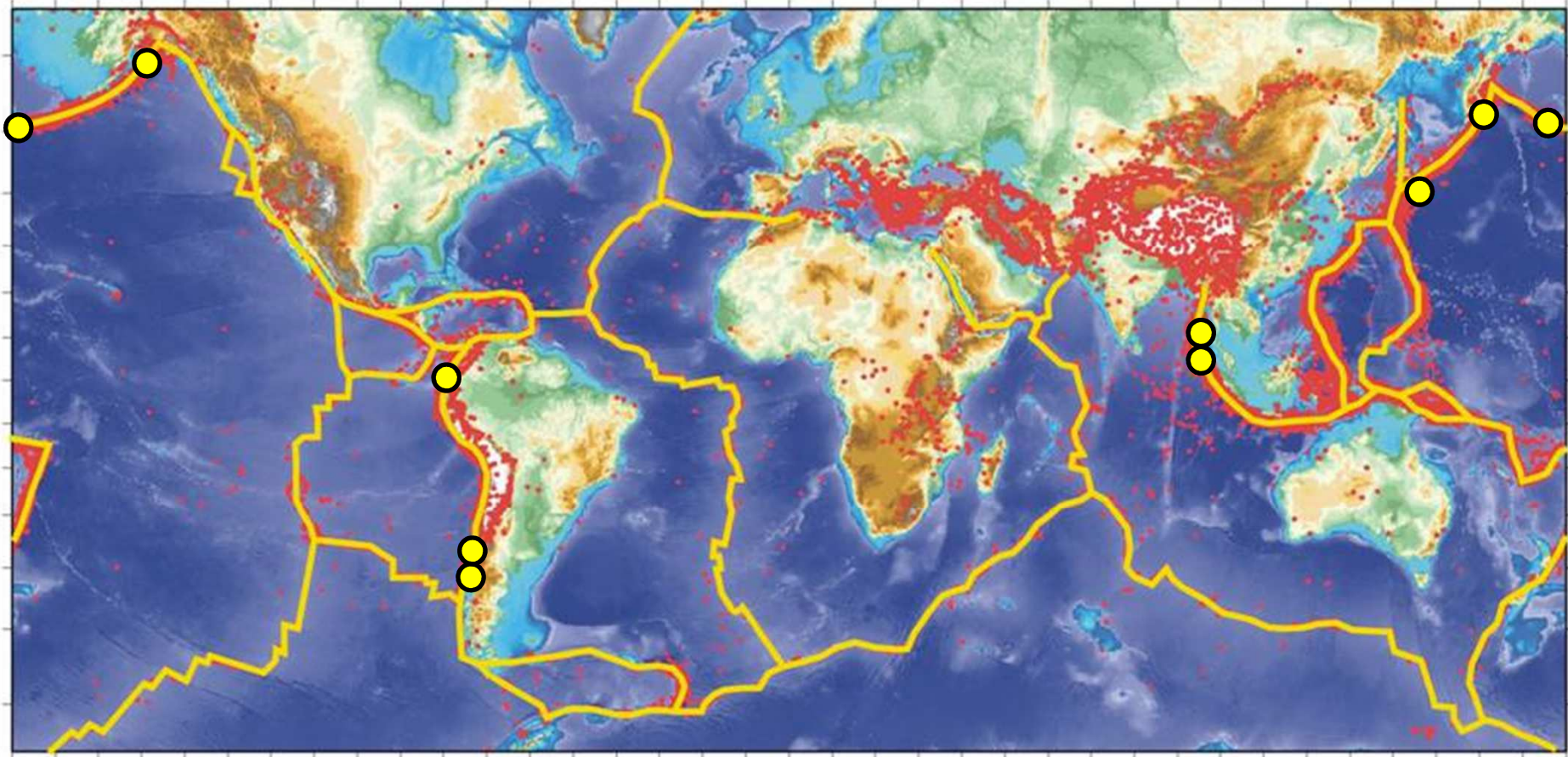


# Earthquake science and vulnerability in Asia



## The 2015 Gorkha (Nepal) earthquake: unfinished business

James Jackson, Department of Earth Sciences, University of Cambridge

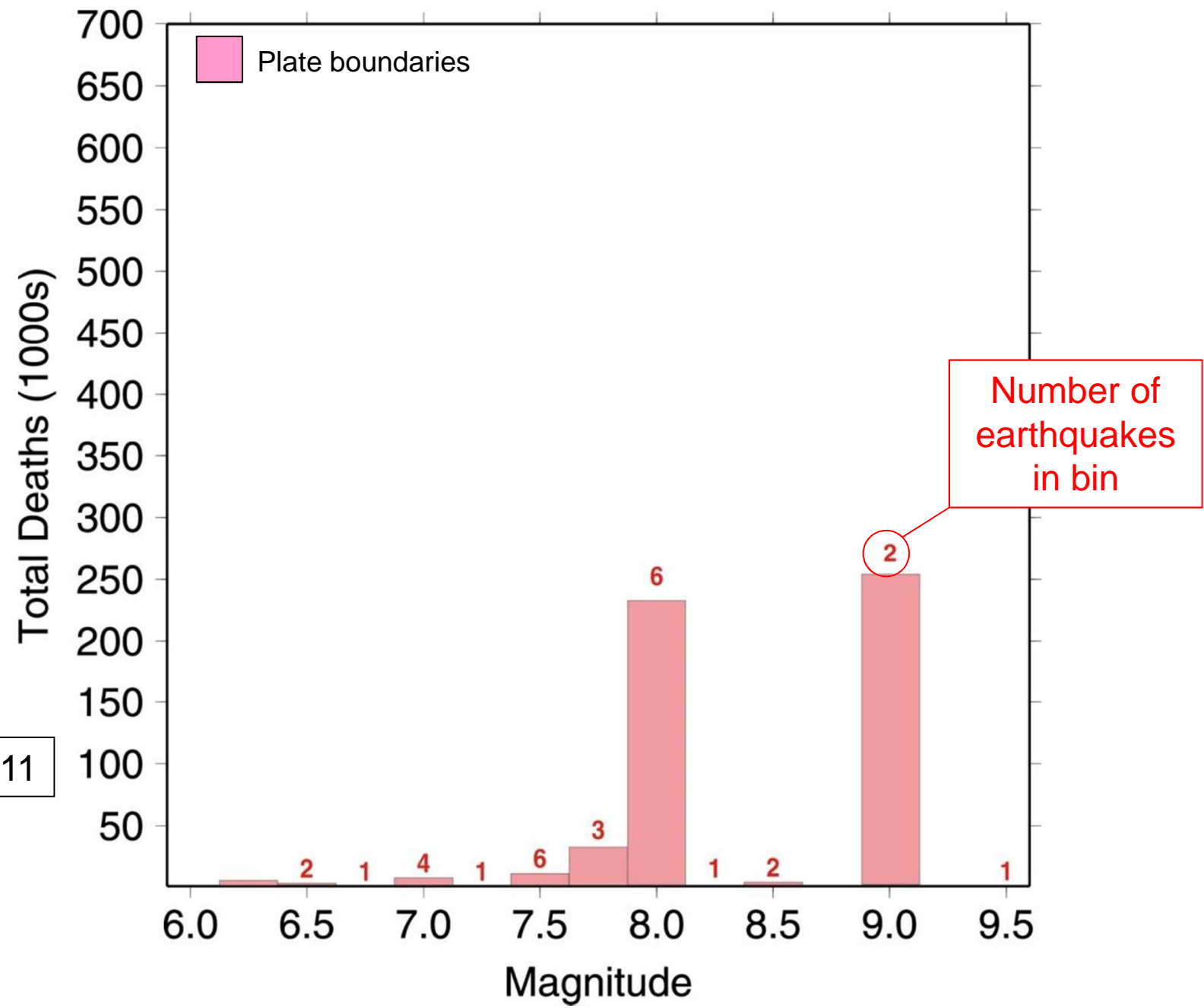


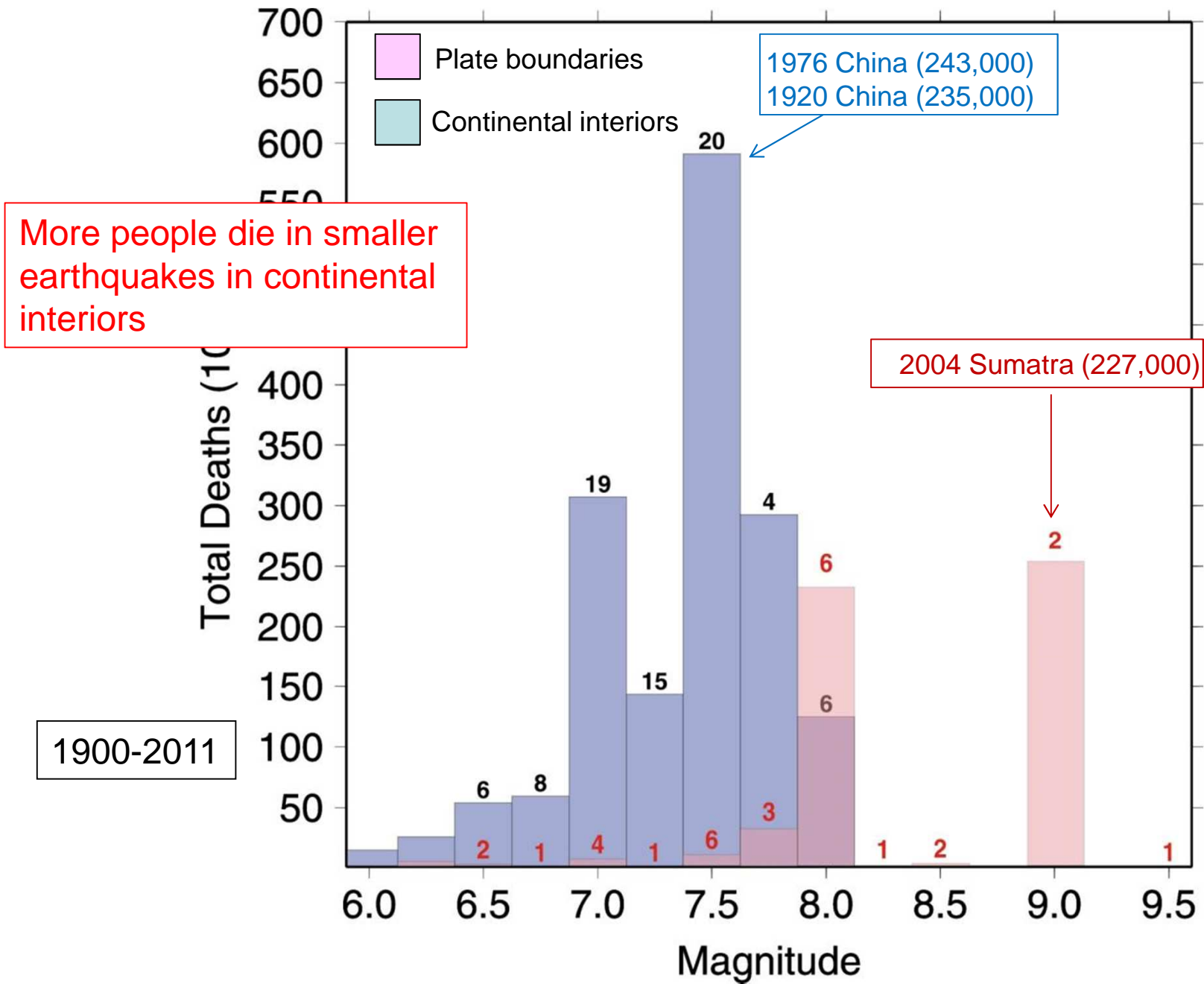
**10 biggest earthquakes since 1900**

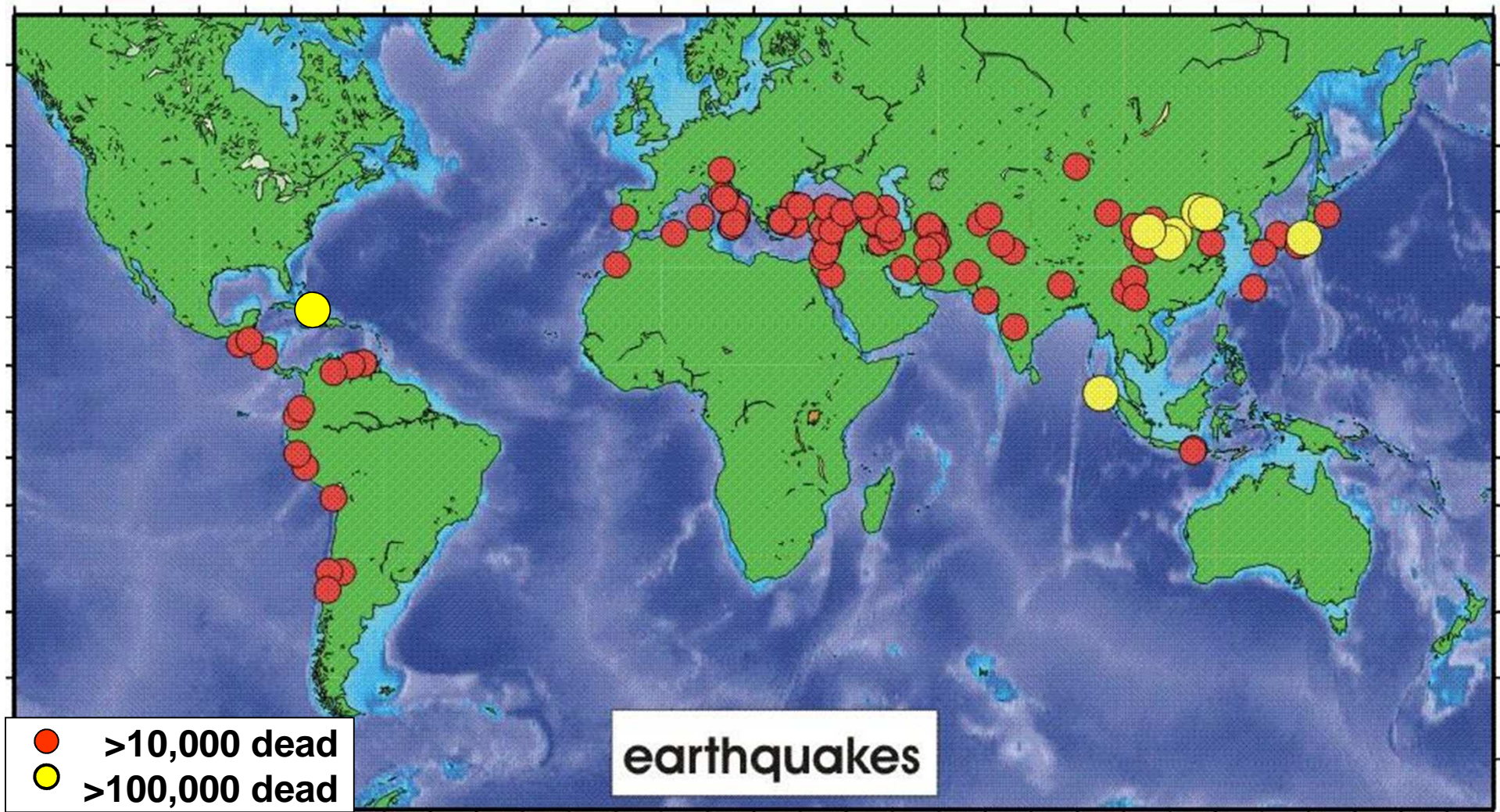
- |                        |                      |                         |
|------------------------|----------------------|-------------------------|
| 1. 1960 Chile          | 5. <b>2011 Japan</b> | 9. 1965 Aleutians       |
| 2. <b>2004 Sumatra</b> | 6. 1952 Kamchatka    | <b>10. 2005 Sumatra</b> |
| 3. 1964 Alaska         | 7. <b>2010 Chile</b> |                         |
| 4. 1957 Aleutians      | 8. 1906 Ecuador      |                         |

