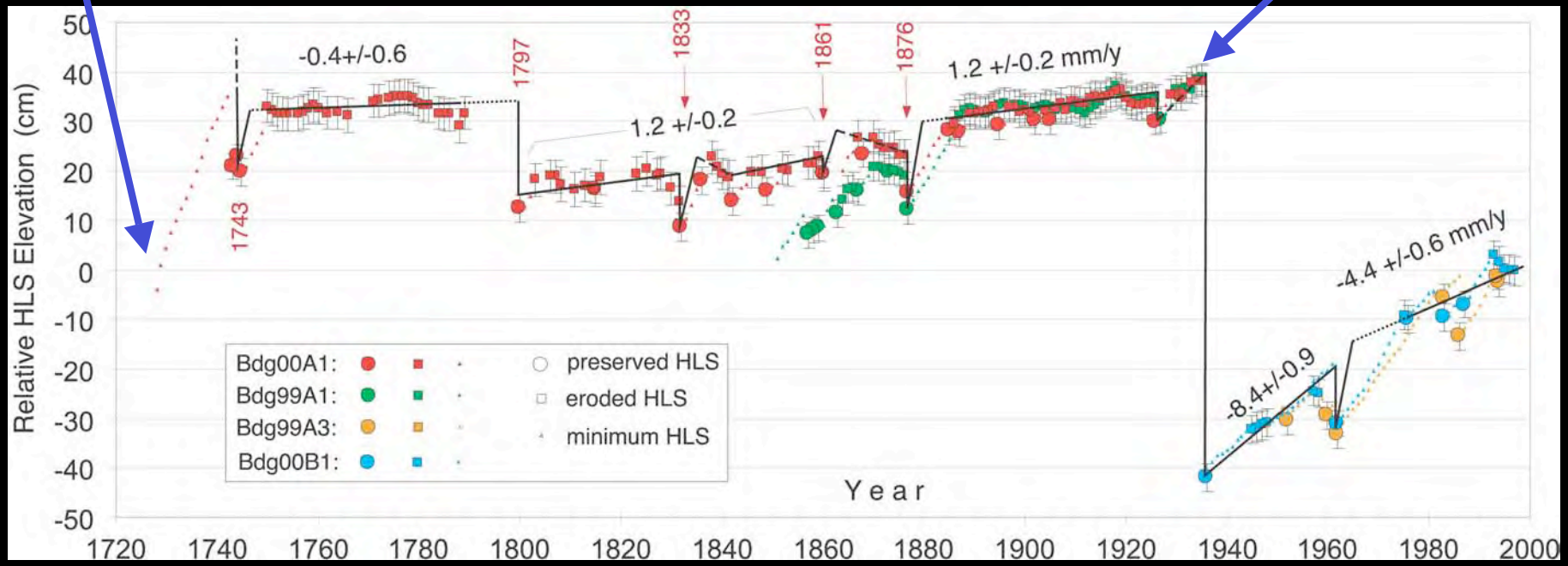


Let's take a look at the longer term.

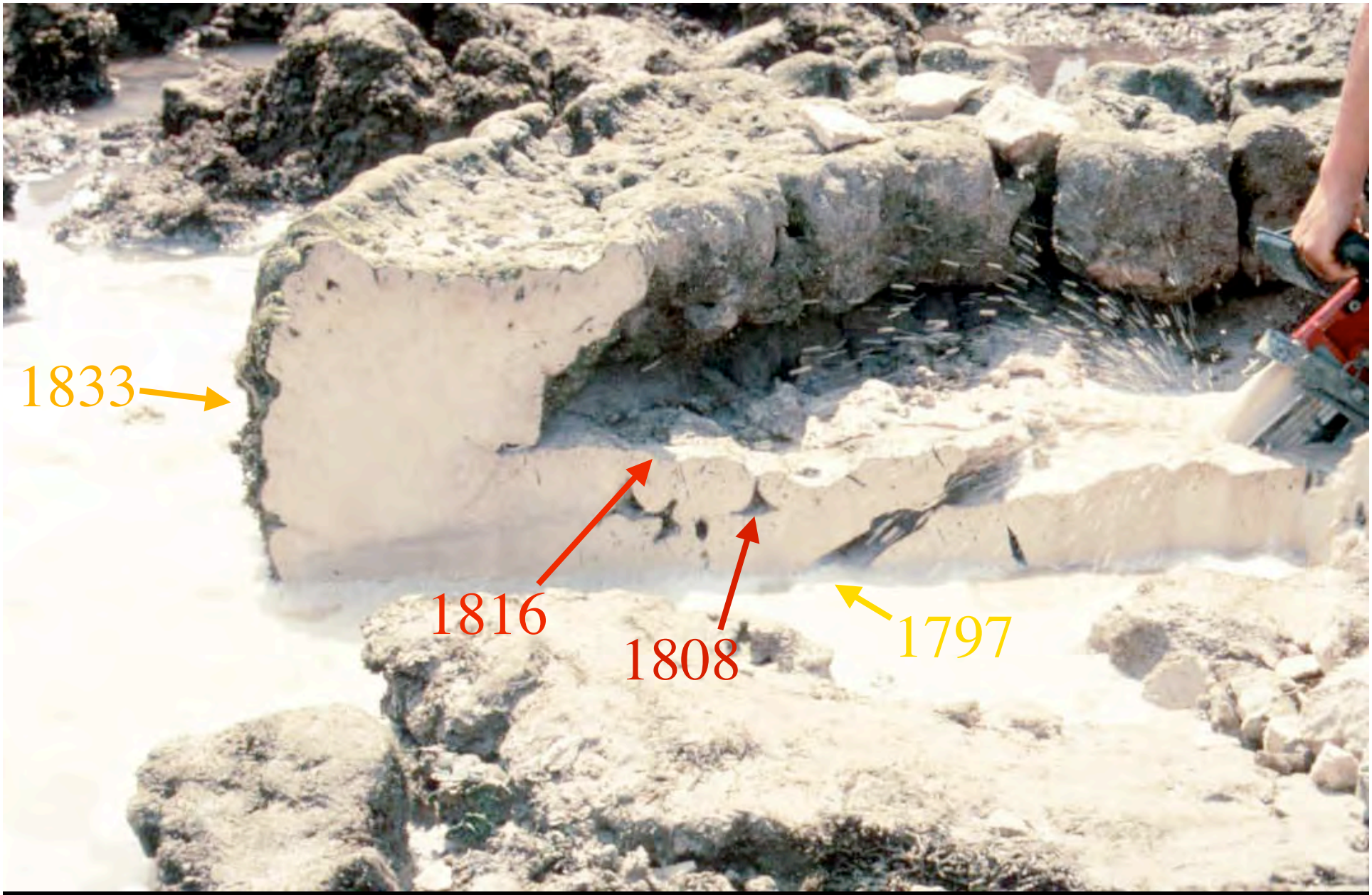
First here

Then here

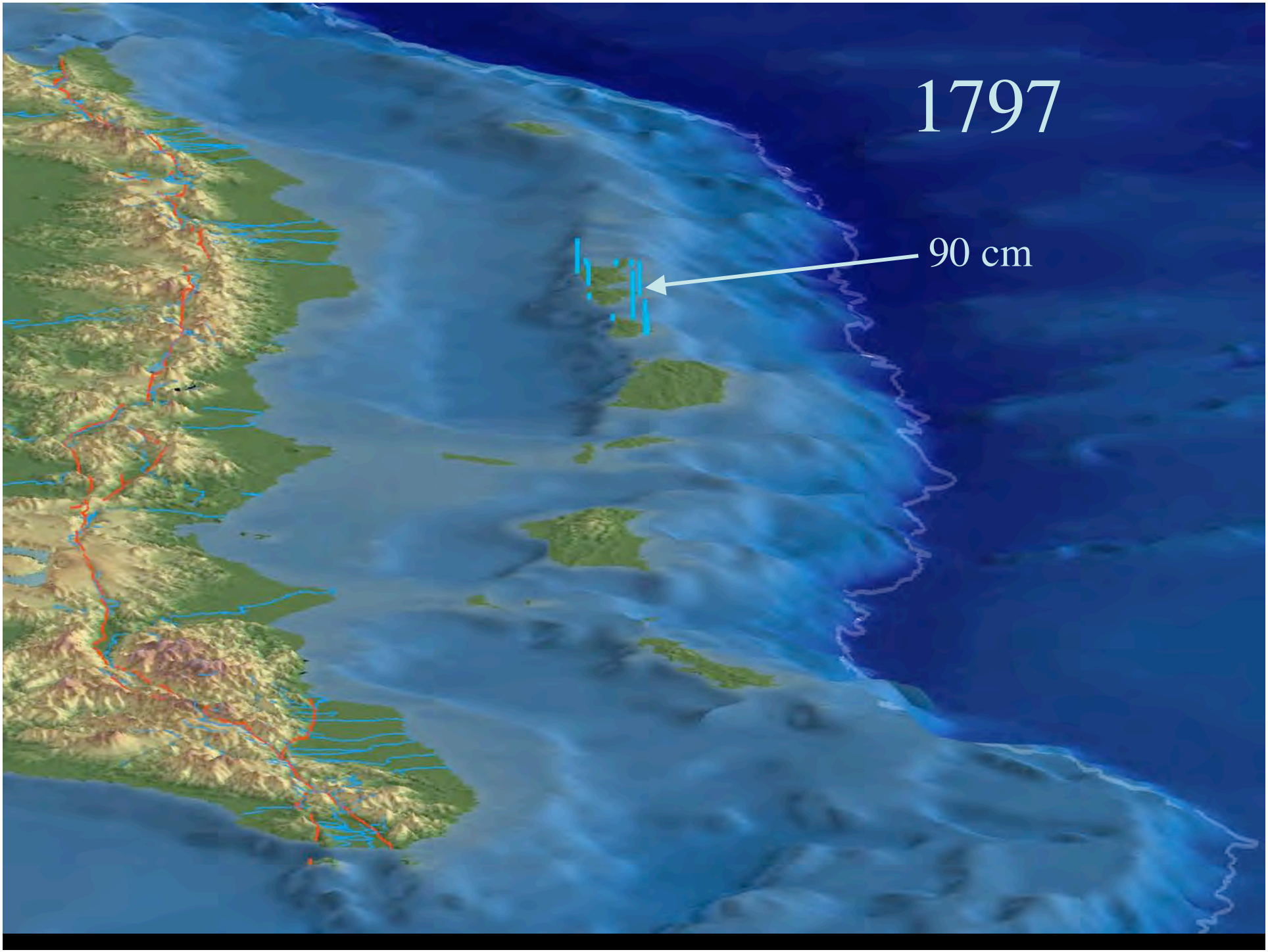




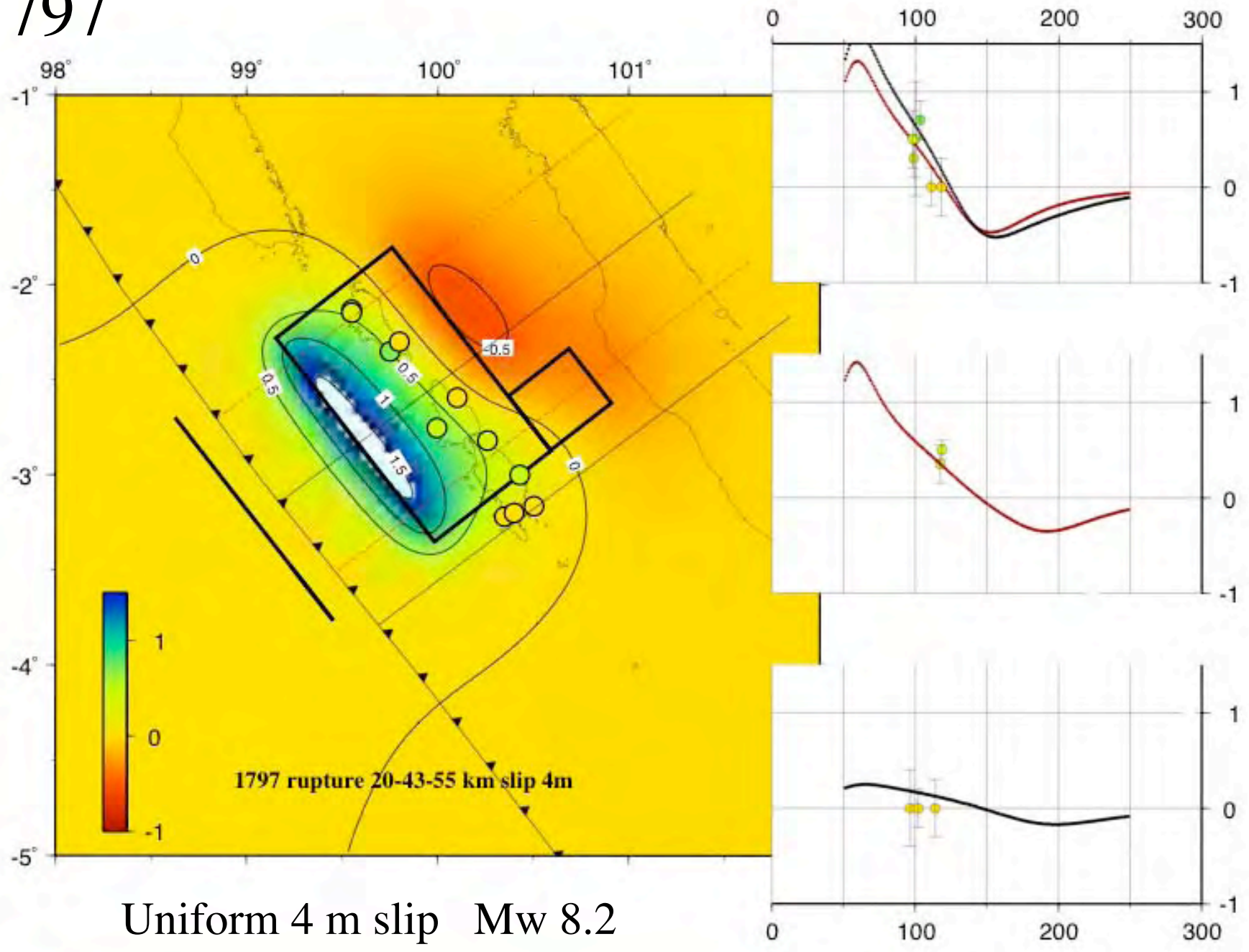
Paleogeodetic records near the Equator show very-long-term changes in vertical rates of deformation



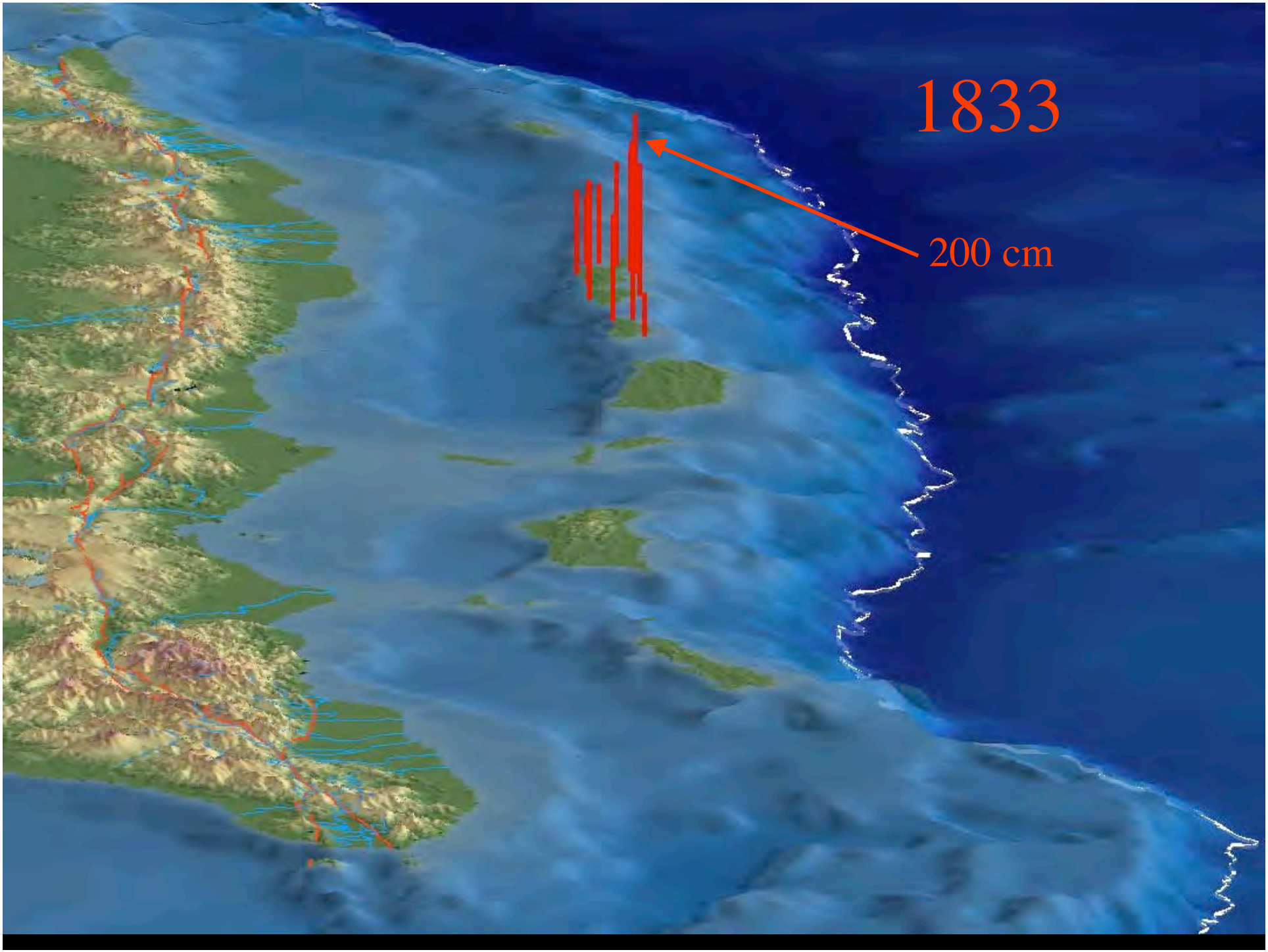
Two giant earthquakes and intermittent interseismic submergence