**...all on plate boundaries in the oceans**

1900-2011



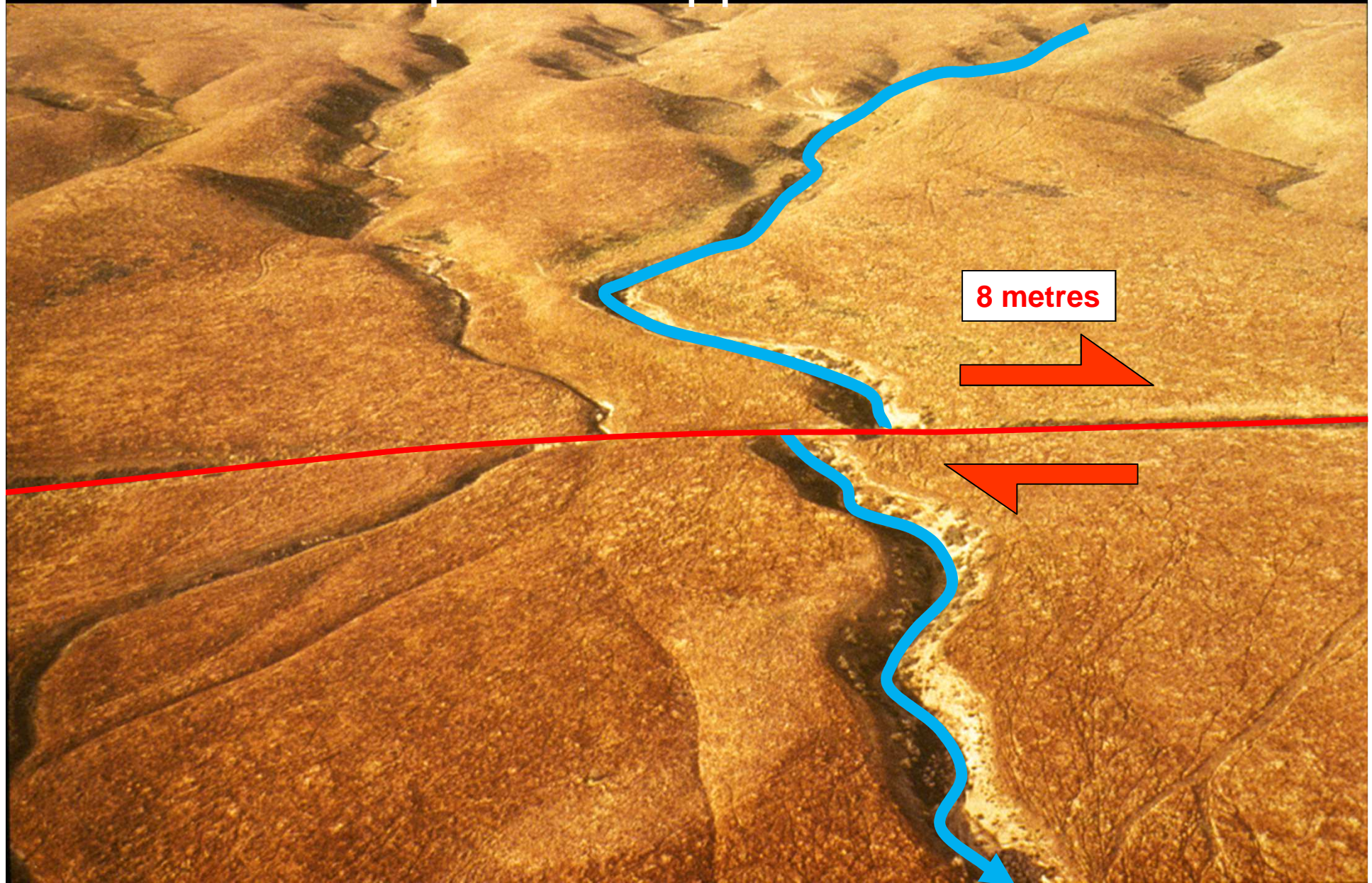




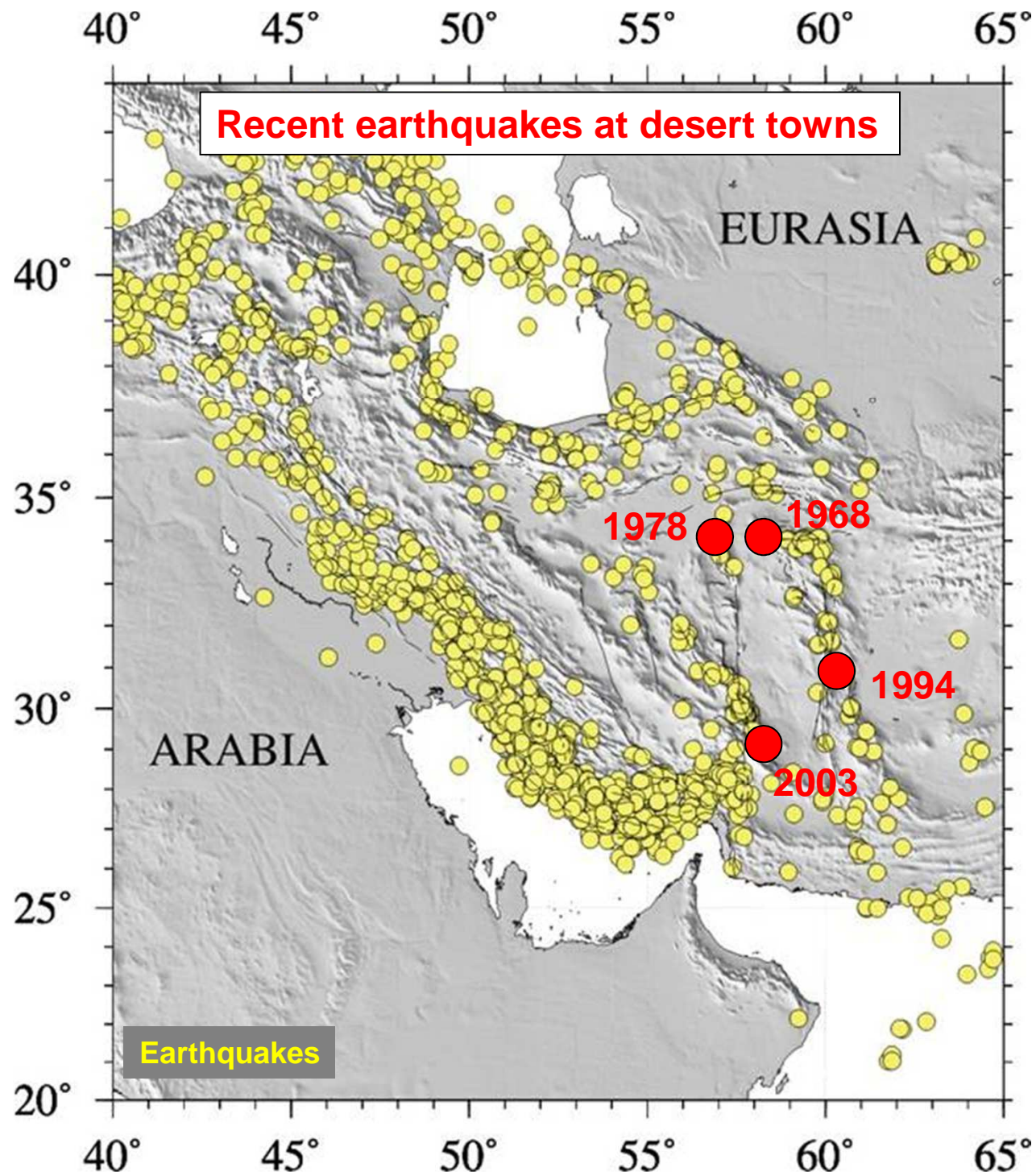
Earthquakes that killed more than 10,000 people in the last 1000 years

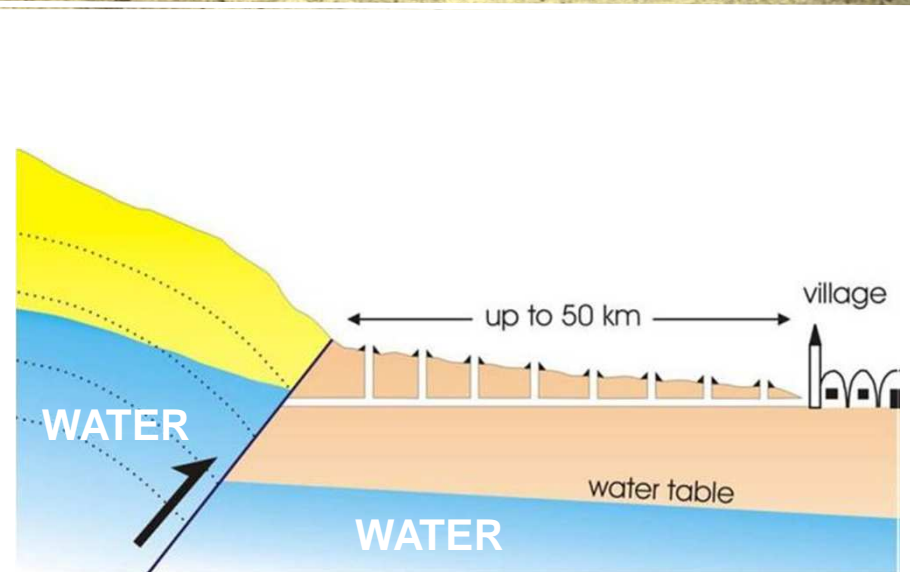
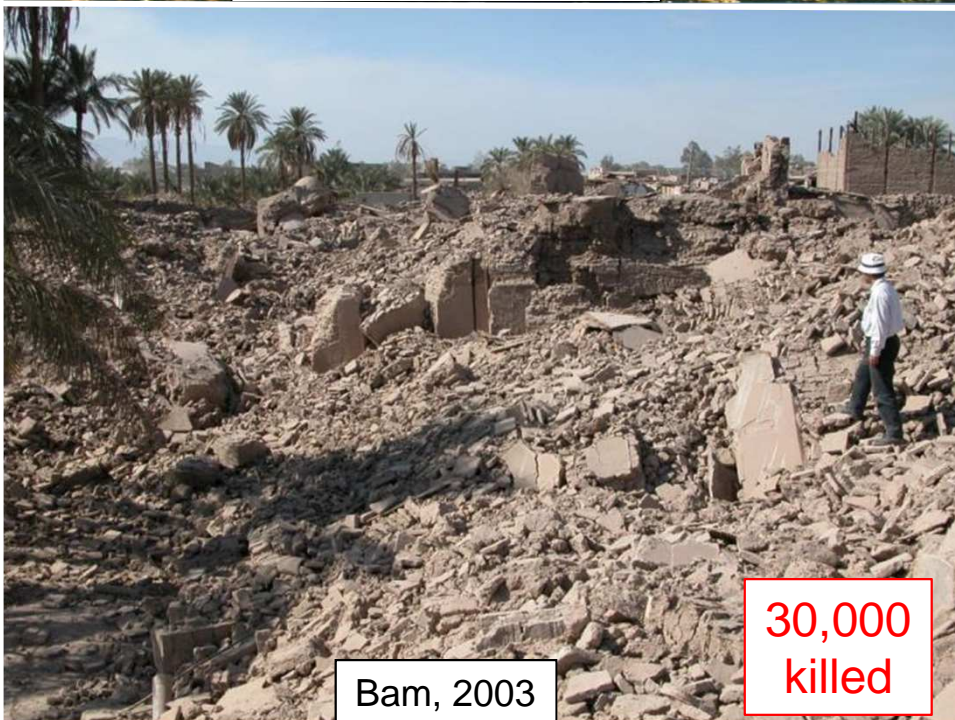
120 in total: 36 of them in the last 100 years