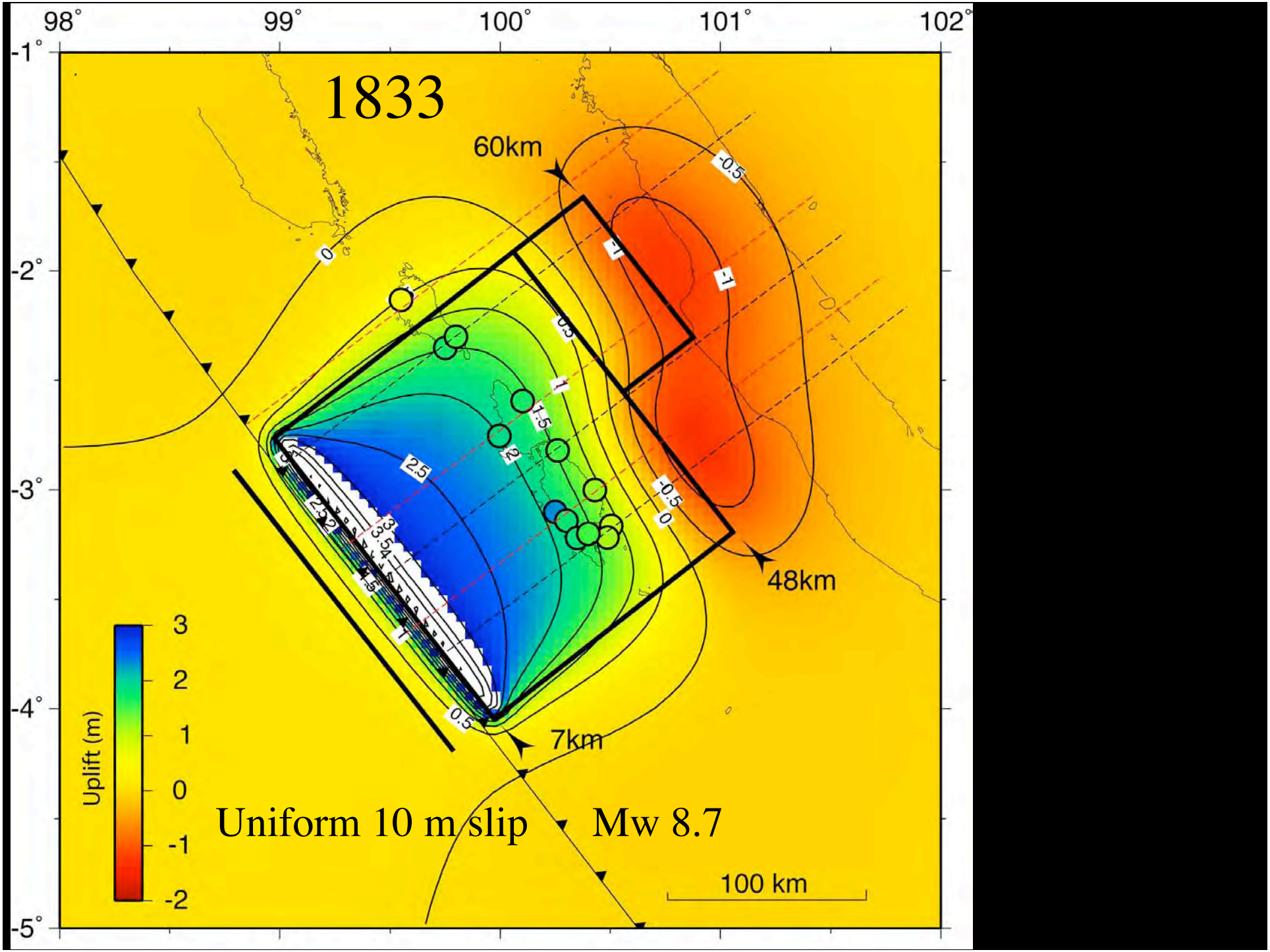

1797
90 cm

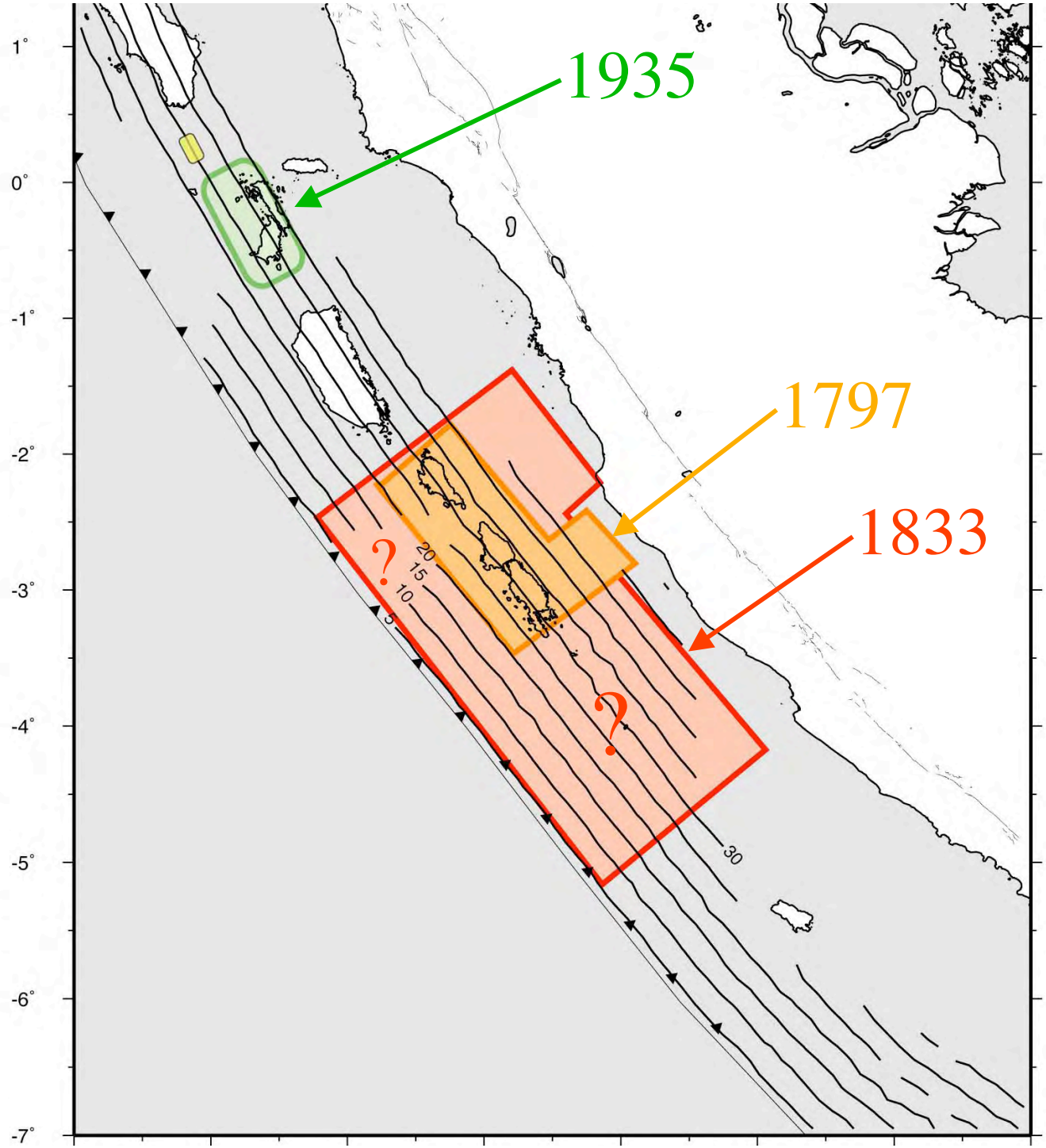
1797



Uniform 4 m slip Mw 8.2

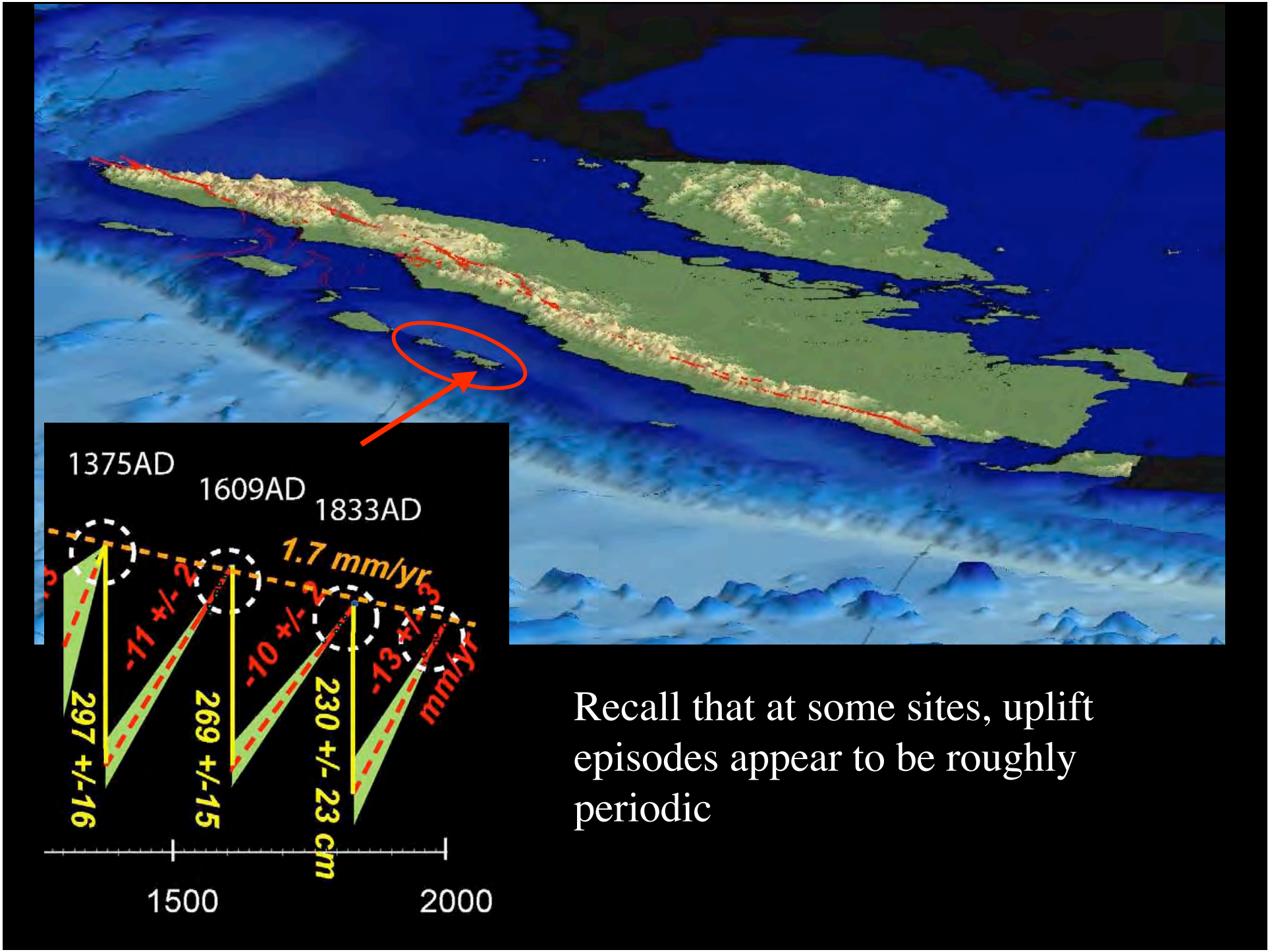

1833
200 cm


1833
60km
48km
7km
Uniform 10 m slip