# Earthquakes happen on faults



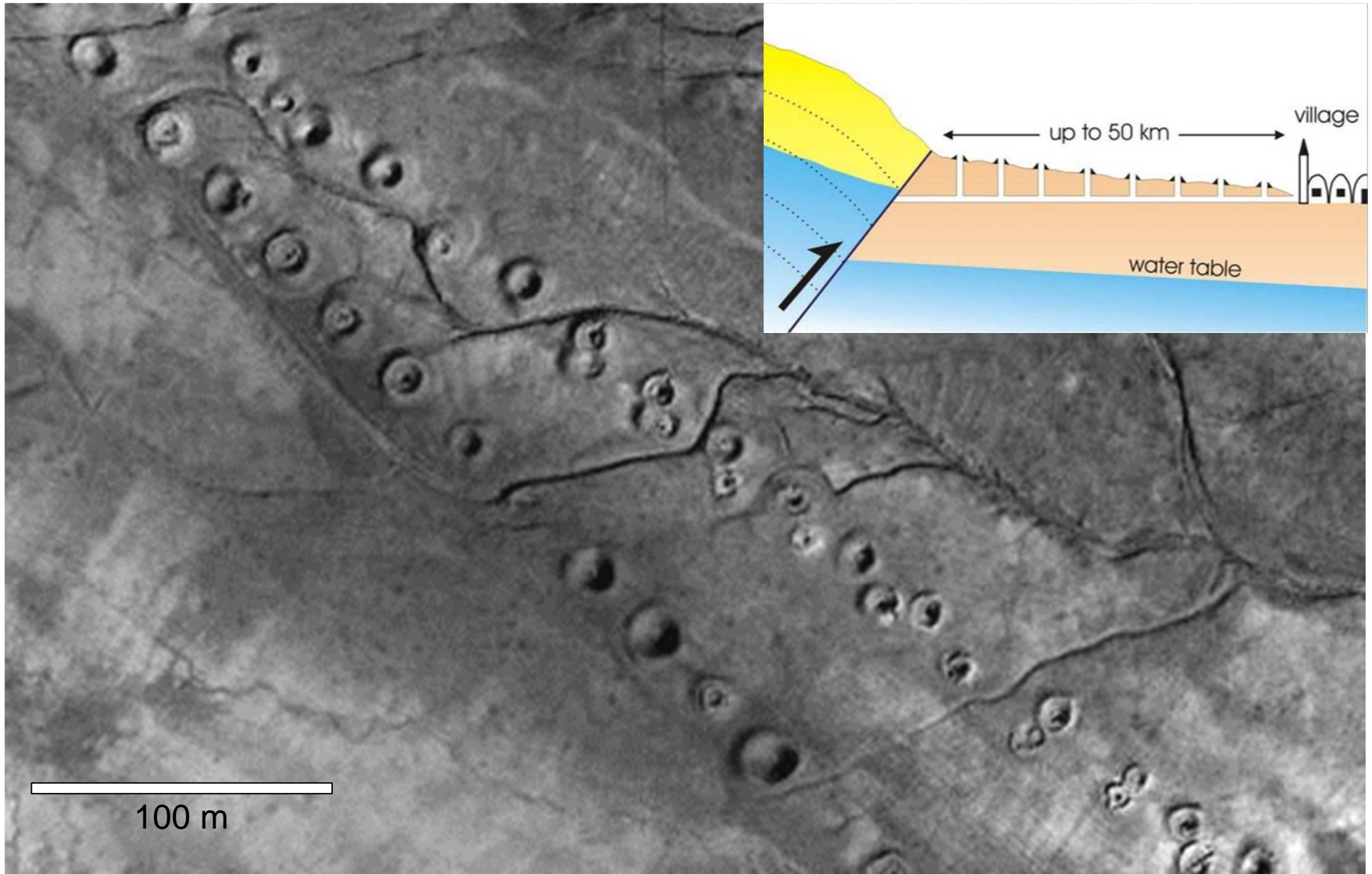
1857 California: San Andreas Fault



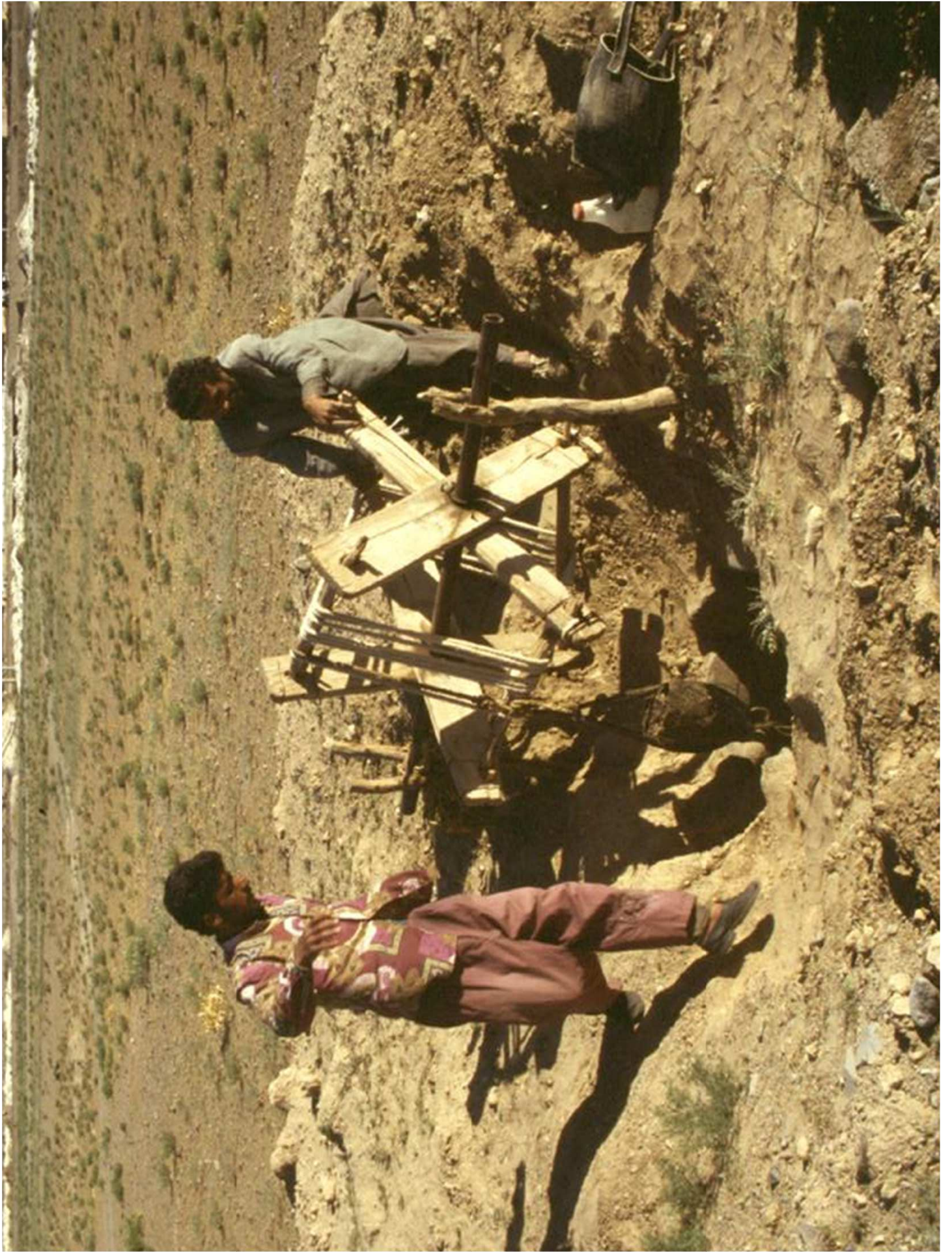


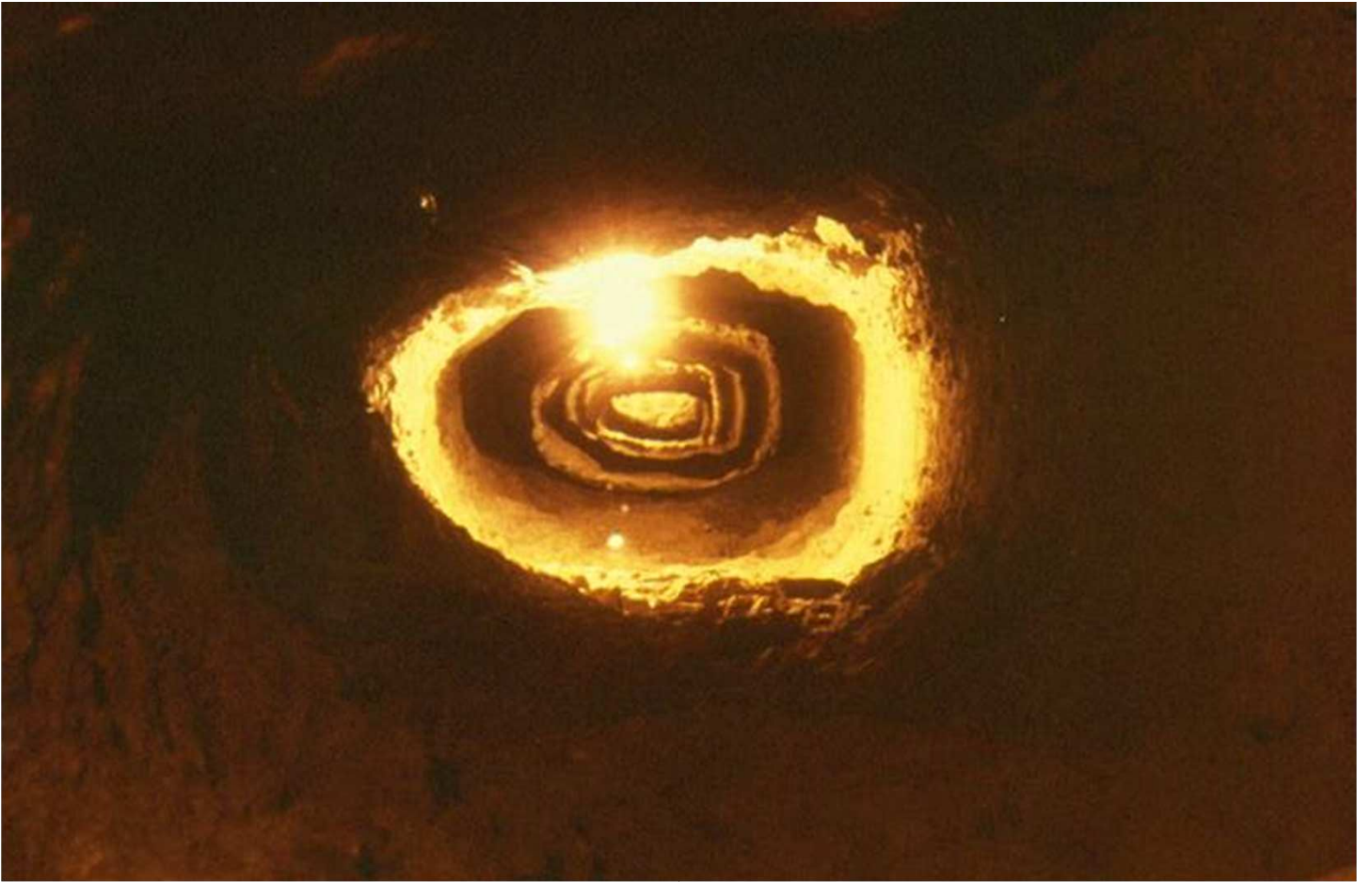
qanats



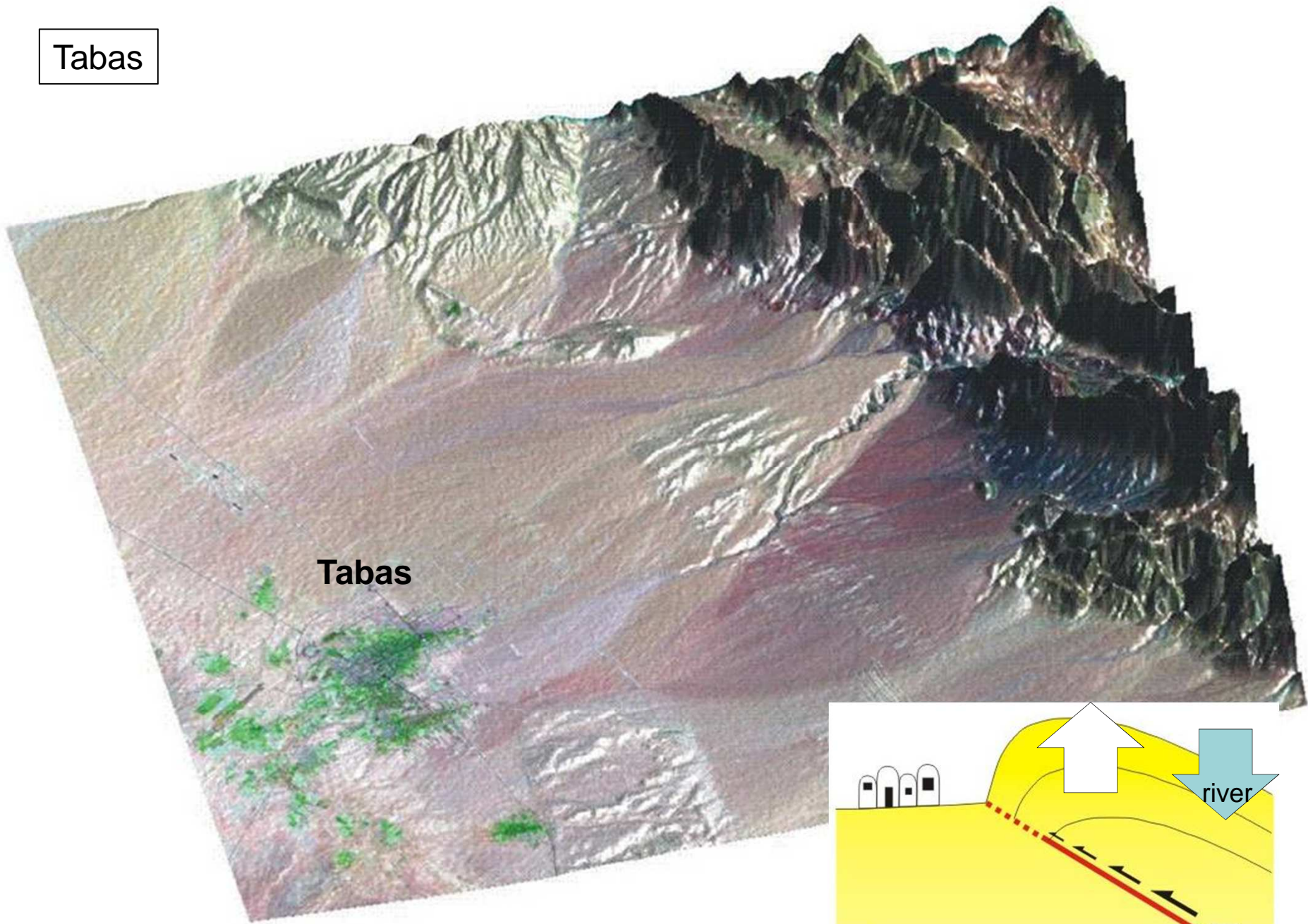


Qanats

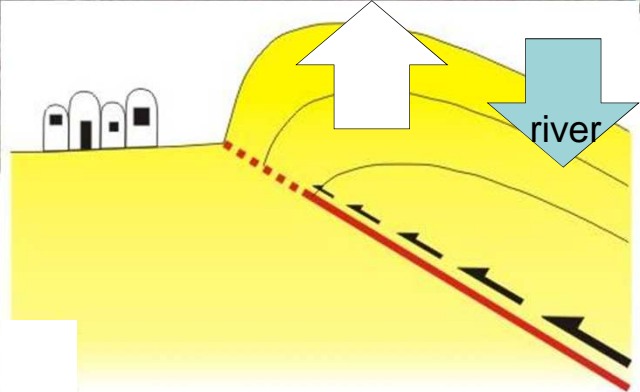




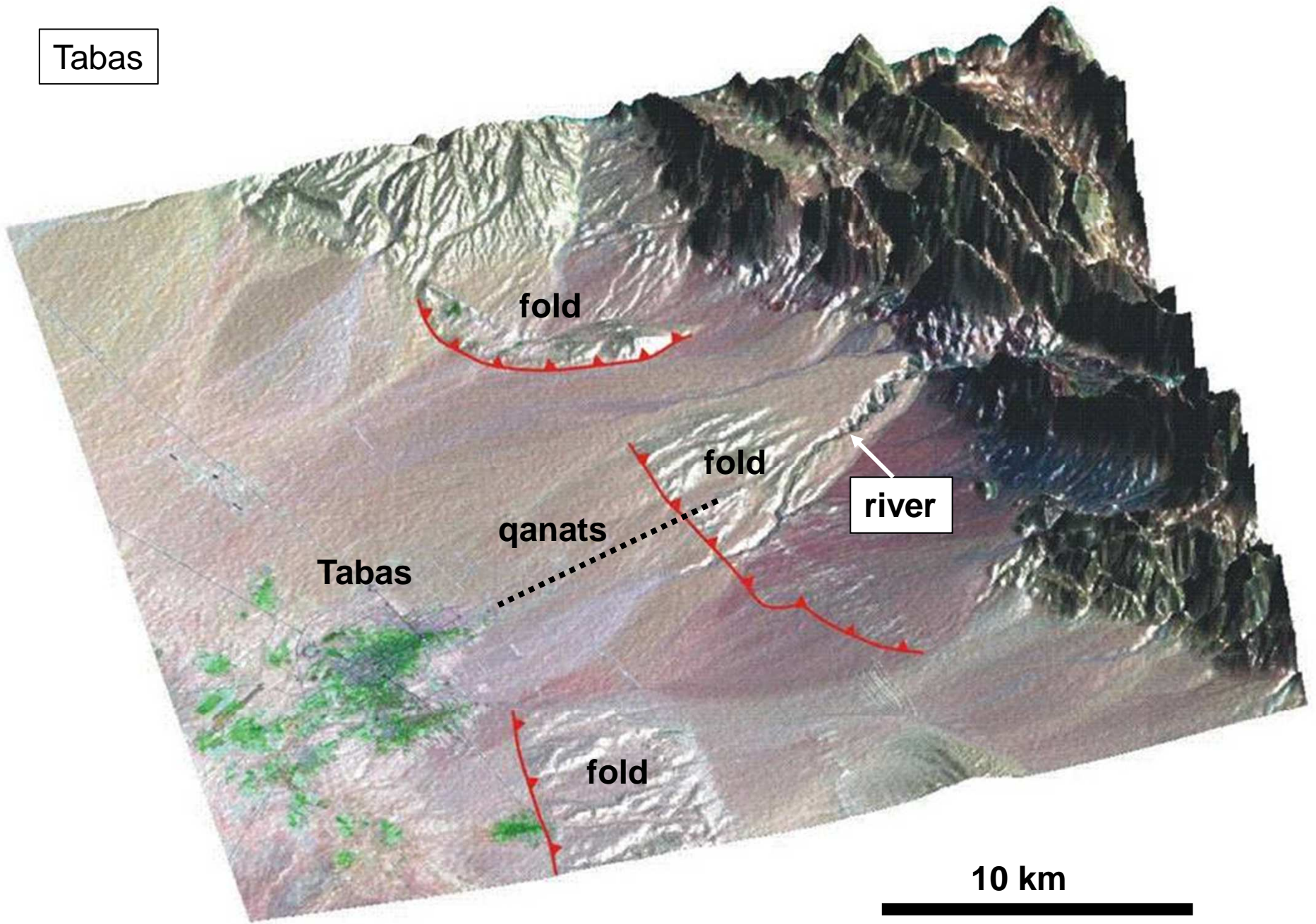
Tabas

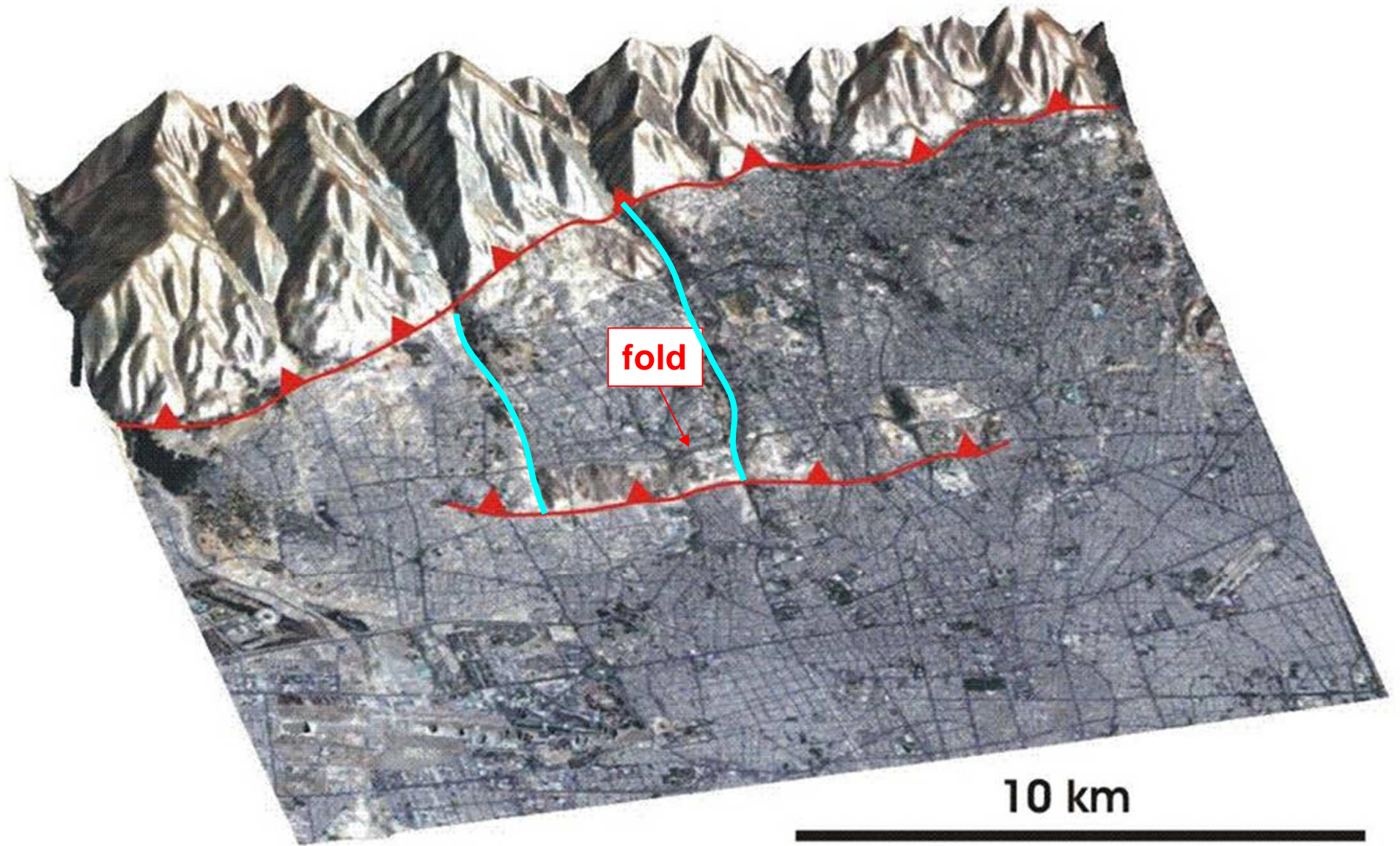


Tabas



Tabas



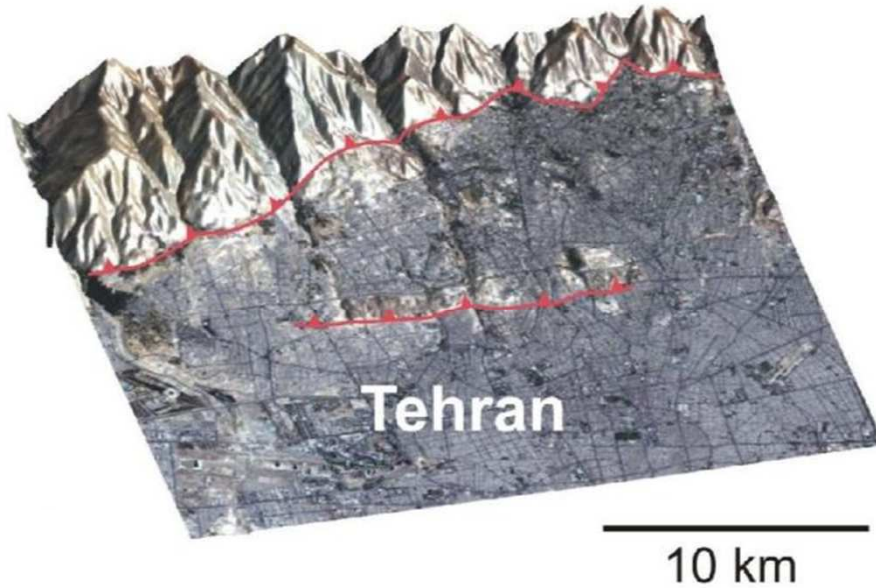


fold

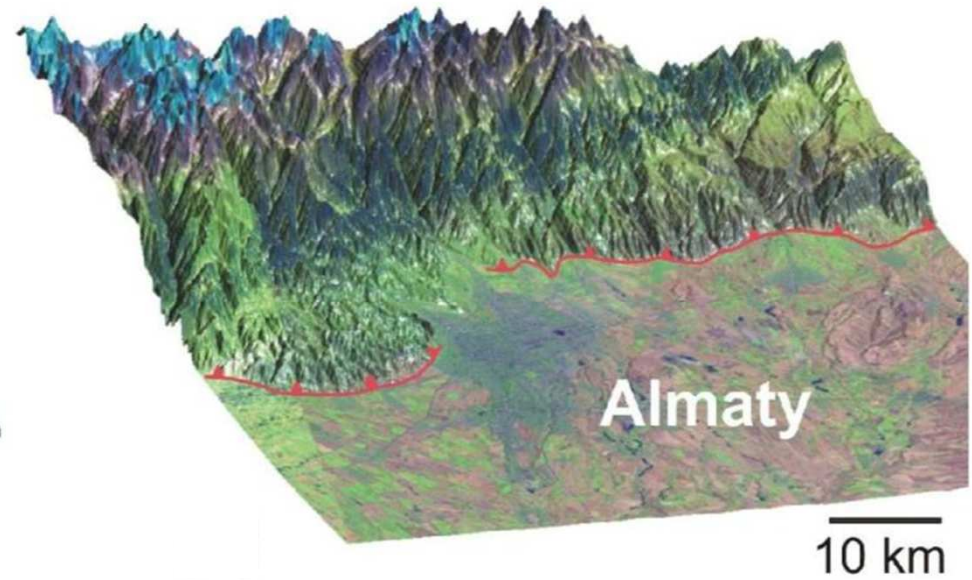
10 km

Tehran

destroyed in  
855, 958, 1137, 1830



damaged in  
1887, 1889, 1911



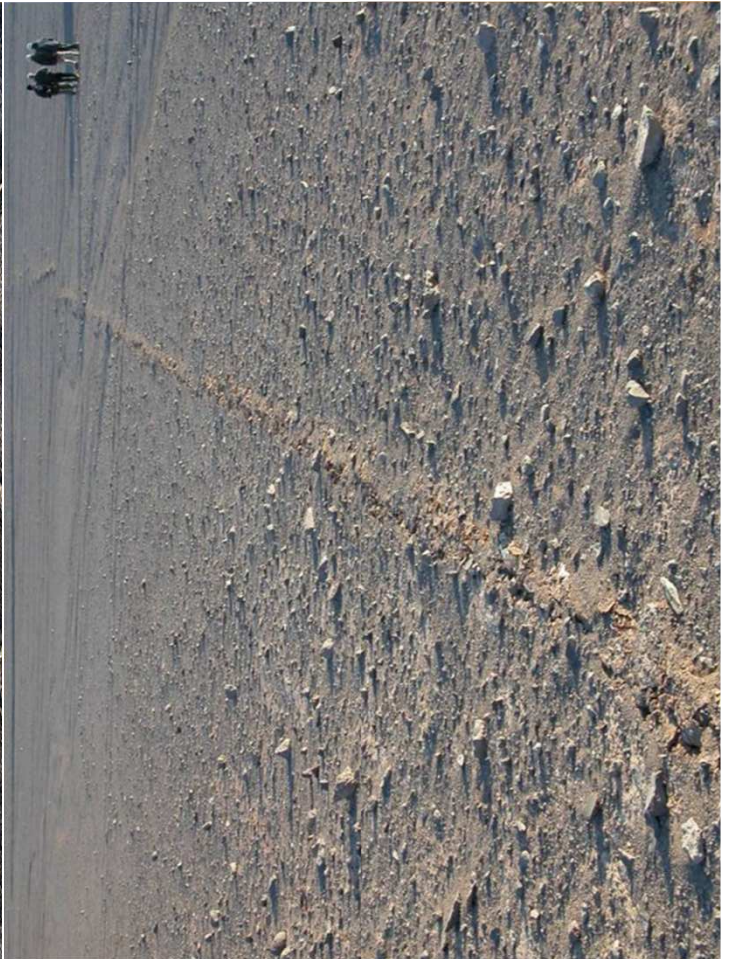
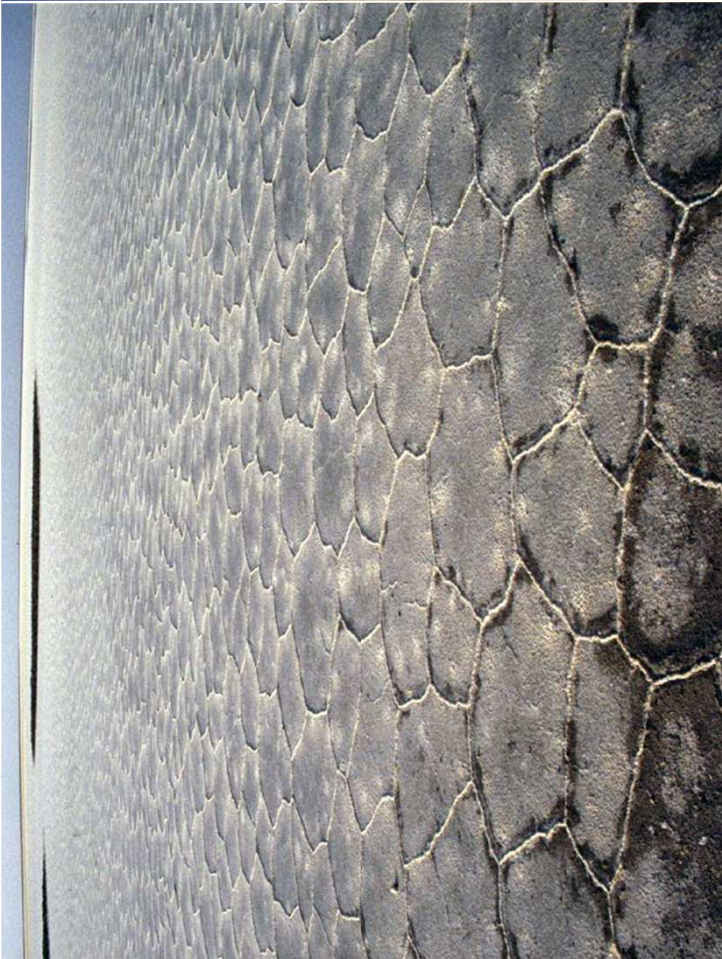
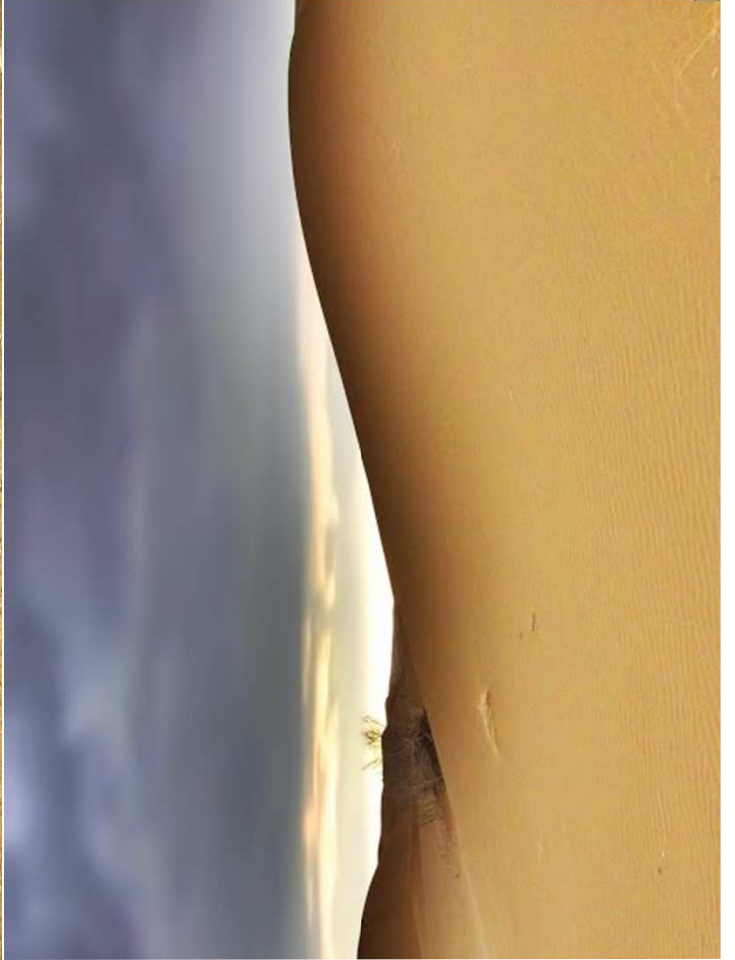
Why not  
live  
somewhere  
else?