Mw 8.7
100 km
Uplift (m)
3
2
1
0
-1
-2
98°
99°
100°
101°
102°
-1°
-2°
-3°
-4°
-5°



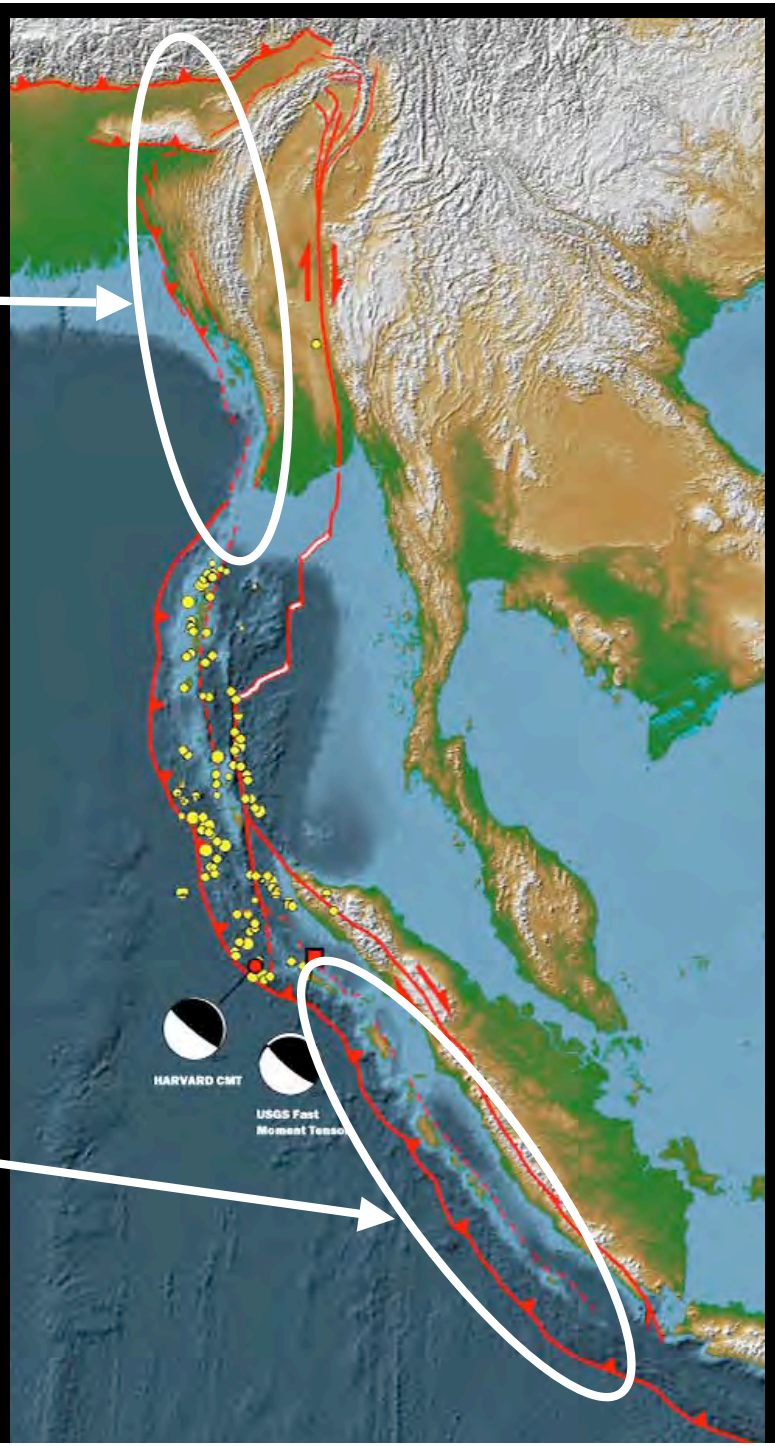
Smaller earthquakes, thinner locked patches.

Giant earthquake, thicker locked patches.