damaged in  
1883

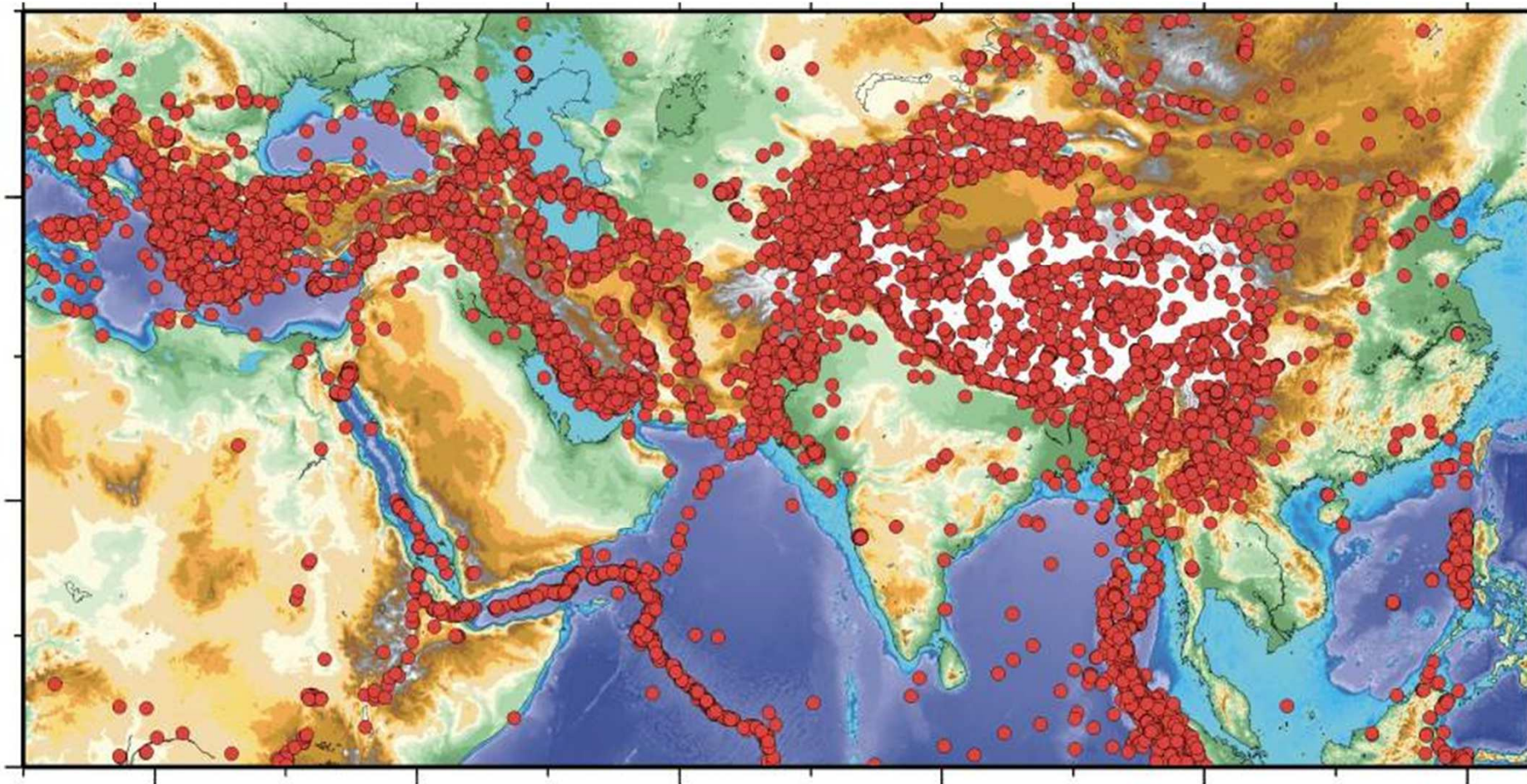
Also Ashkhabad (1948), Tashkent (1966), Wenchuan (2008)....

Little places become big places...



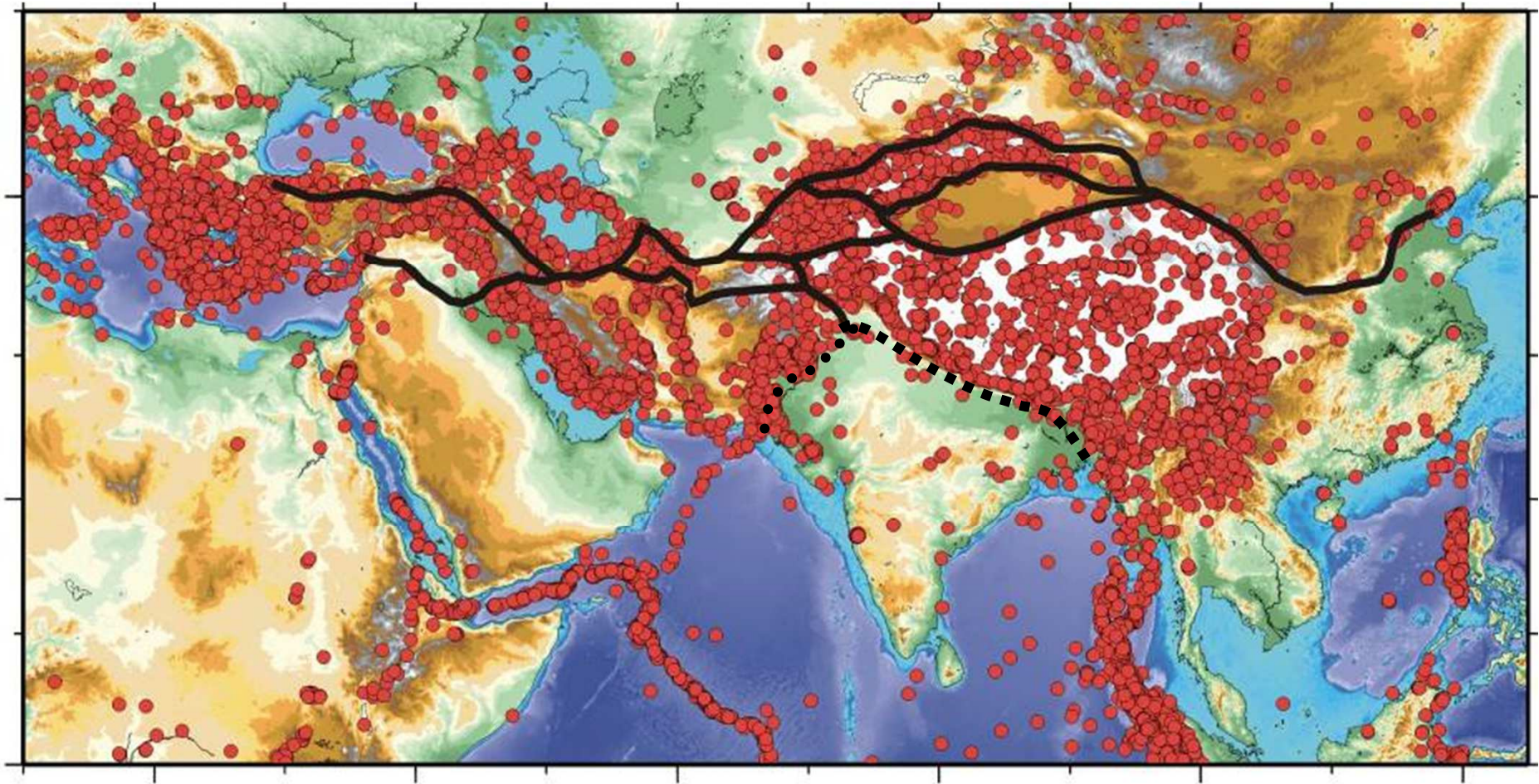


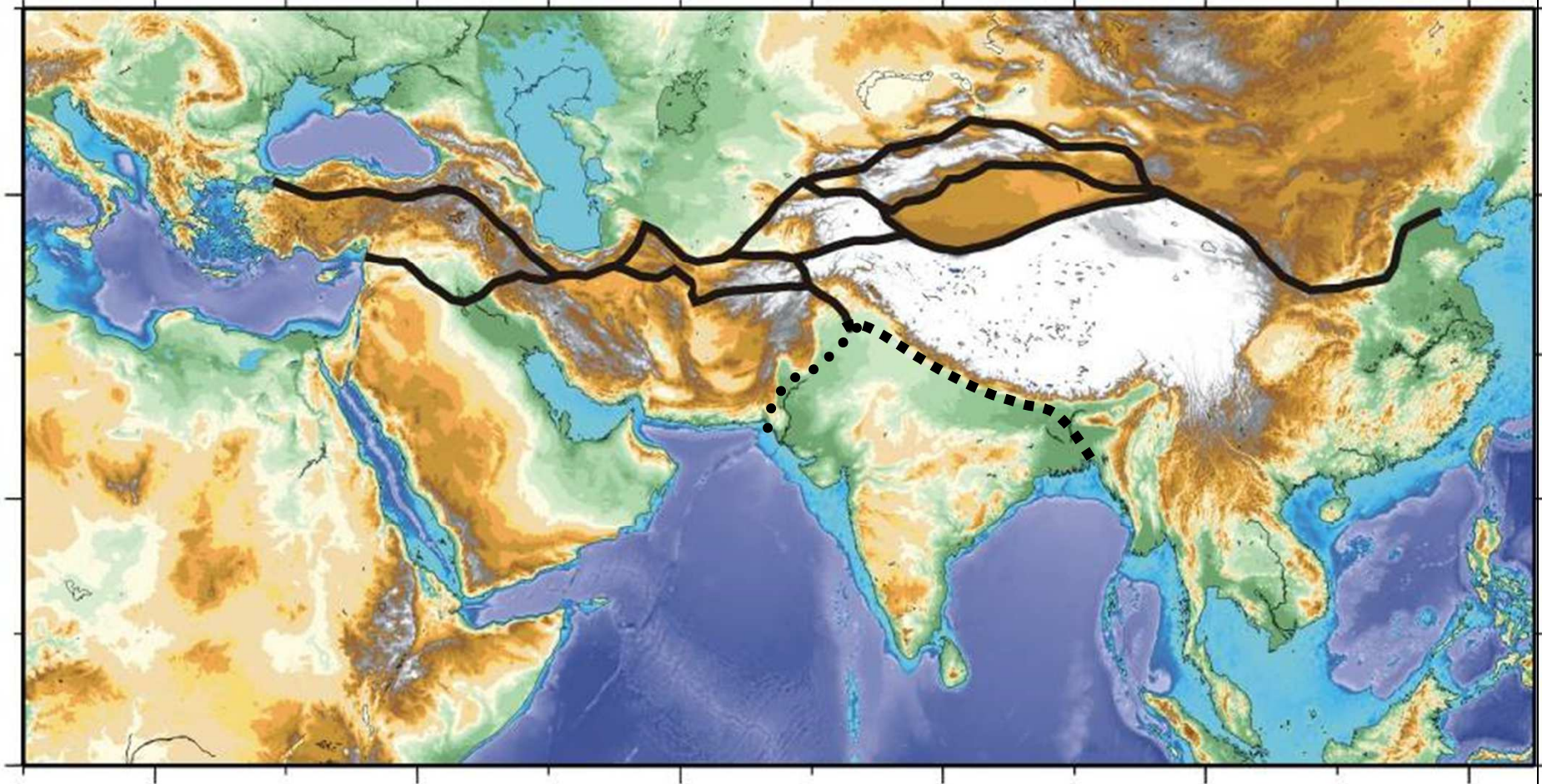
The earthquake belt of the Mediterranean – Middle East - Asia



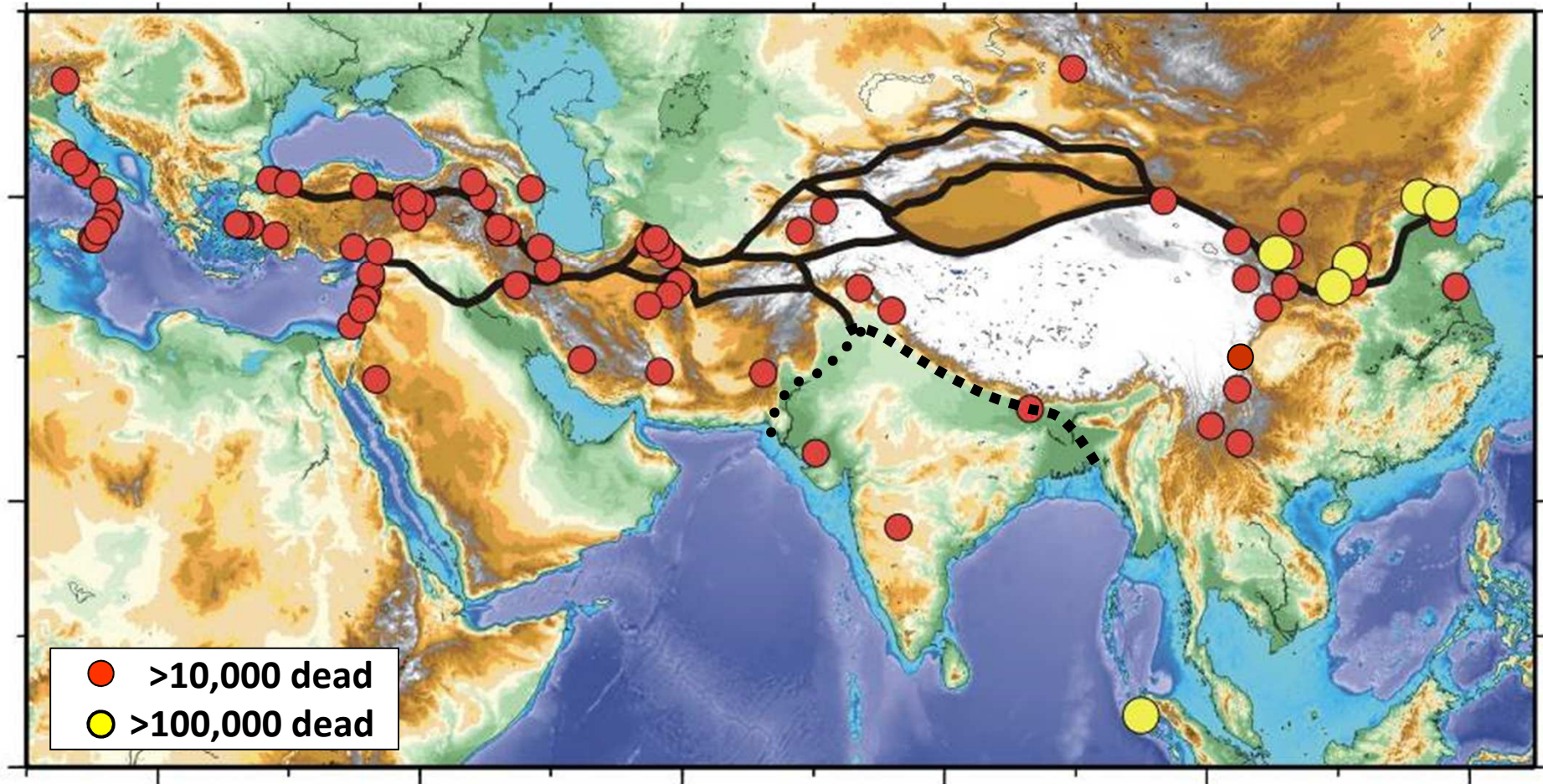
Earthquakes 1962-2003

East-west trade routes: the 'Silk Road'





**Trade routes follow the geological structures:**  
the edges of deserts, plateaus and mountains  
are all formed by earthquake faulting