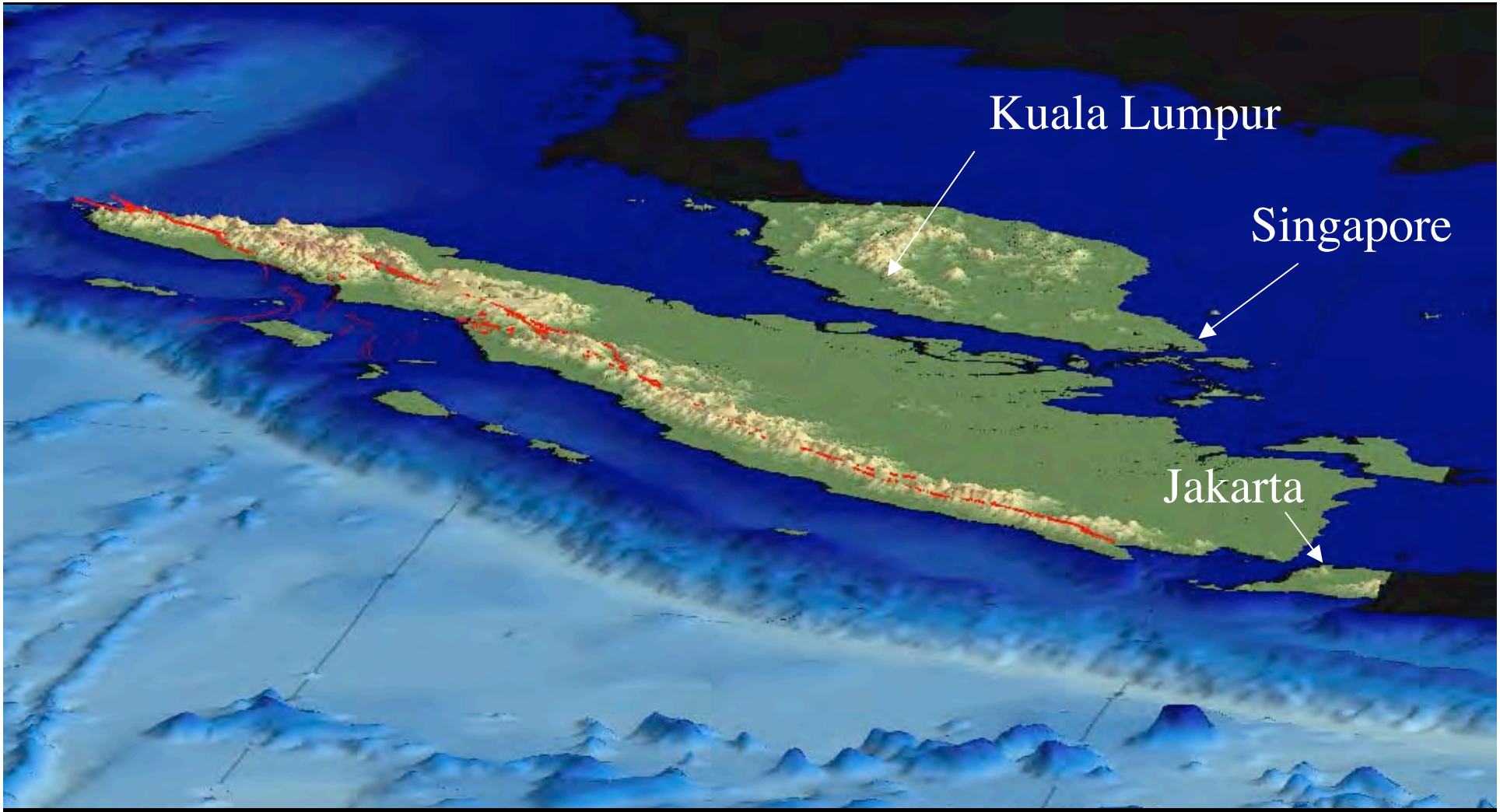


Recall that at some sites, uplift episodes appear to be roughly periodic

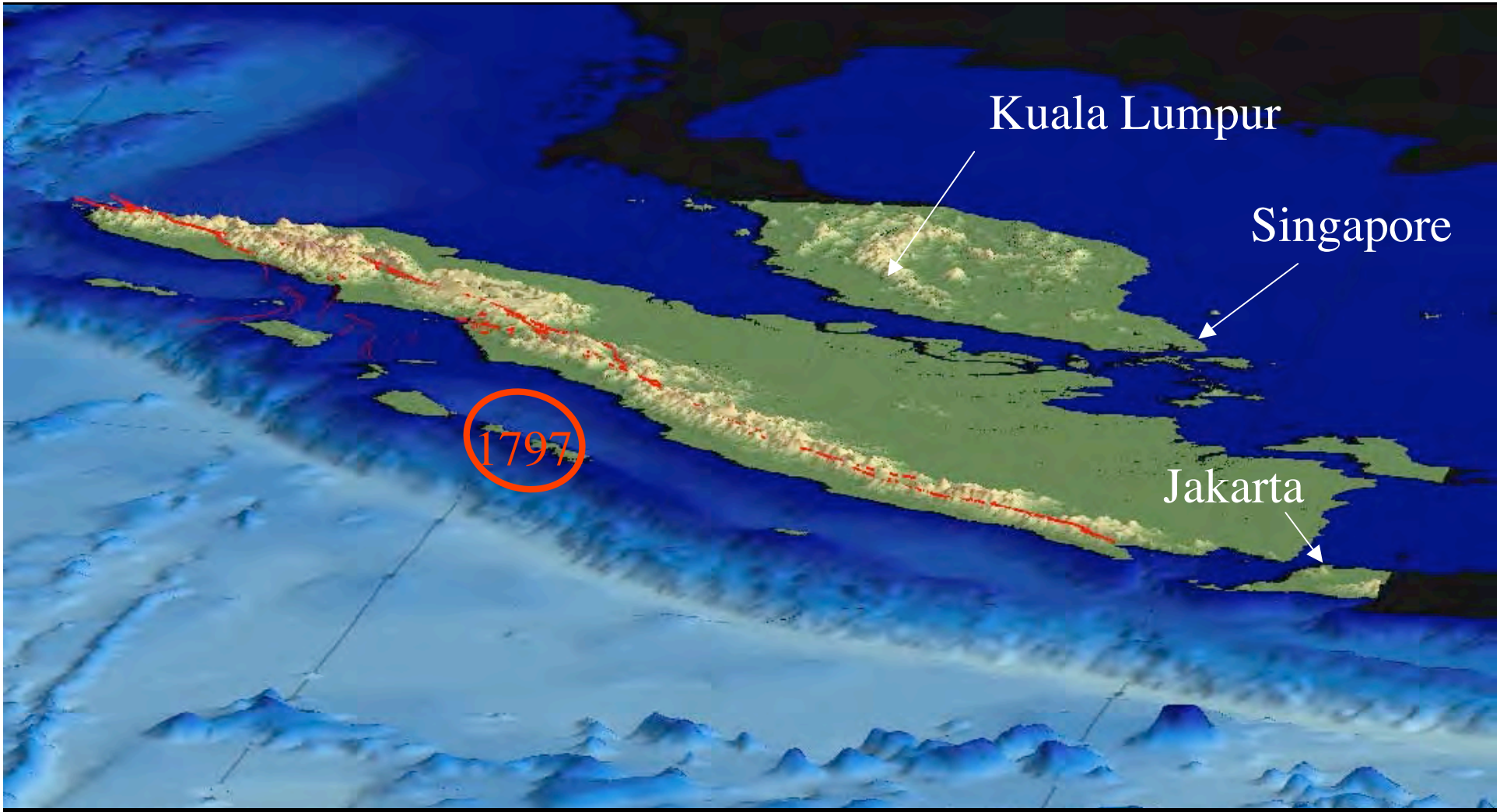
An Indo-burman source(s)