Earthquakes that killed more than 10,000 people: 1000-2008 AD

Populations and cities concentrate in the dangerous places in Asia



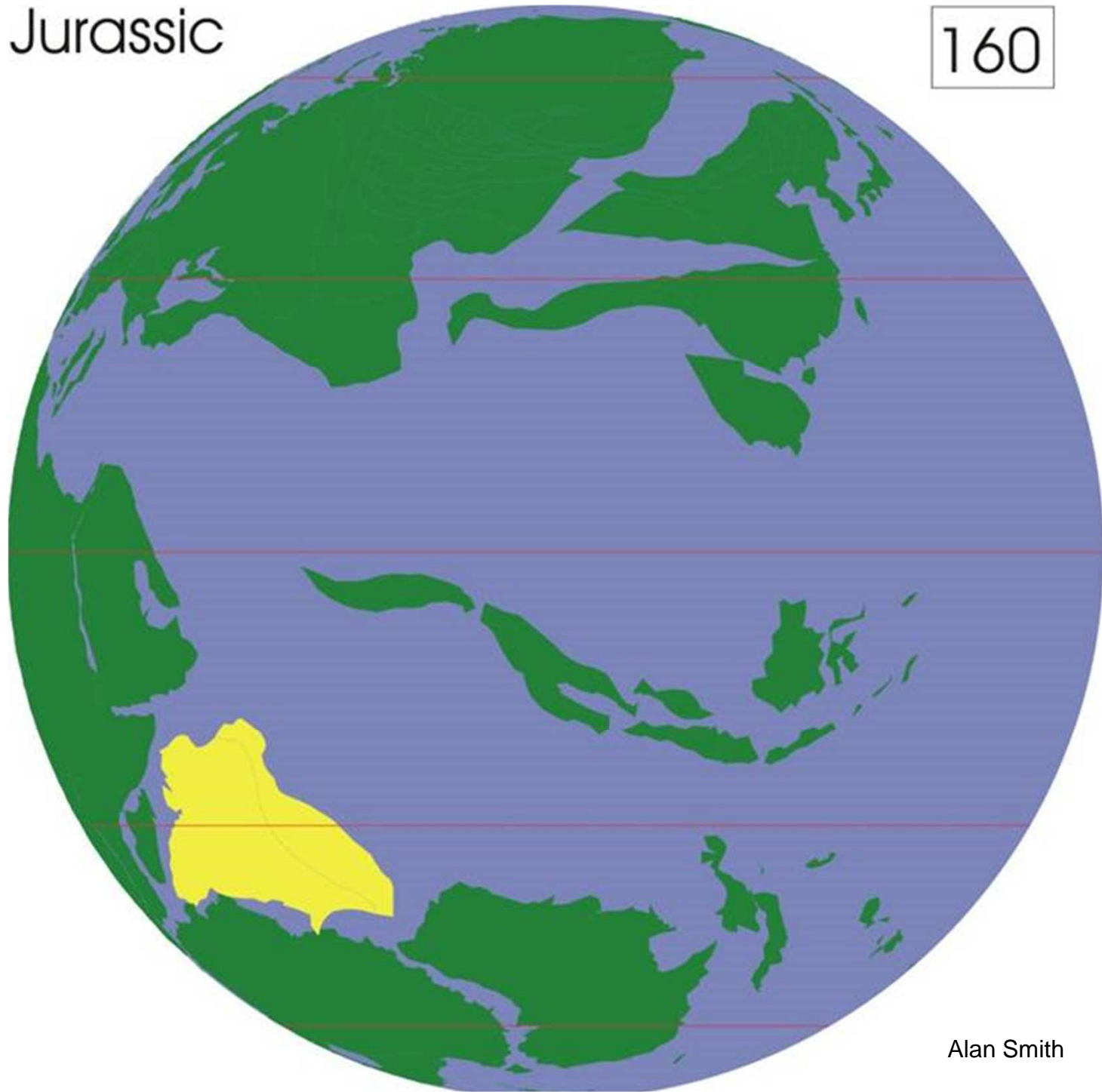
The 2015 Gorkha (Nepal) earthquake



300 million years ago

Jurassic

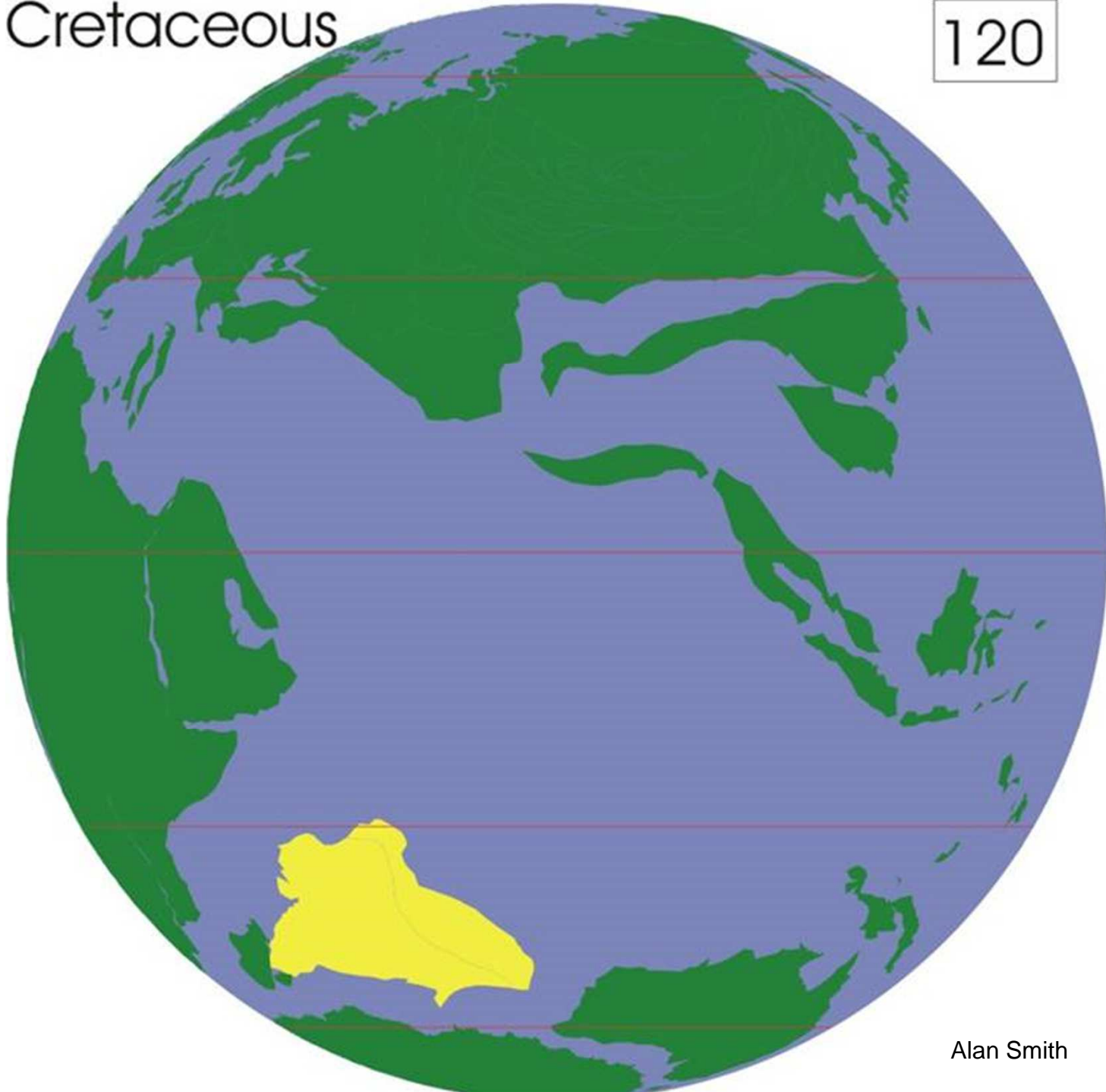
160



Alan Smith

Cretaceous

120

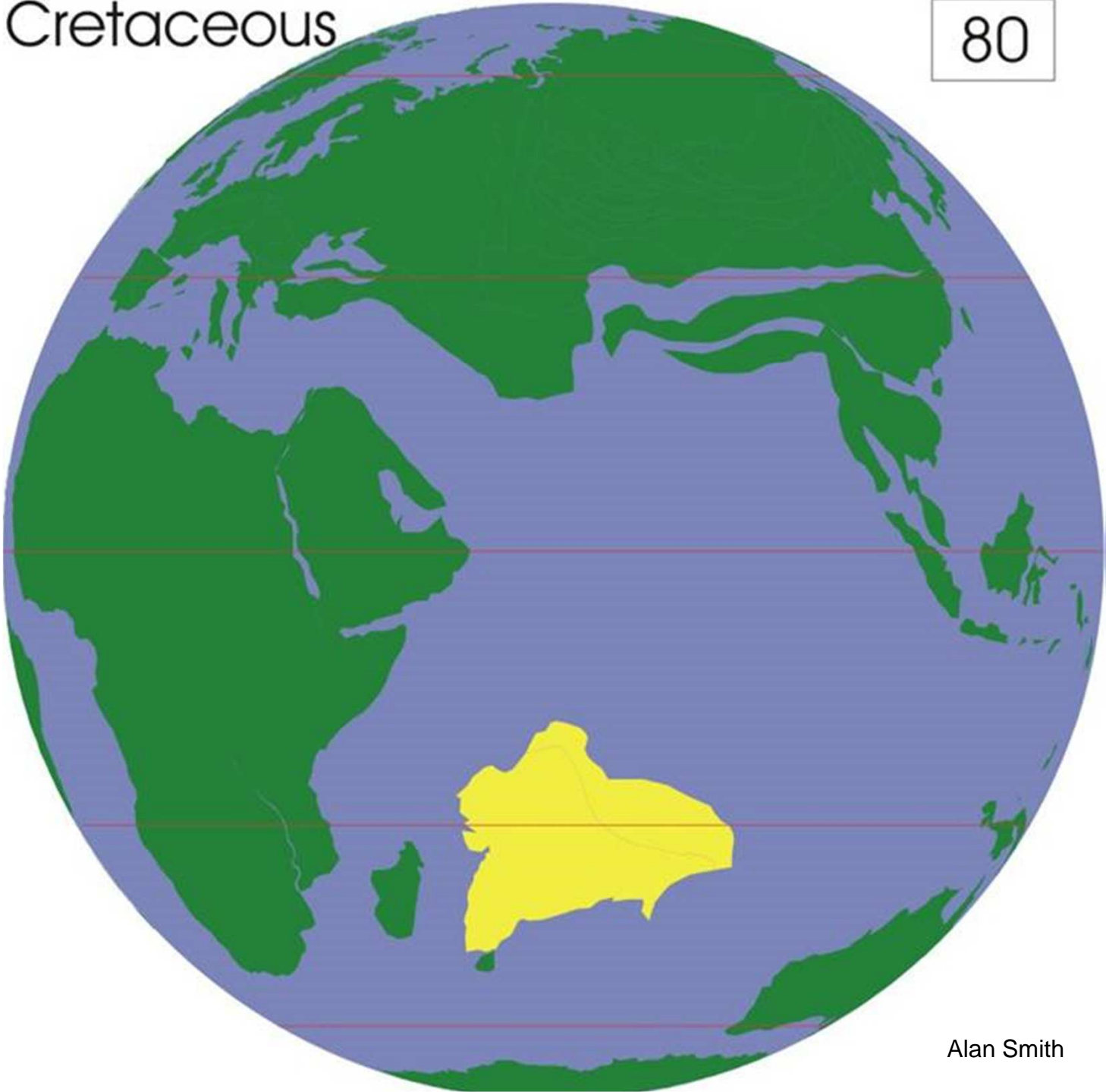


Alan Smith



Cretaceous

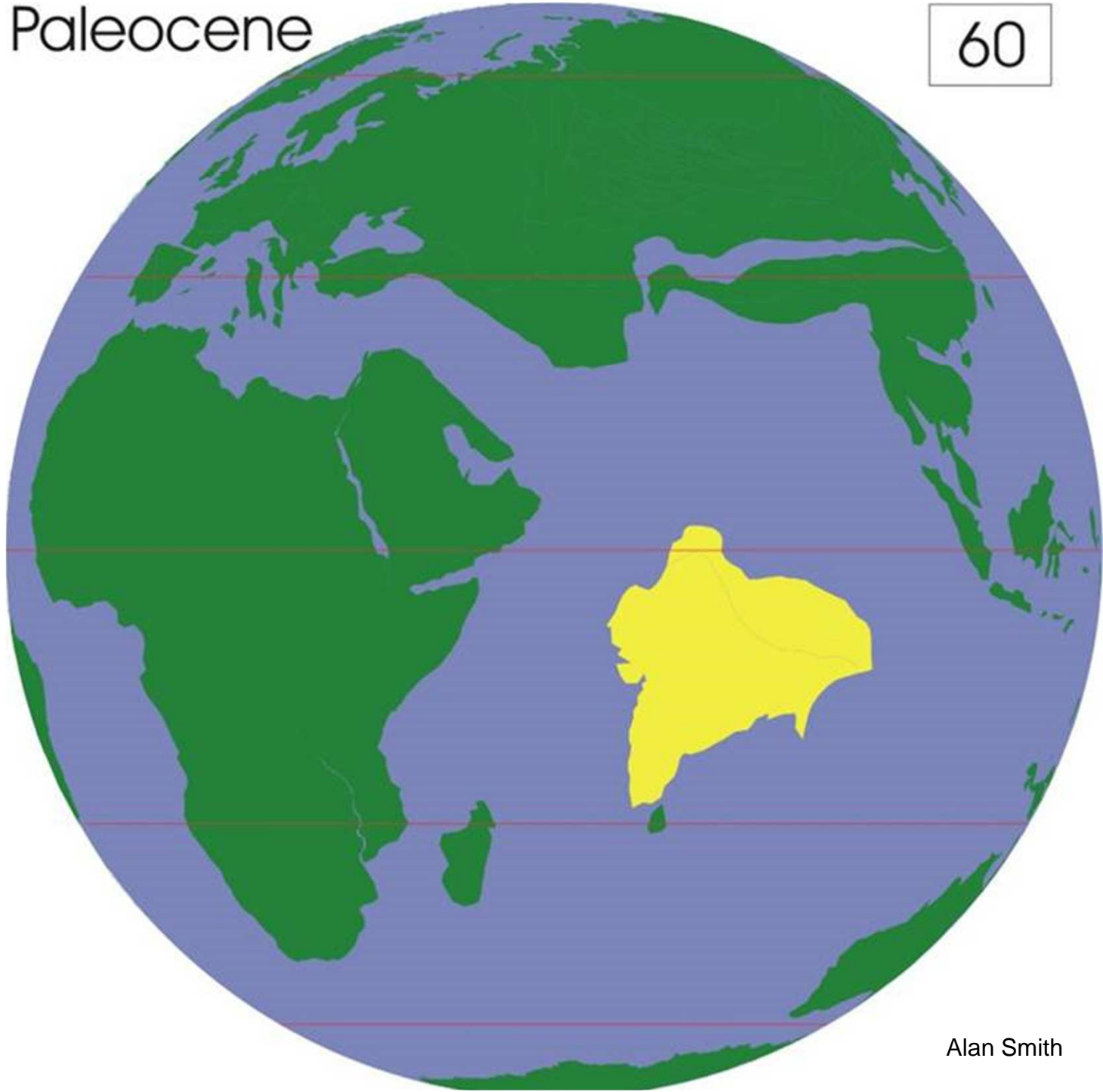
80



Alan Smith

Paleocene

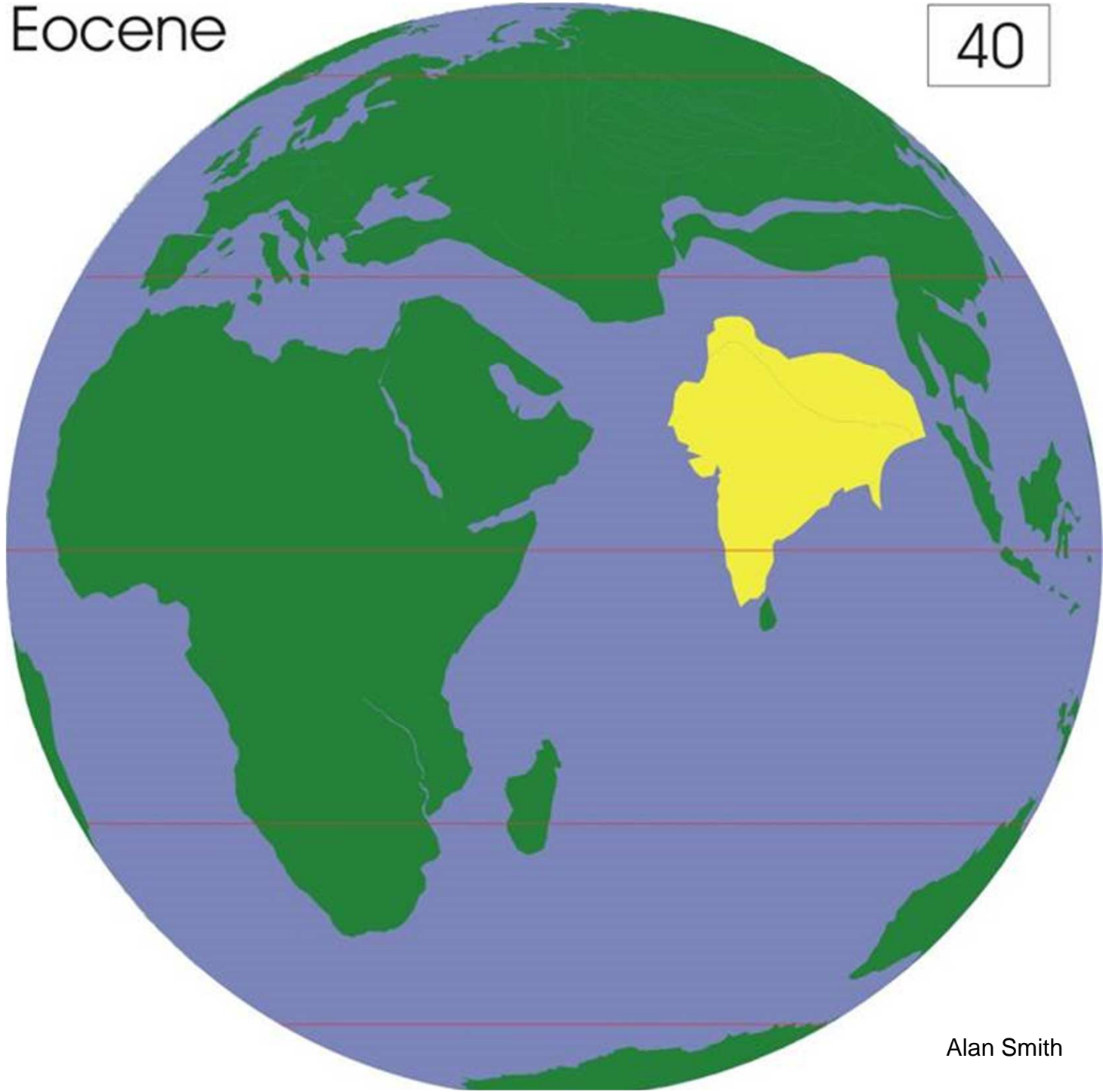
60



Alan Smith