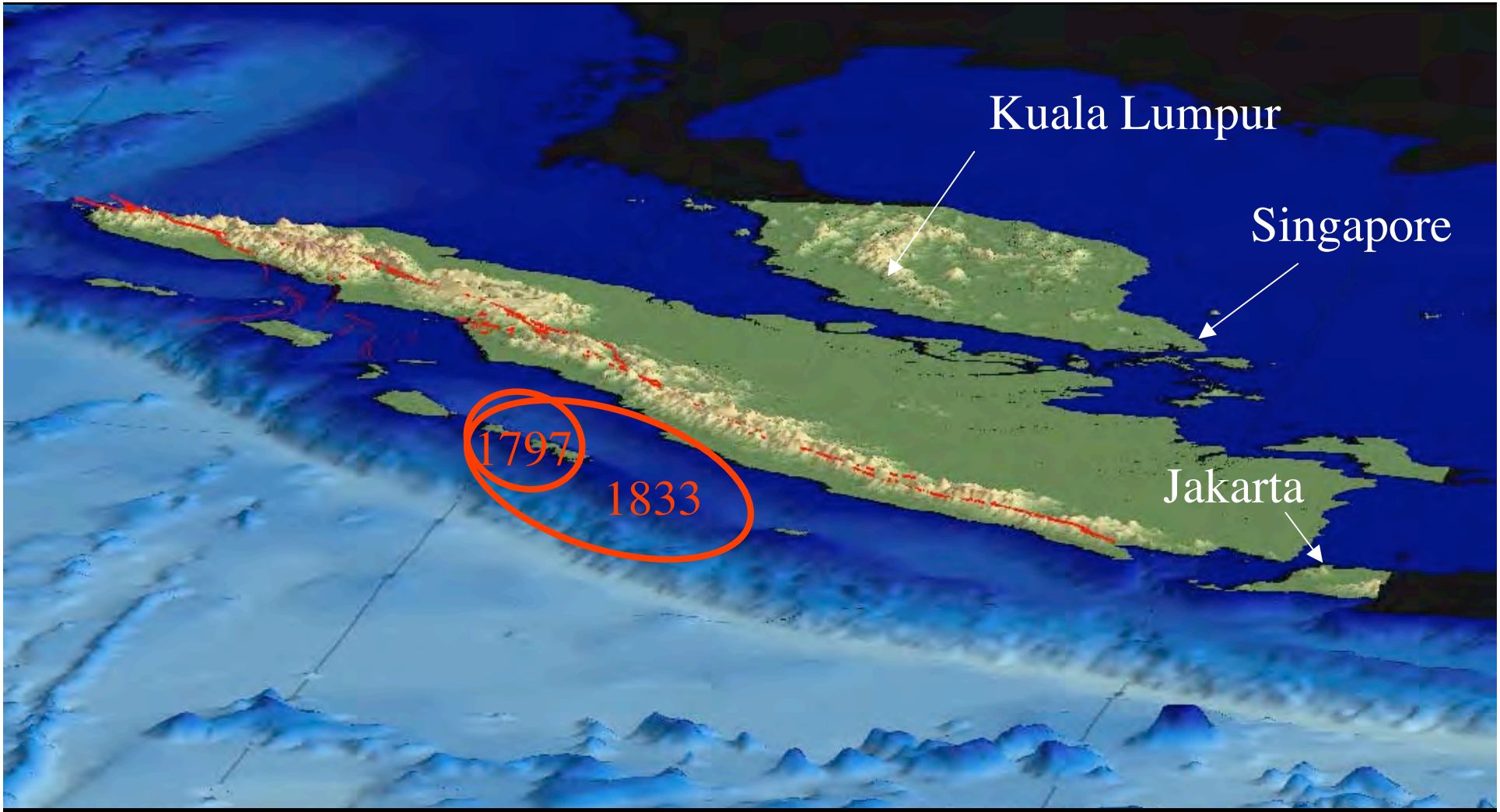
west Sumatran sources



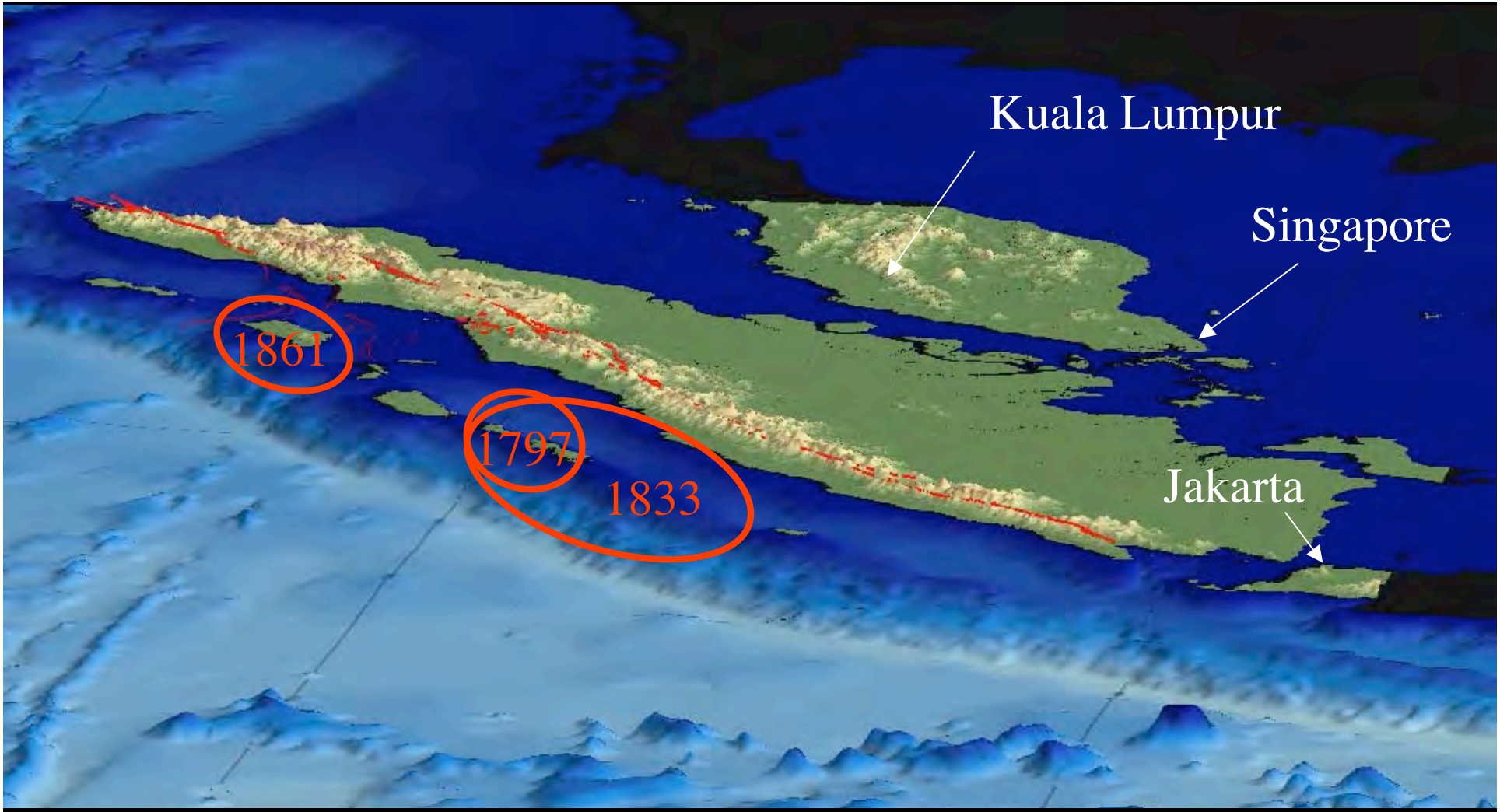
The past record of large megathrust events in North and West Sumatra suggests the next events are not too far off



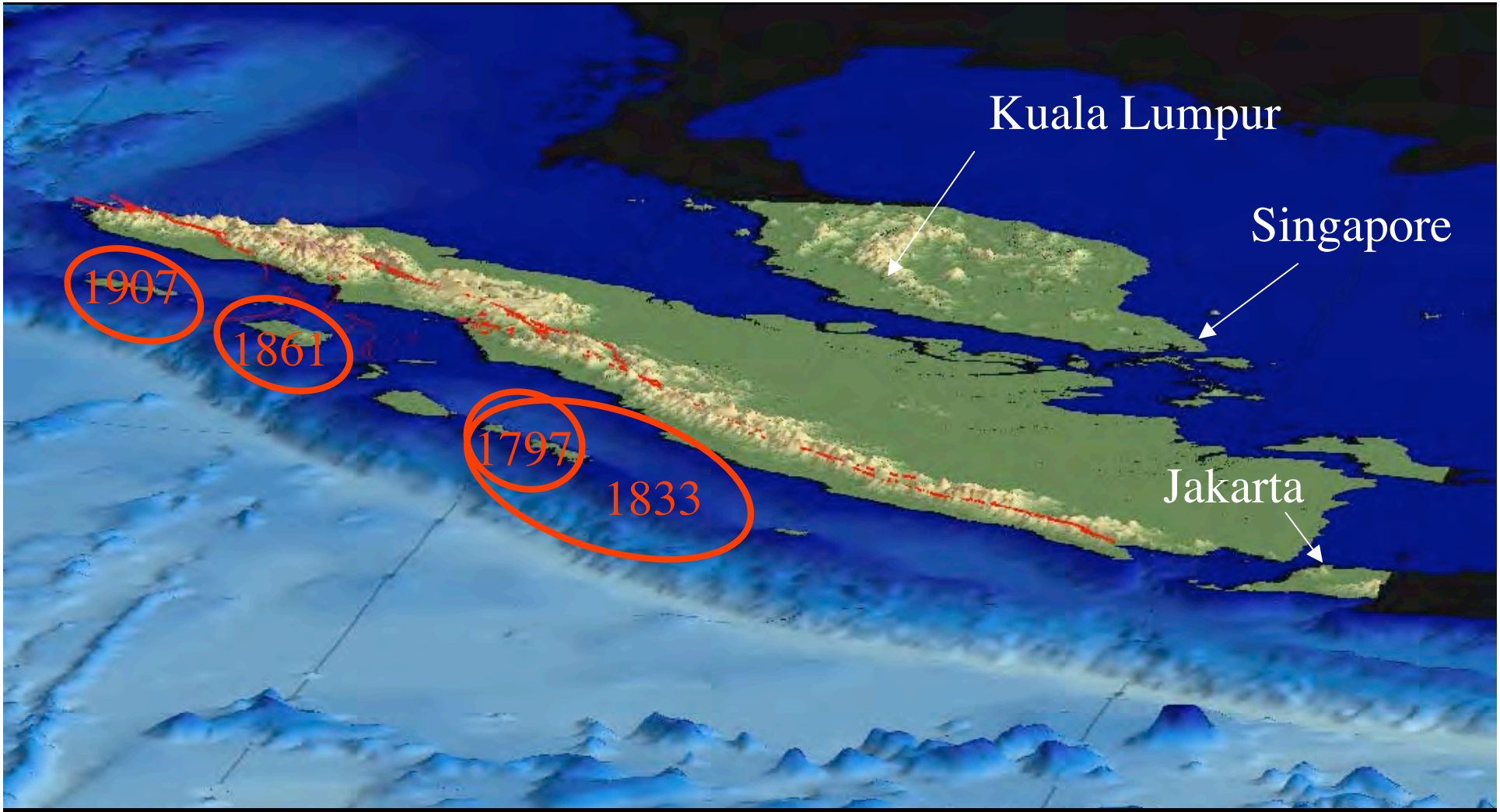
Most of the megathrust failed between 1797 and 1907