Eocene

40



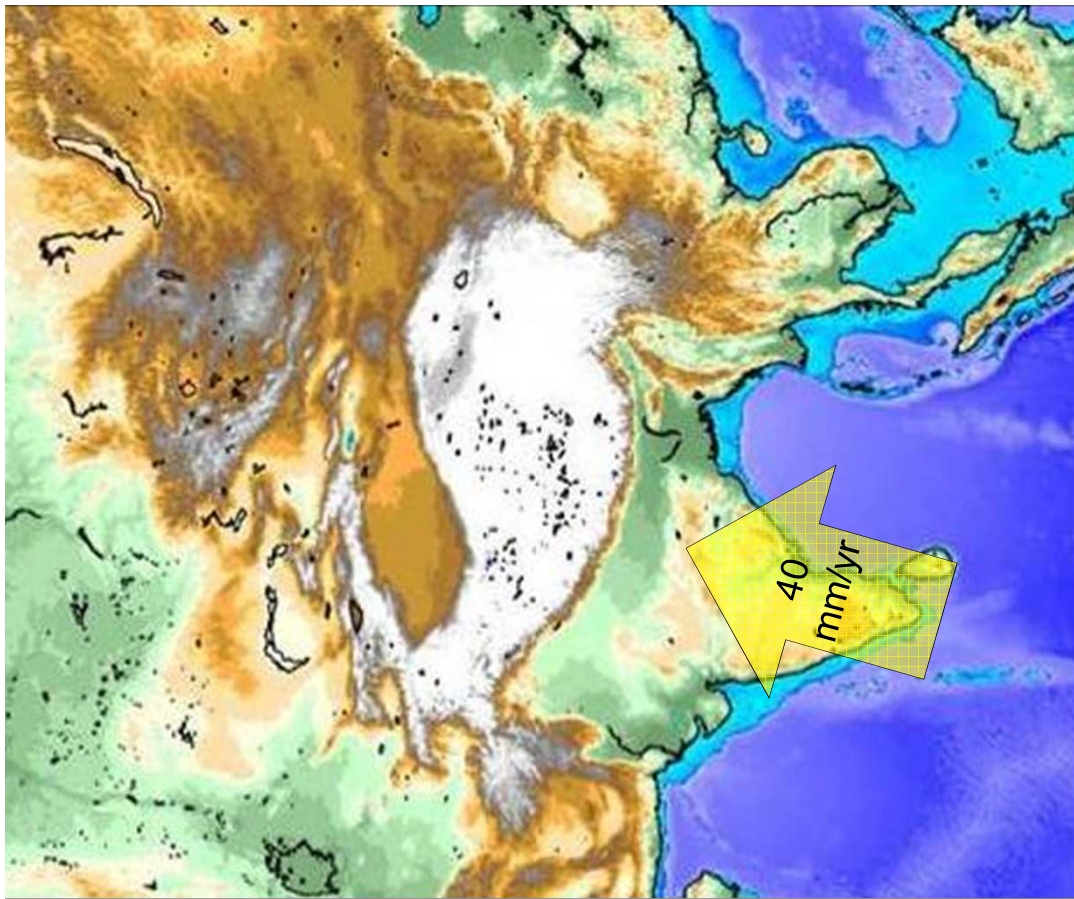
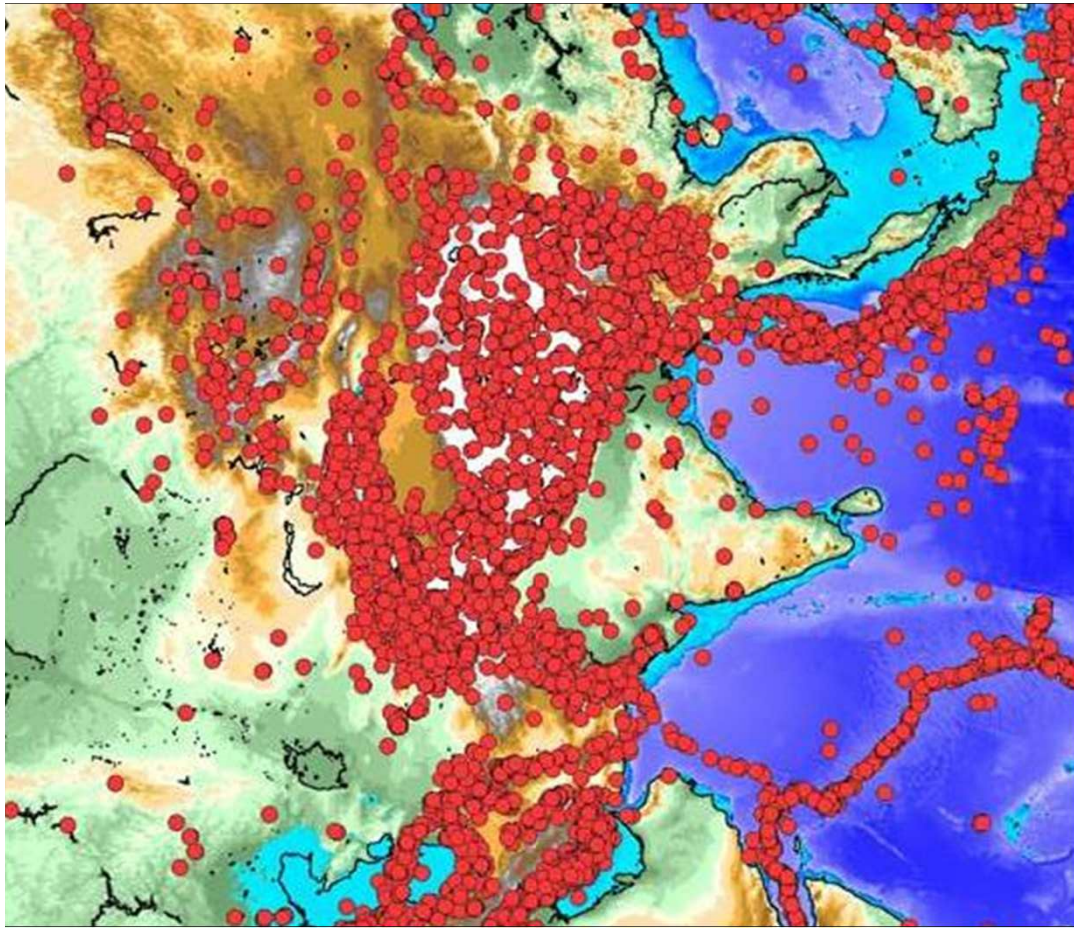
Alan Smith

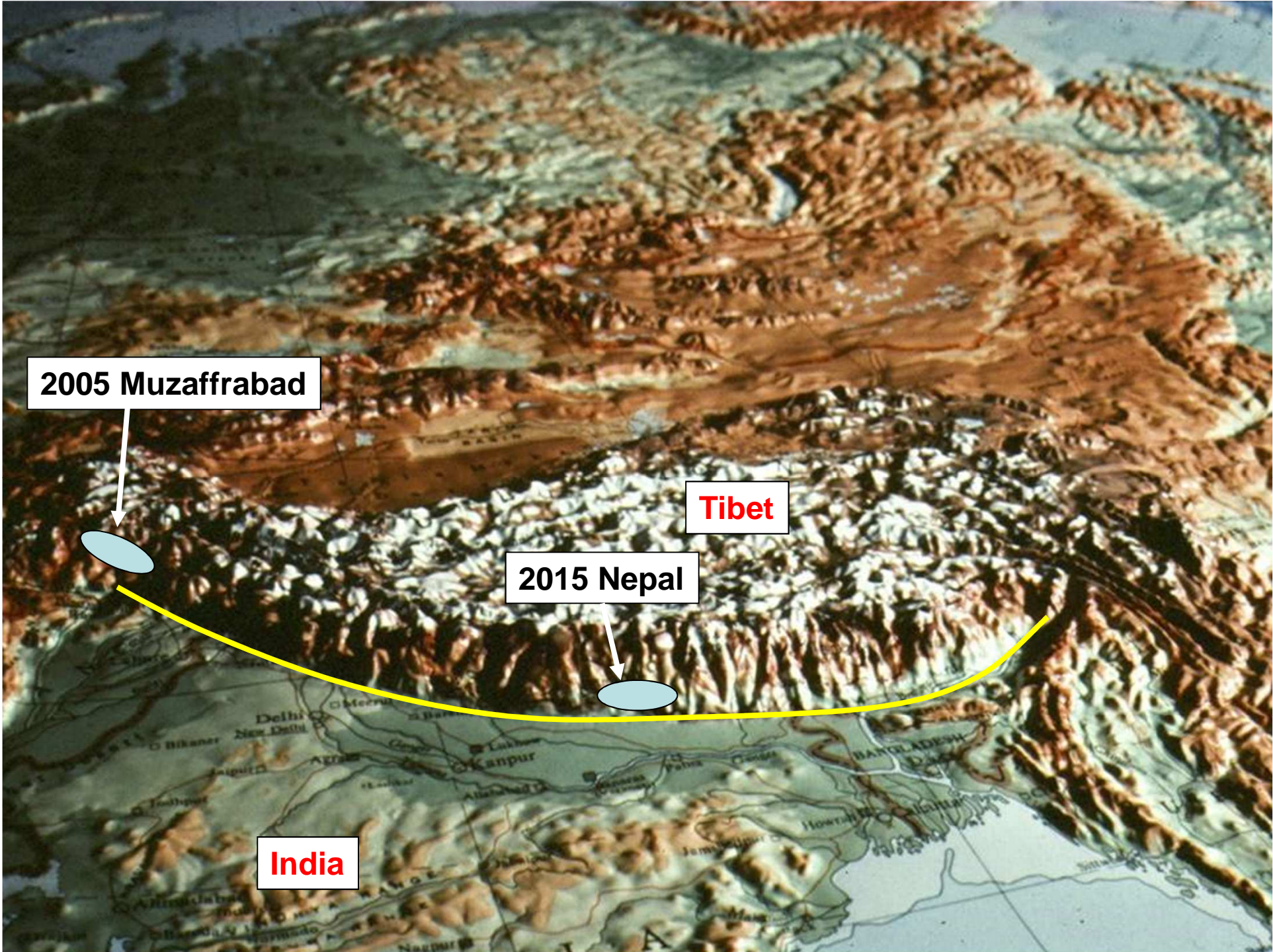
Today

0



Alan Smith



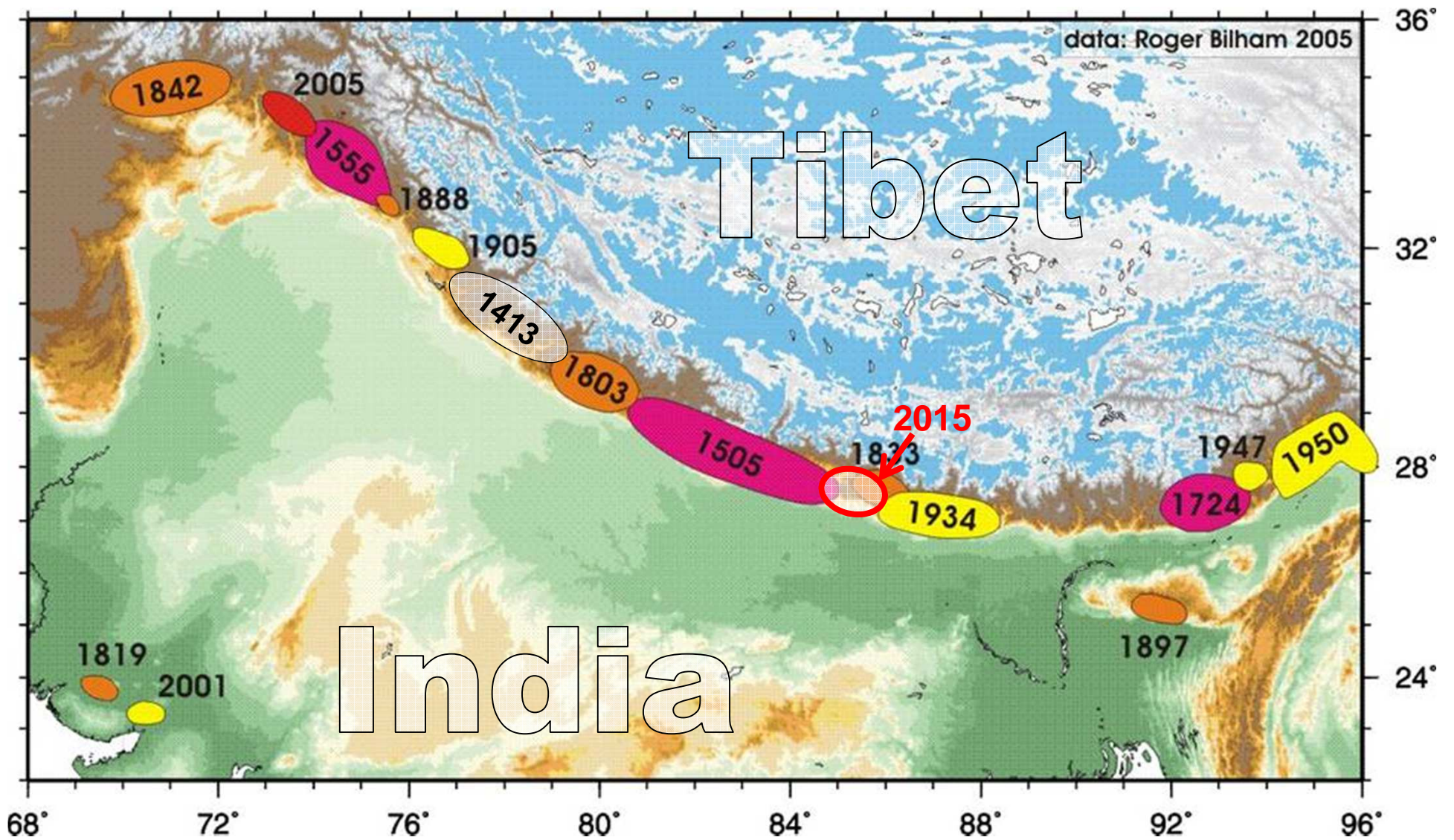


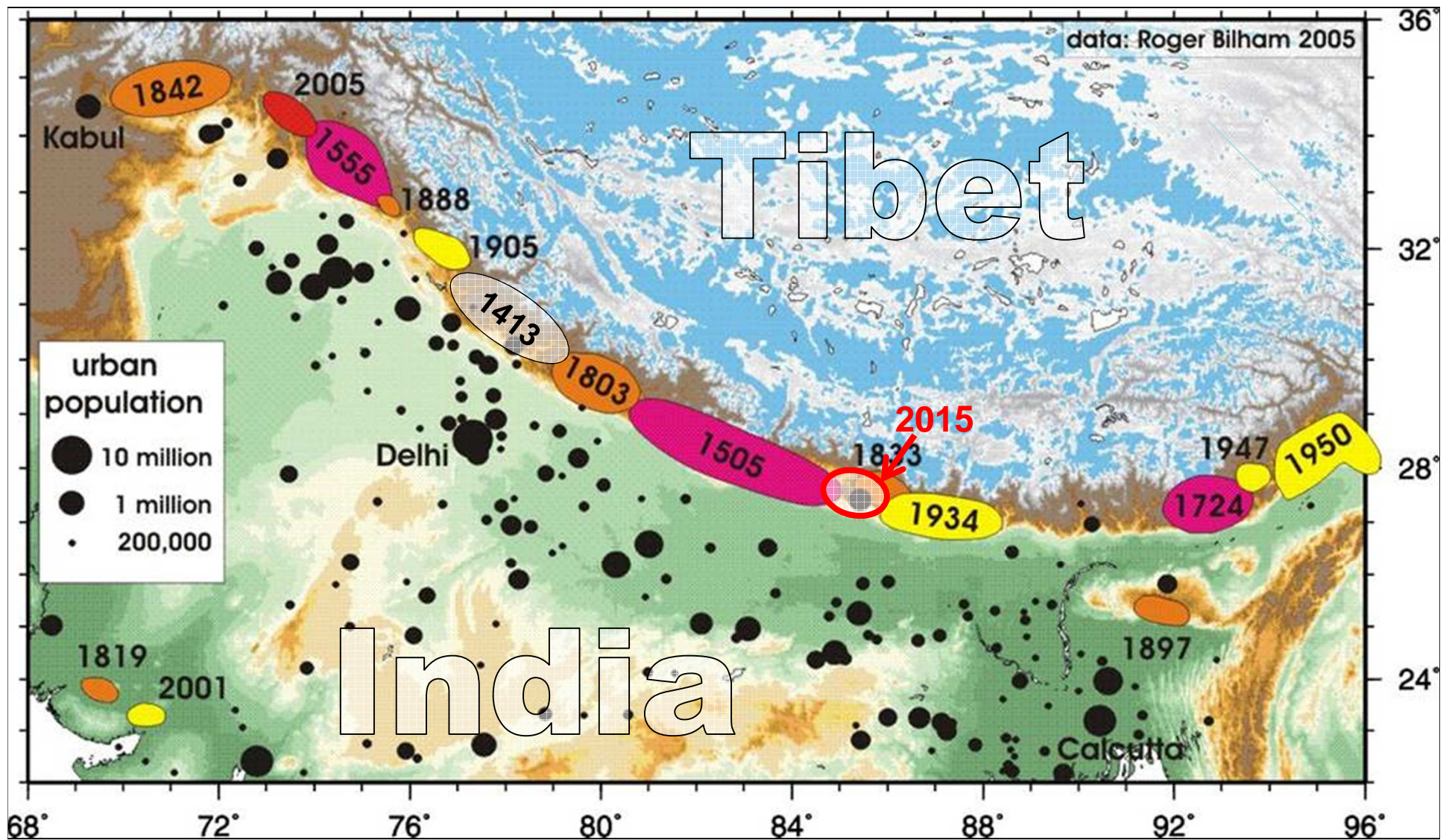
2005 Muzaffabad

Tibet

2015 Nepal

India



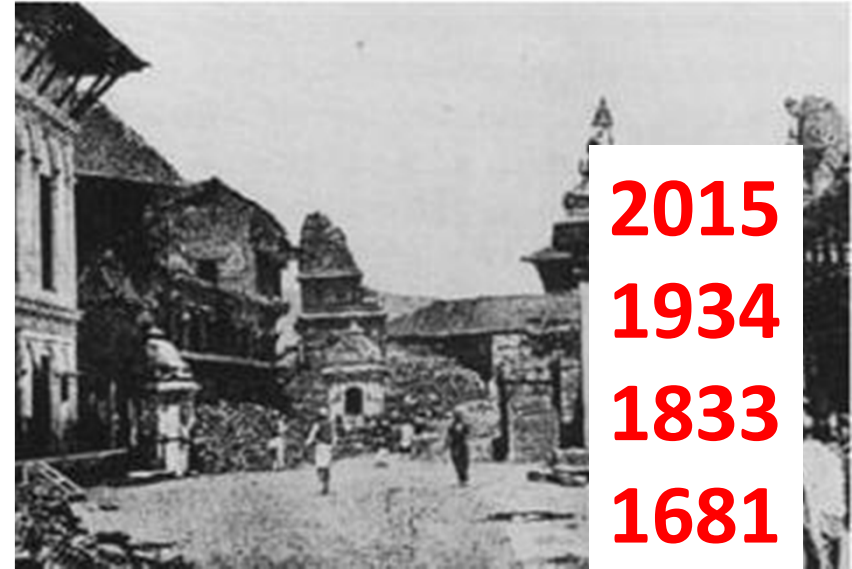




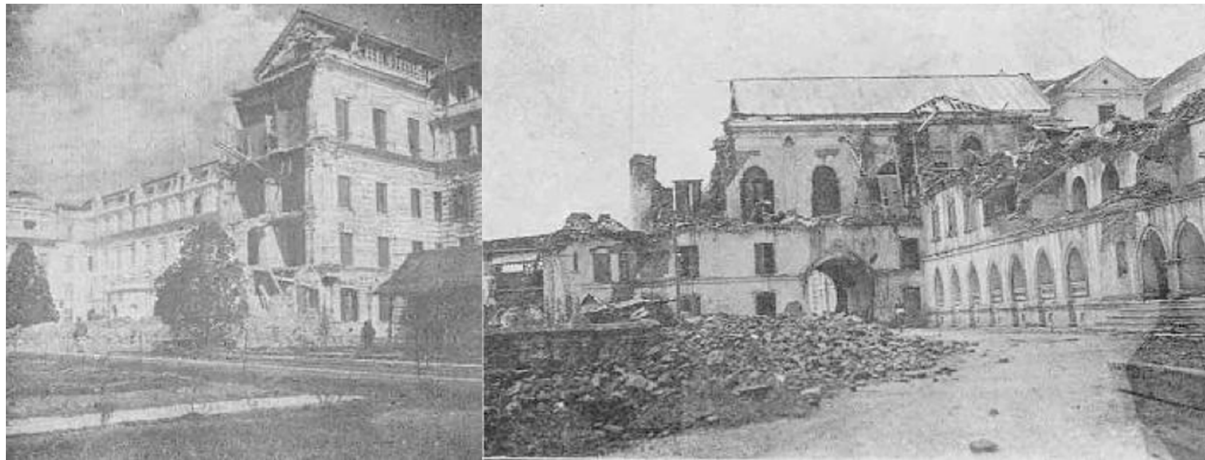
# 1934 $M_W \sim 8.1$ Bihar-Nepal earthquake



Durbar Square Bhaktapur



2015  
1934  
1833  
1681  
1401  
1344  
1255  
...



Royal palace, Kathmandu



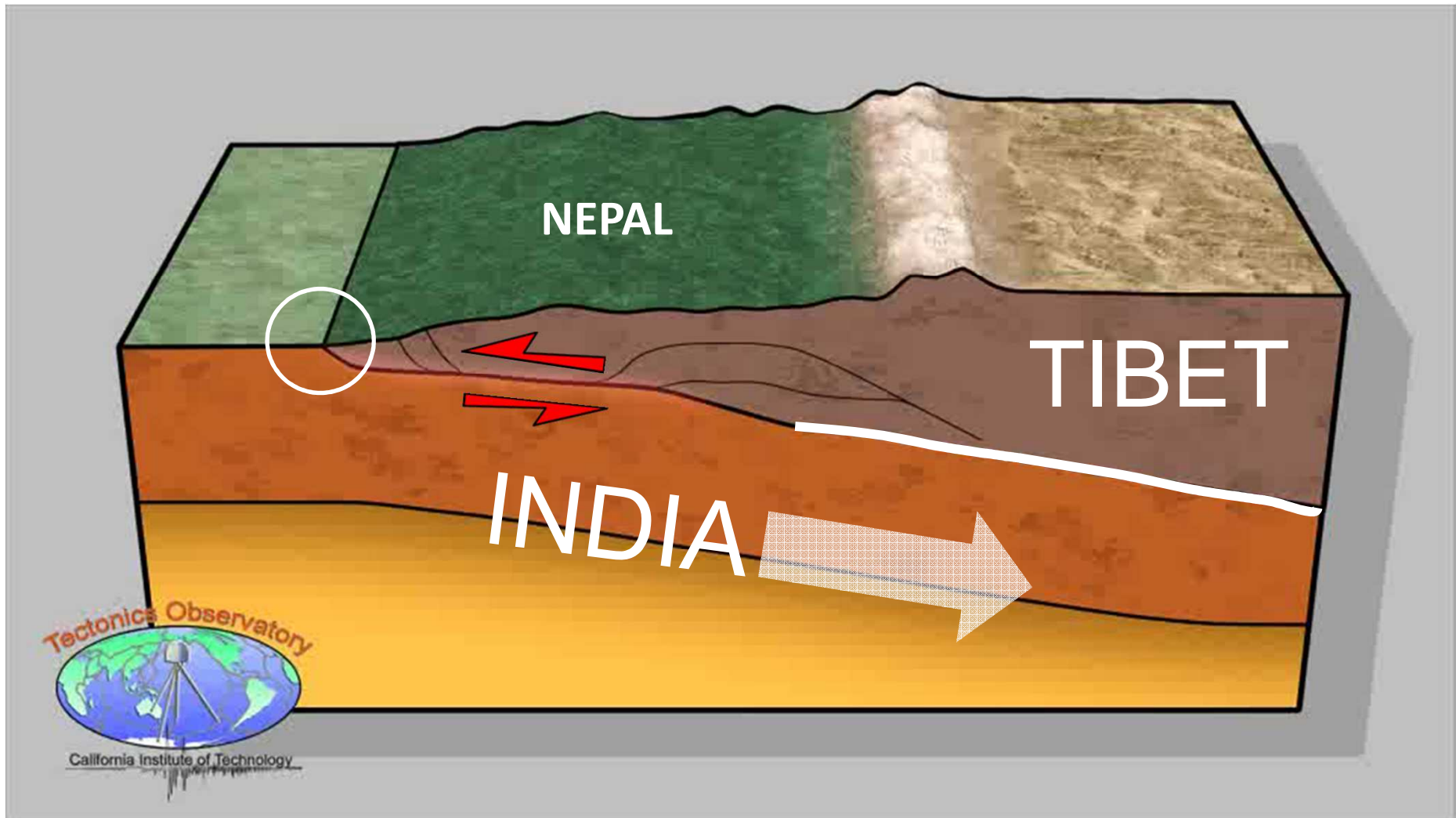
Degutale temple, Patan

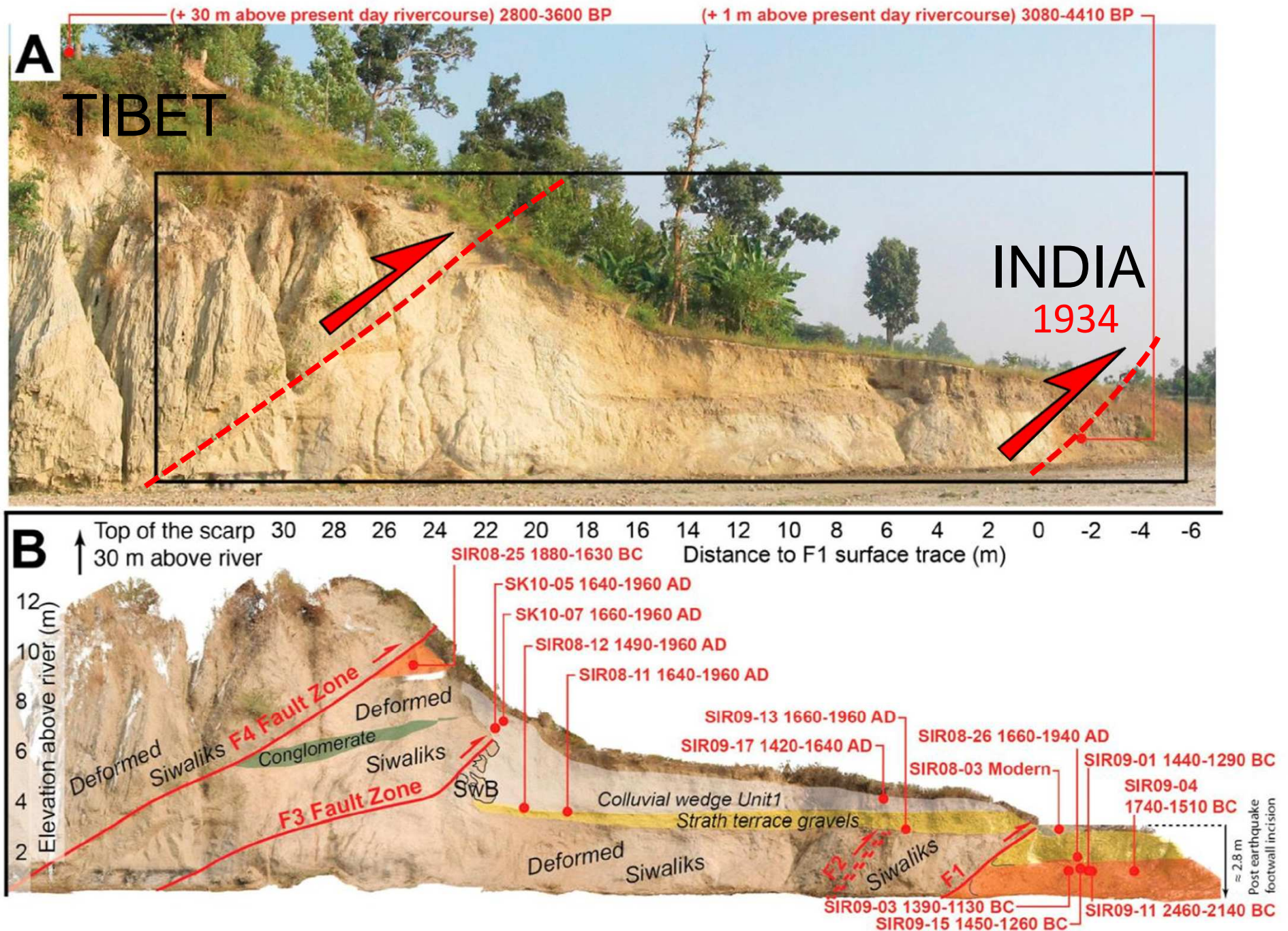


1934 Bihar



Jawaharlal Nehru





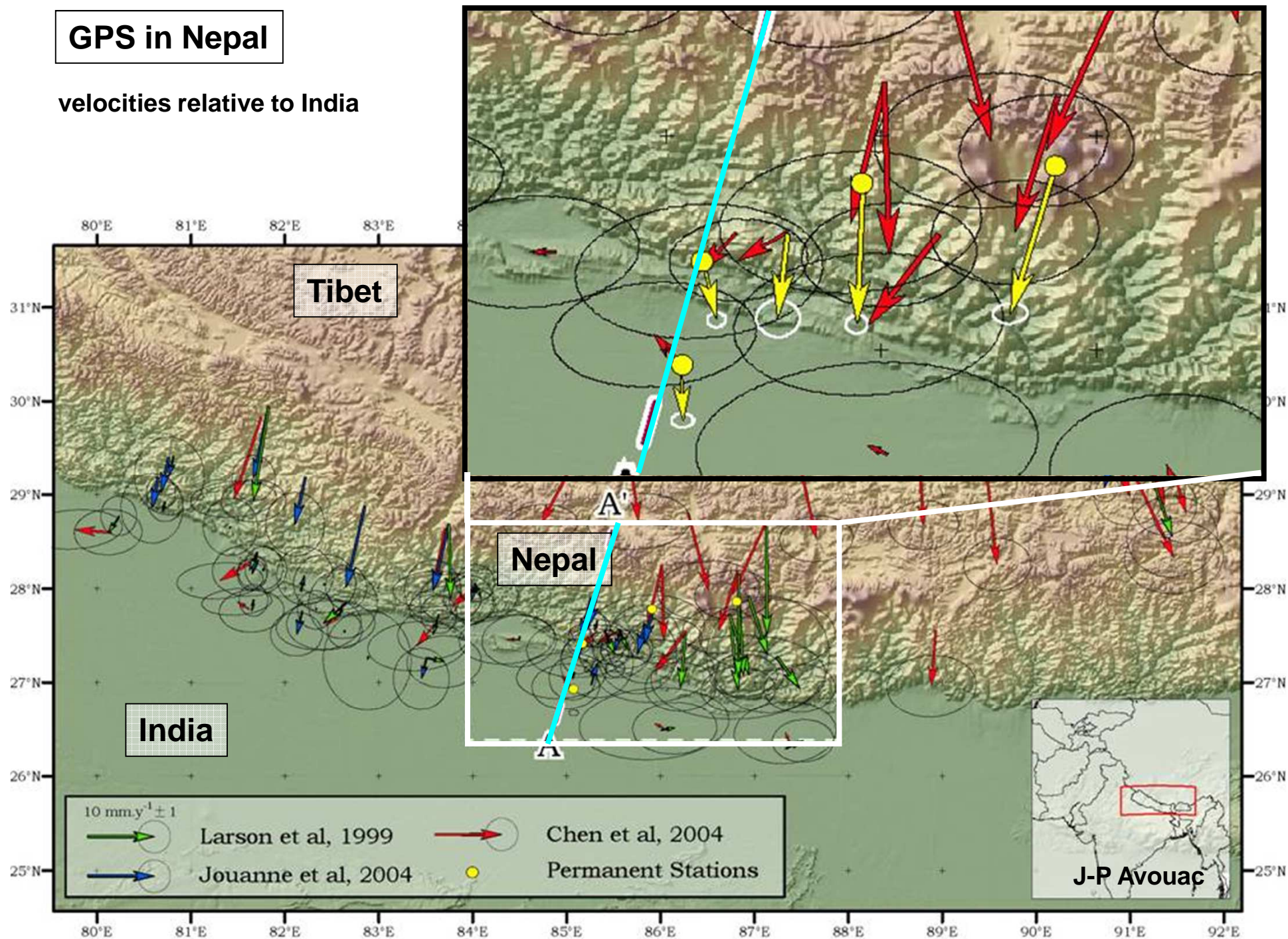
Bollinger et al., 2014, *JGR*, Fig8; also Sapkota et al, 2013, *Nature Geoscience*

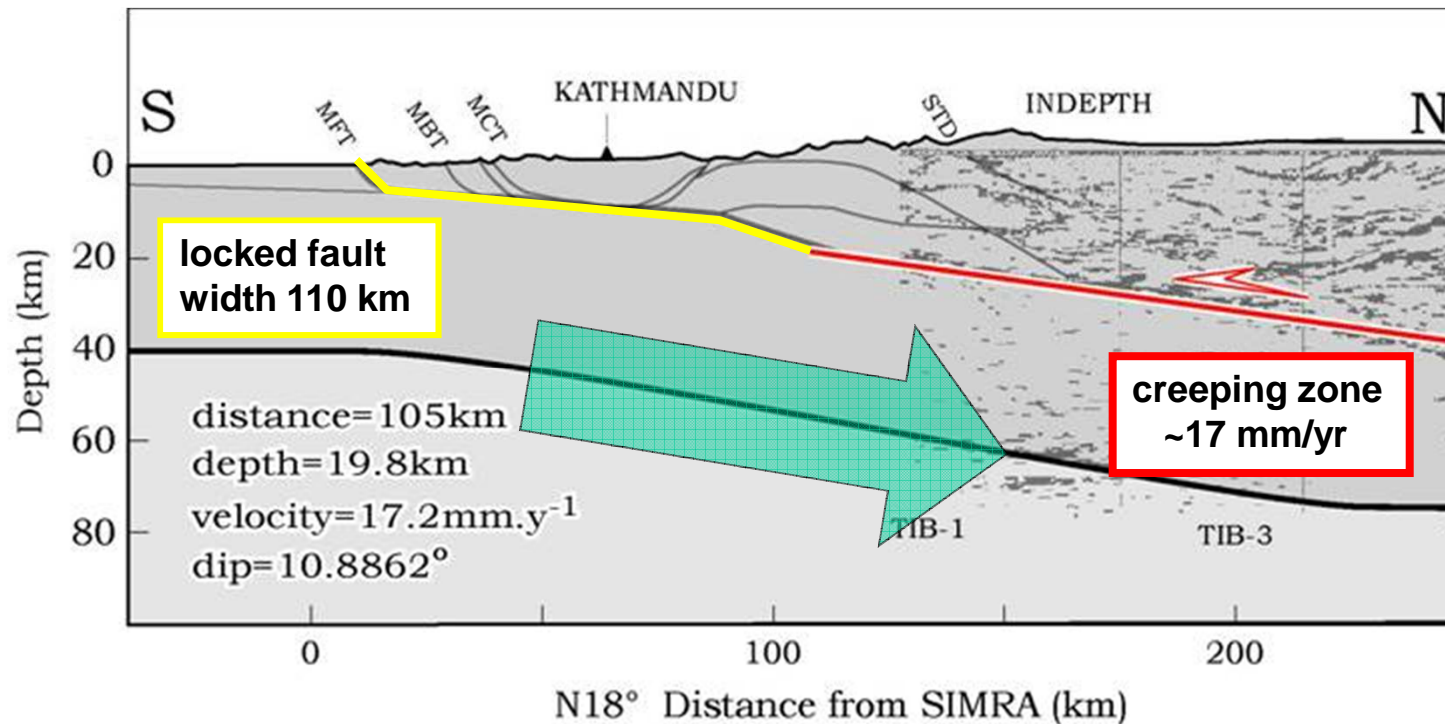
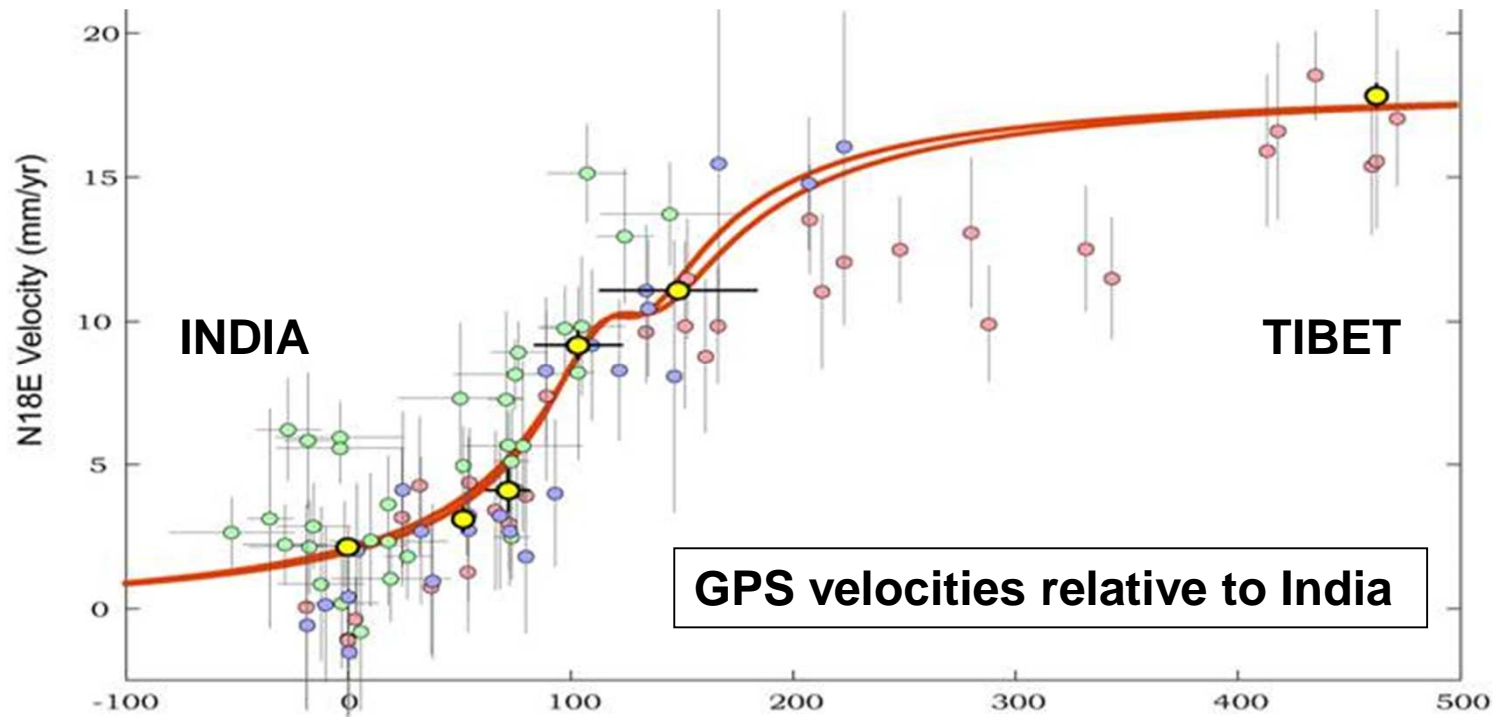
Before the earthquake.... monitoring with GPS