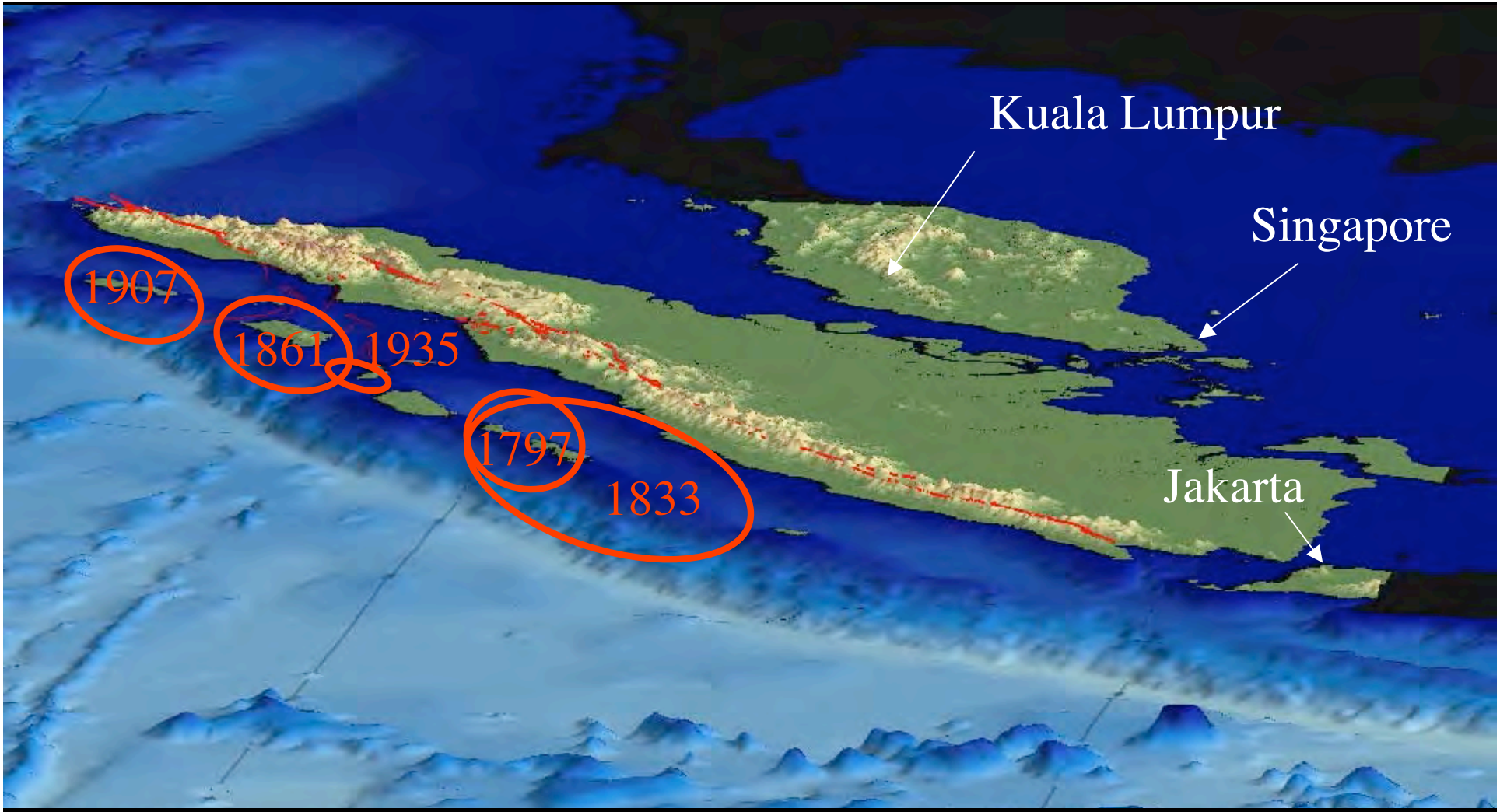
Most of the megathrust failed between 1797 and 1907



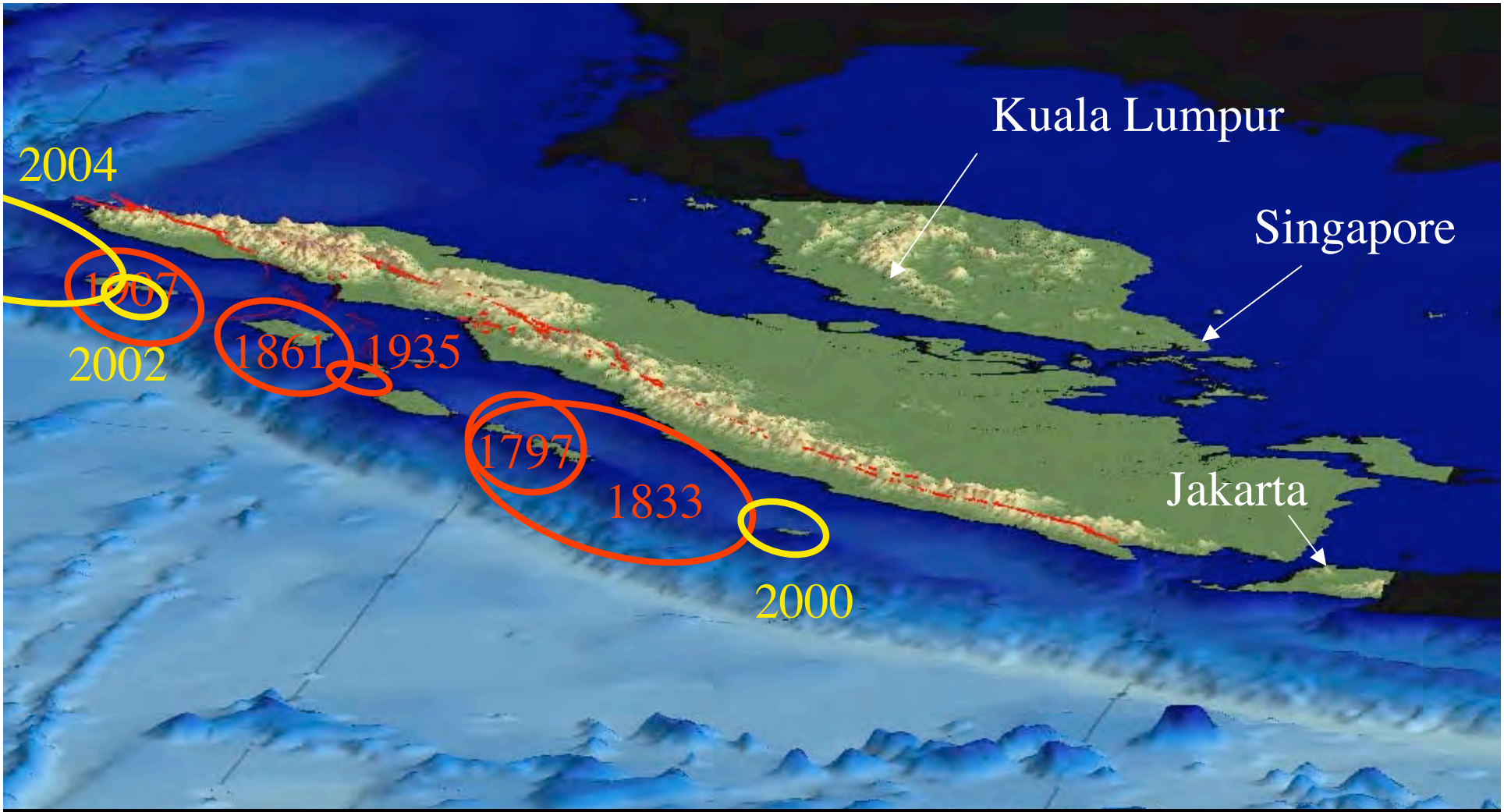
Most of the megathrust failed between 1797 and 1907



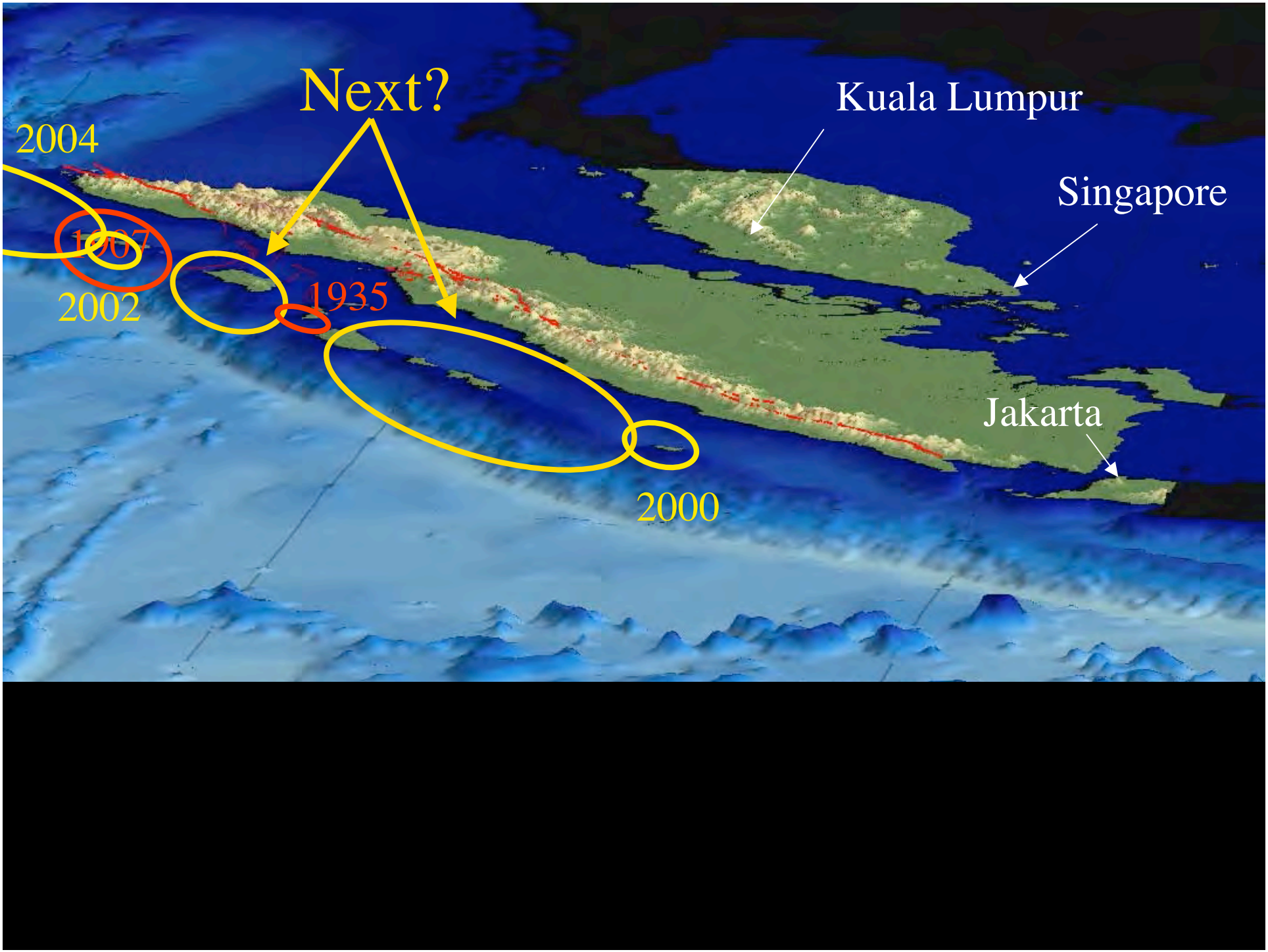
Most of the megathrust failed between 1797 and 1907

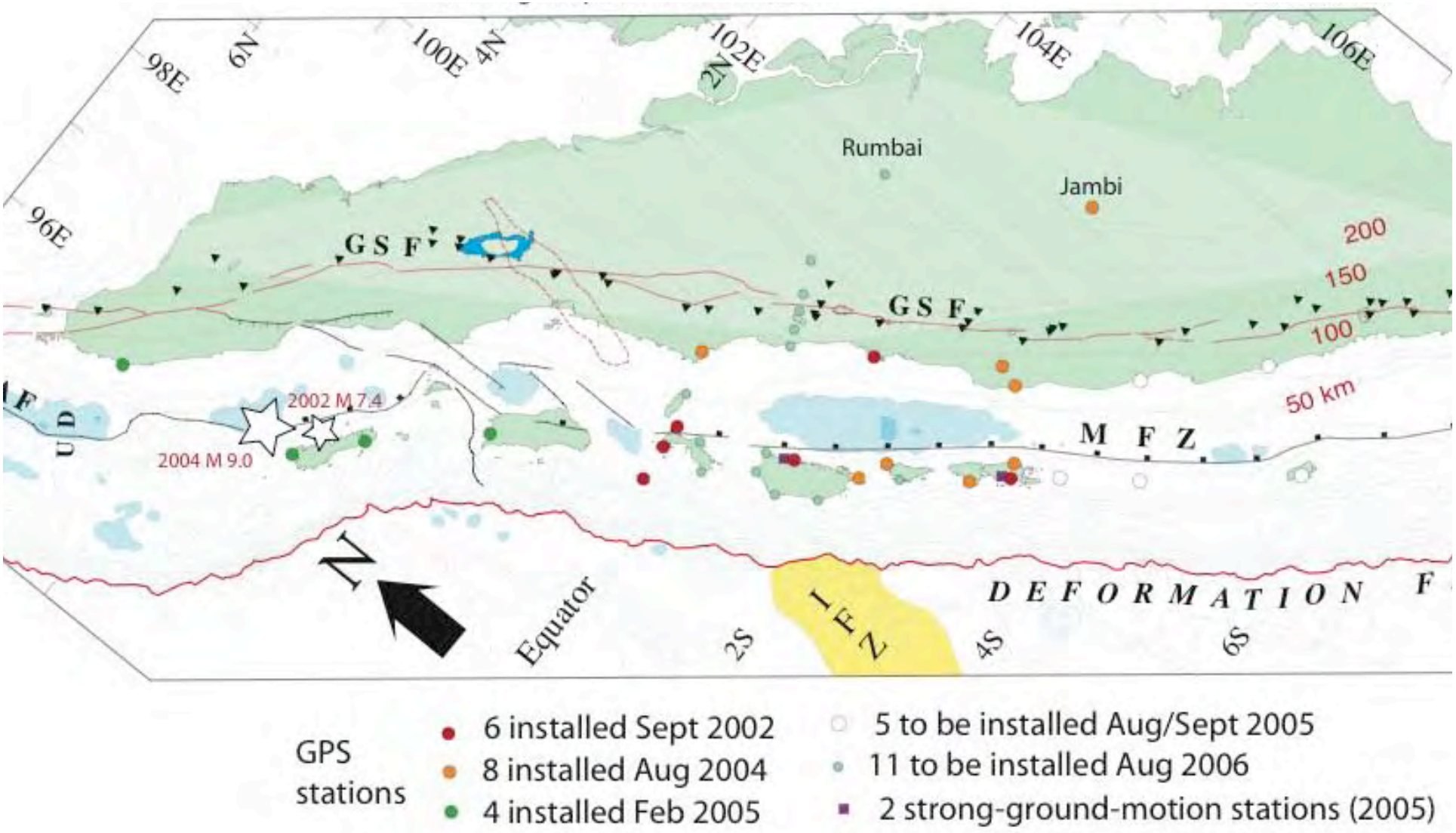


A 70-km long patch failed in 1935, between the giant 1861 and 1833 patches



A flurry of ruptures have occurred since 2000

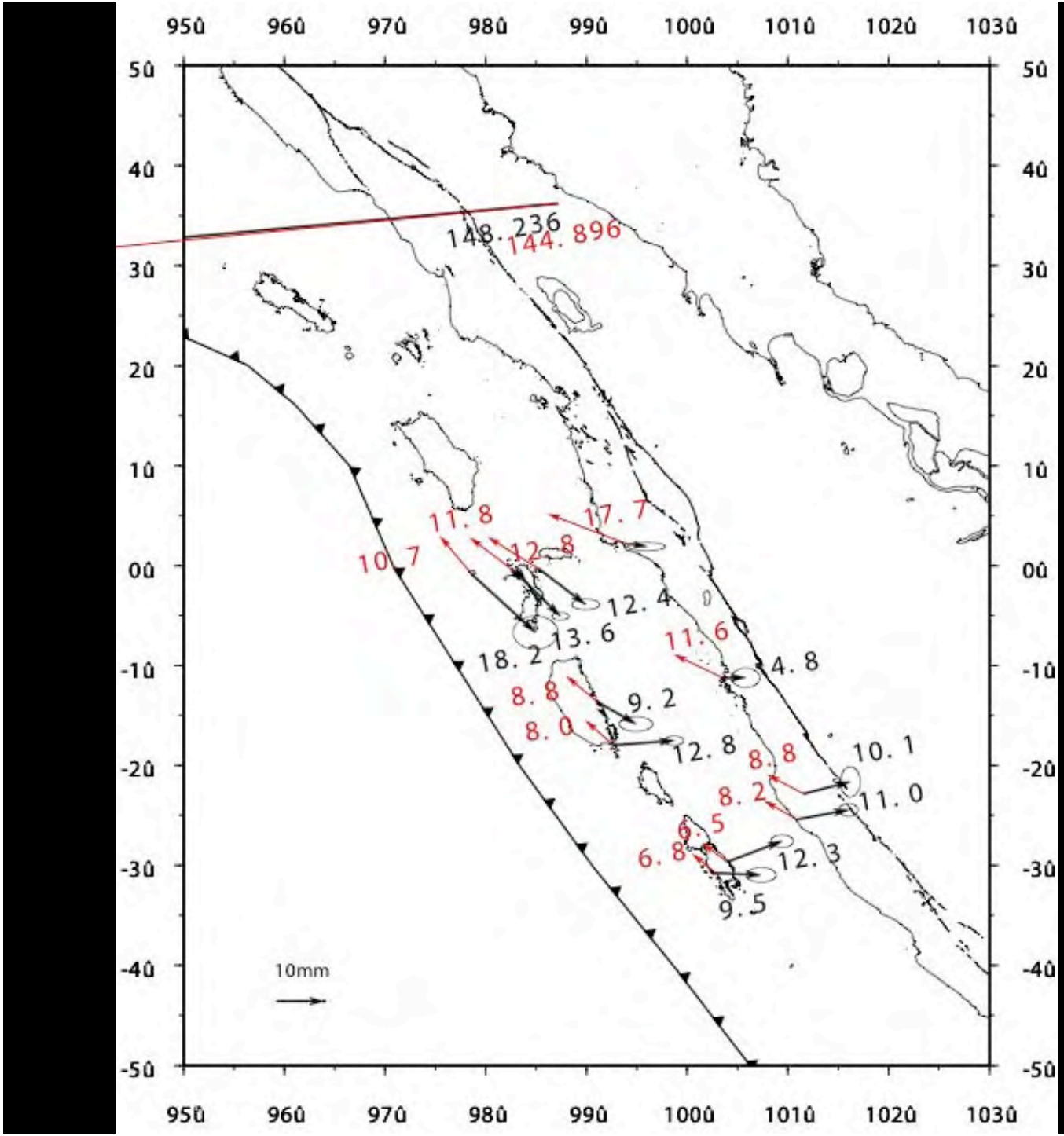

Next?
2004
1907
2002
1935
2000
Kuala Lumpur
Singapore
Jakarta



Based upon what we have seen in the coral microatolls, I expect that we will see transients in the months, years or decades between the 2004 Aceh/Andaman earthquake and the next west-Sumatran earthquakes. … the TO will be ready!

Thank you

(My survivor buddies around a tsunami block, Simeulue island)



Coseismic horizontal vectors from SuGAr (in mm).

Model

Data