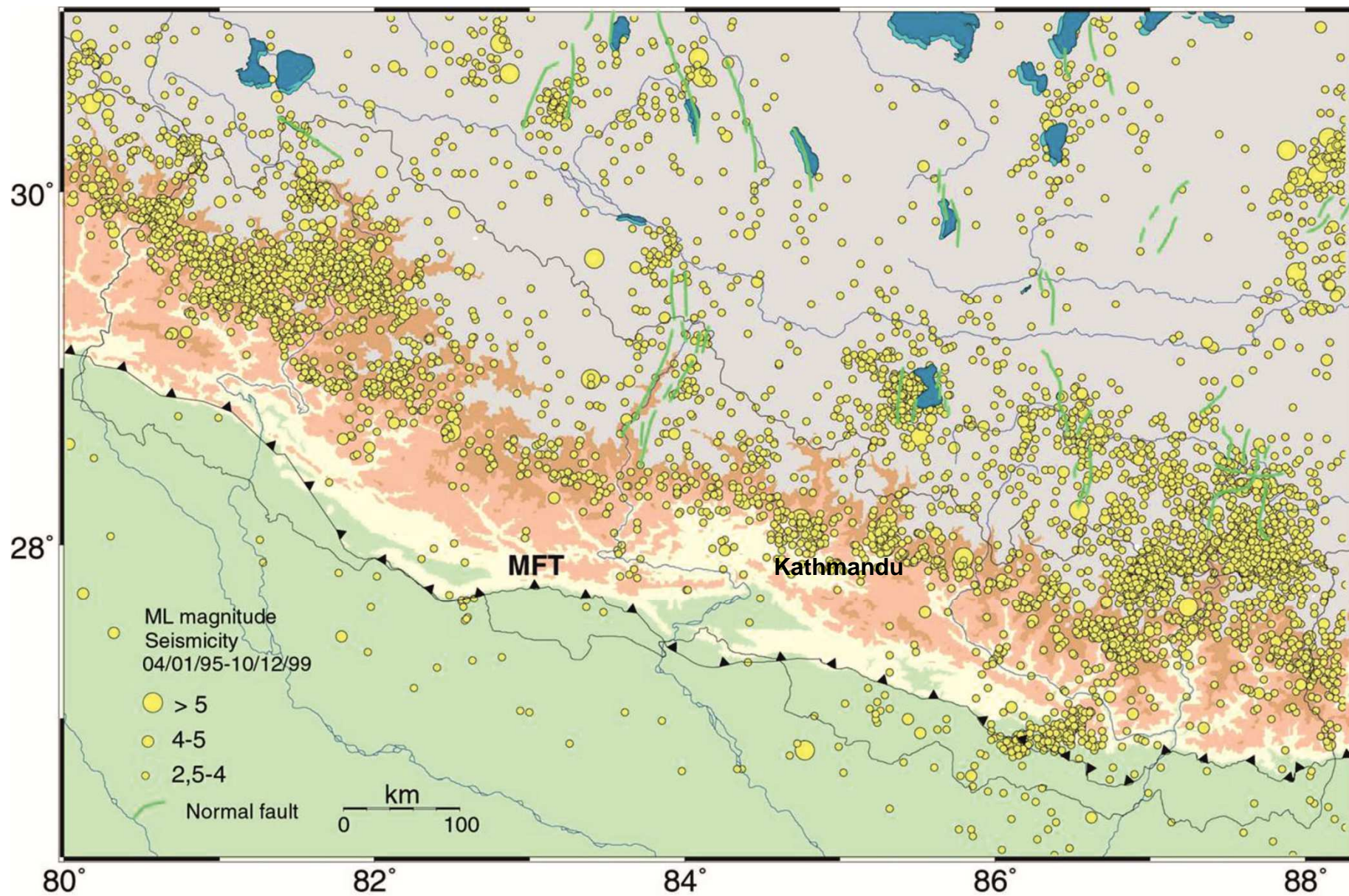


# GPS in Nepal

velocities relative to India

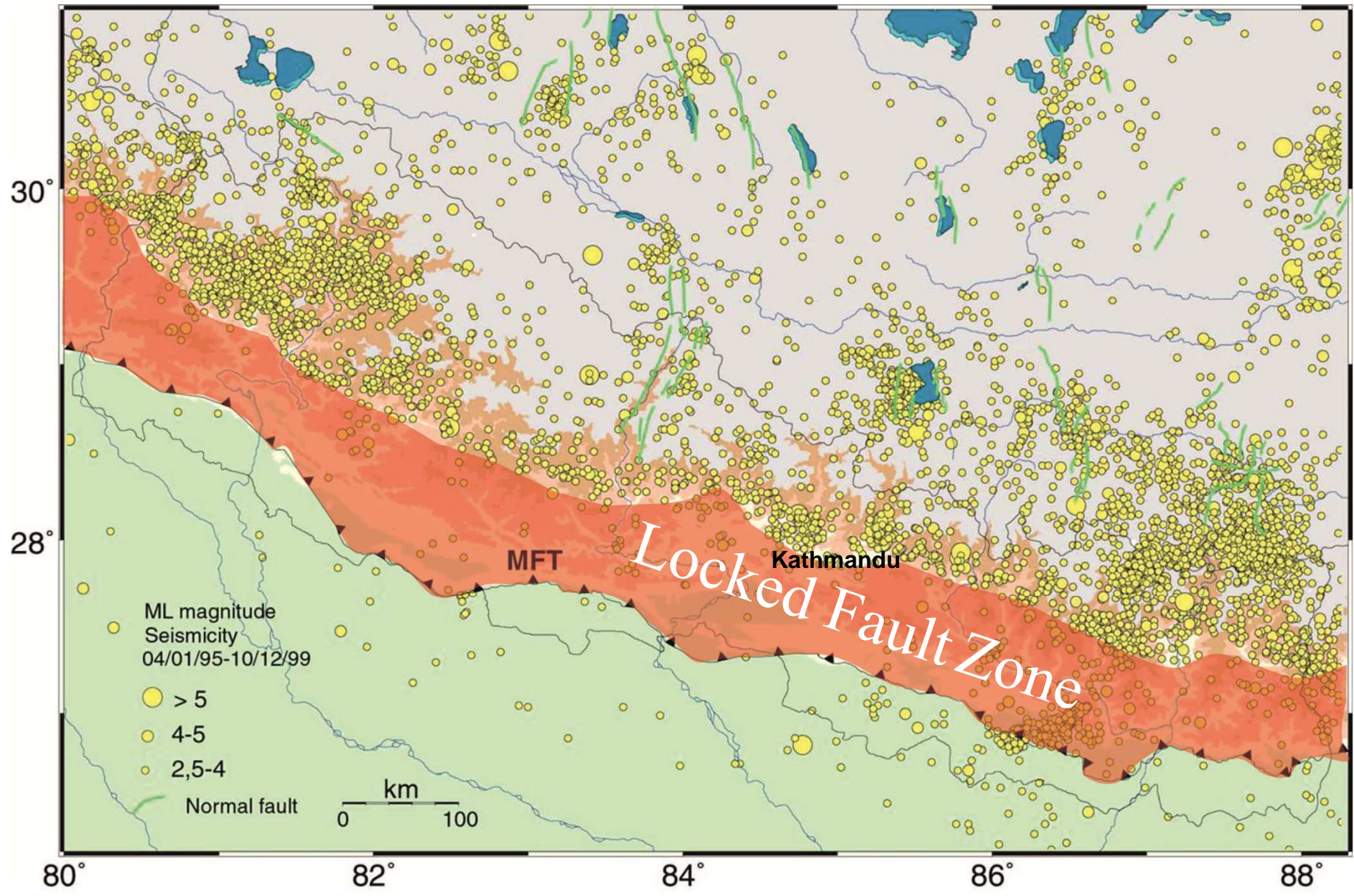


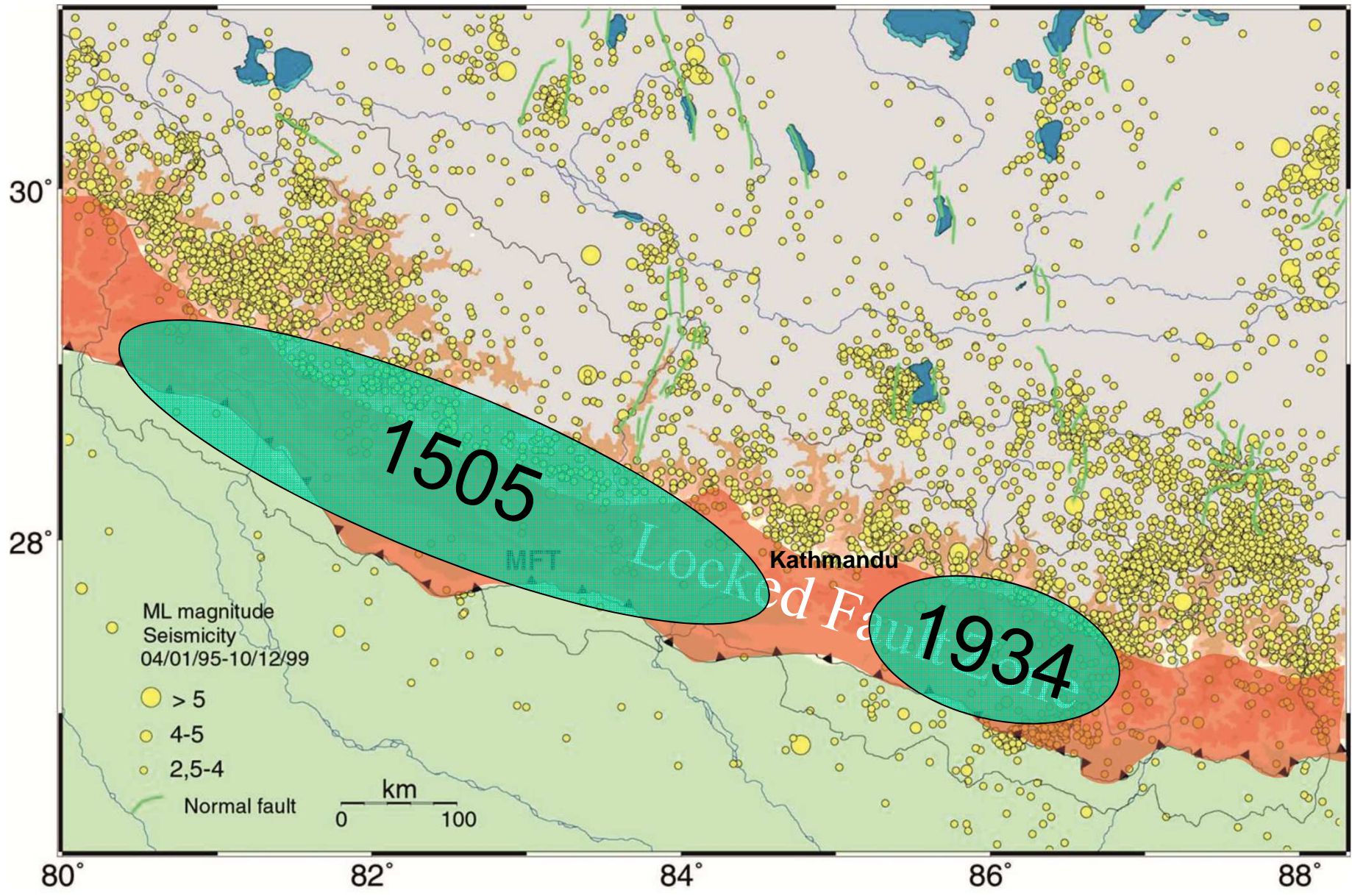




Earthquakes 1995-1999









J-P Avouac

# The Mw 7.8 Gorkha Earthquake, Nepal Preliminary Observations



John Elliott

**Jean-Philippe Avouac**

Bullard Laboratories  
University of Cambridge

## Collaborators

Vicky Stevens  
Kristel Chanard  
Thomas Ader  
Marion Thomas  
Pierre Bettinelli  
Laurent Bollinger  
Francois Ayoub  
Rodolphe Cattin  
Jerome Lave

John Galeztko  
Jeff Genrich  
Mireille Flouzat  
Diego Melgar  
Shengji Wei  
Jean-Paul Ampuero  
Lingsen Meng  
Teng Wang

+ John Elliott (Oxford)

Keith Priestley (Cambridge)

## National Seismic Center (DMG, Nepal):

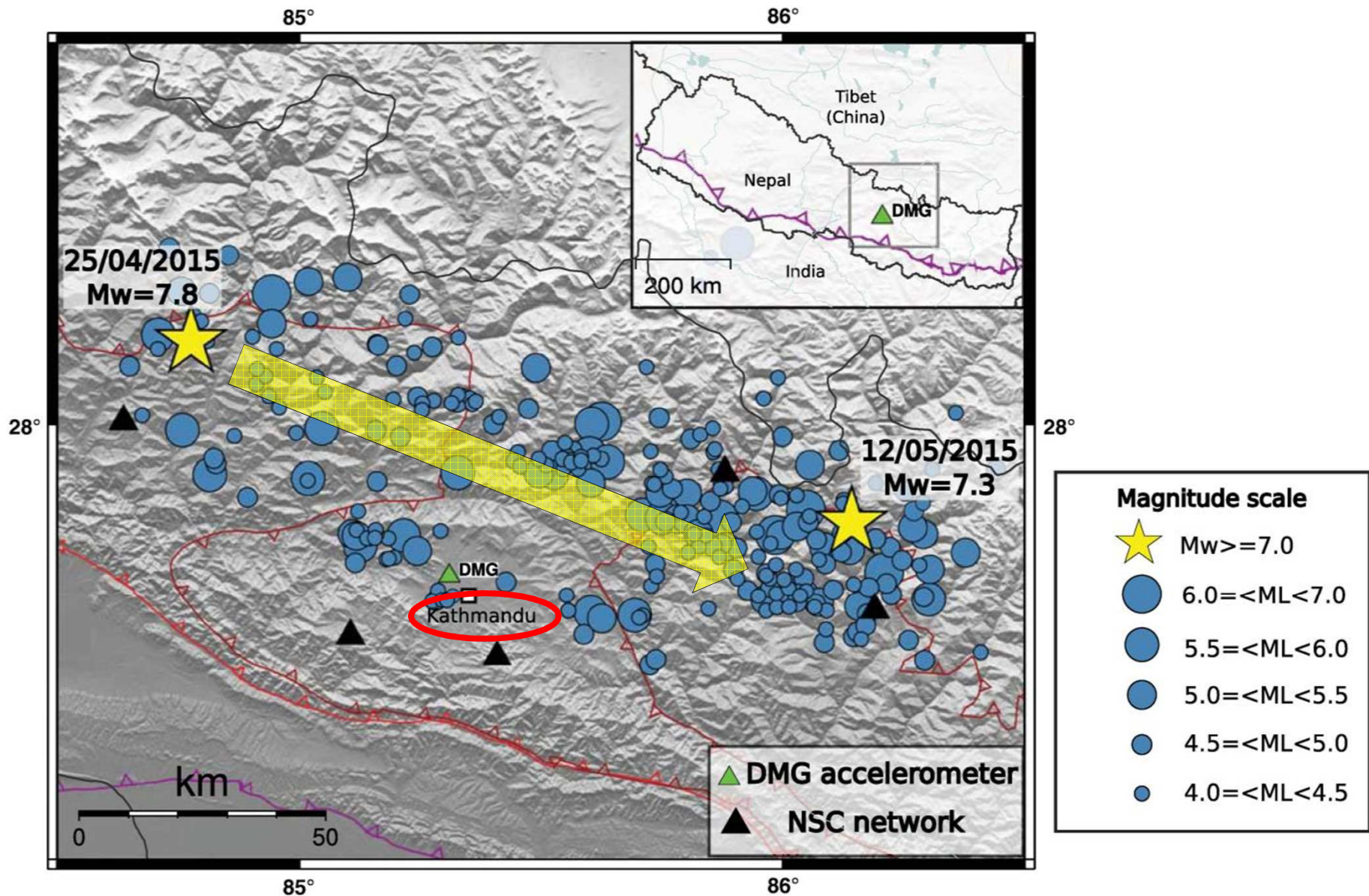
Madhab Pandey  
Sudhir Rajaure  
Som Sapkota

## Institute for Tibet Research (China)

Jing Liu

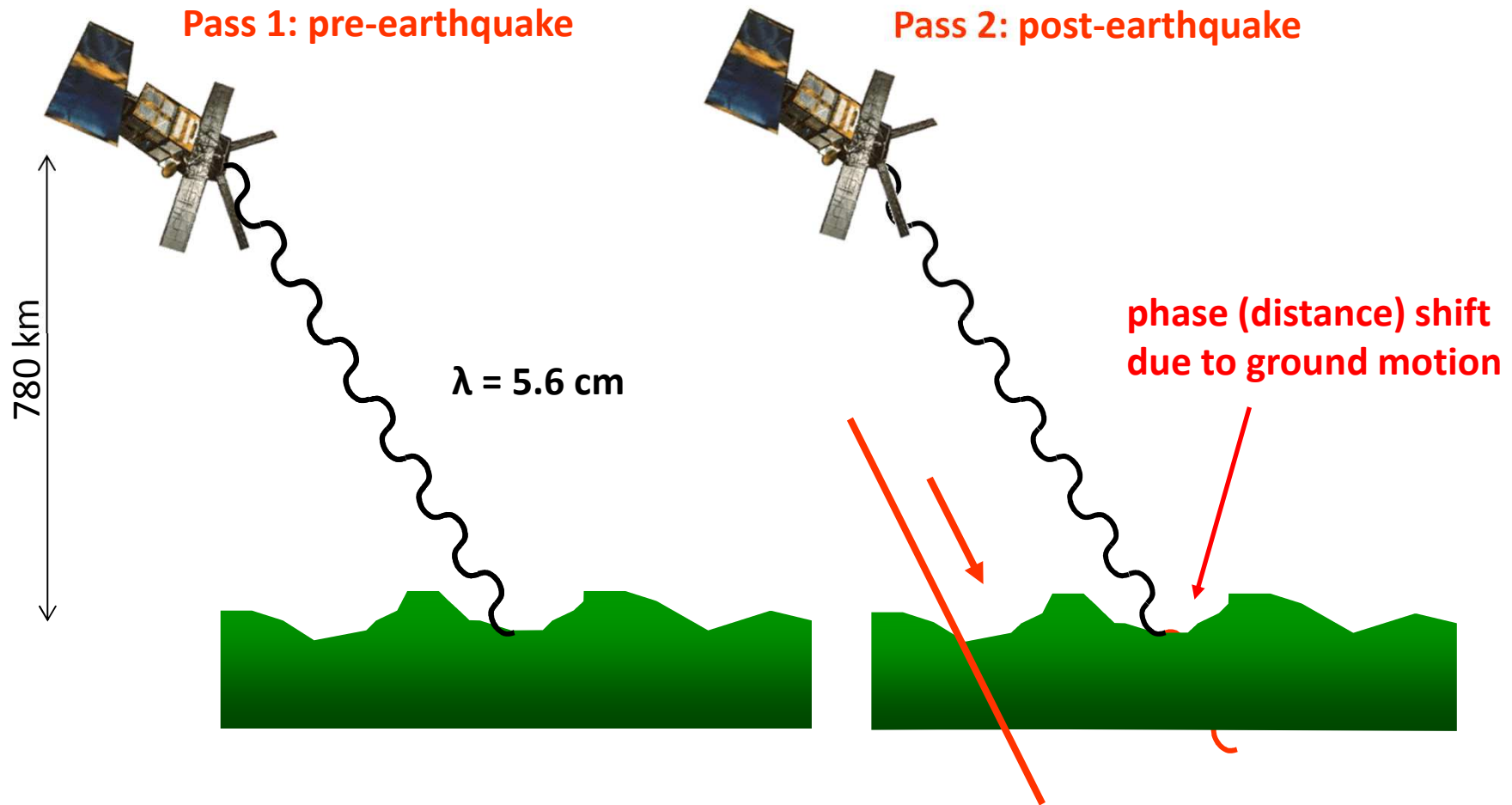
## IISER Kolkata (India)

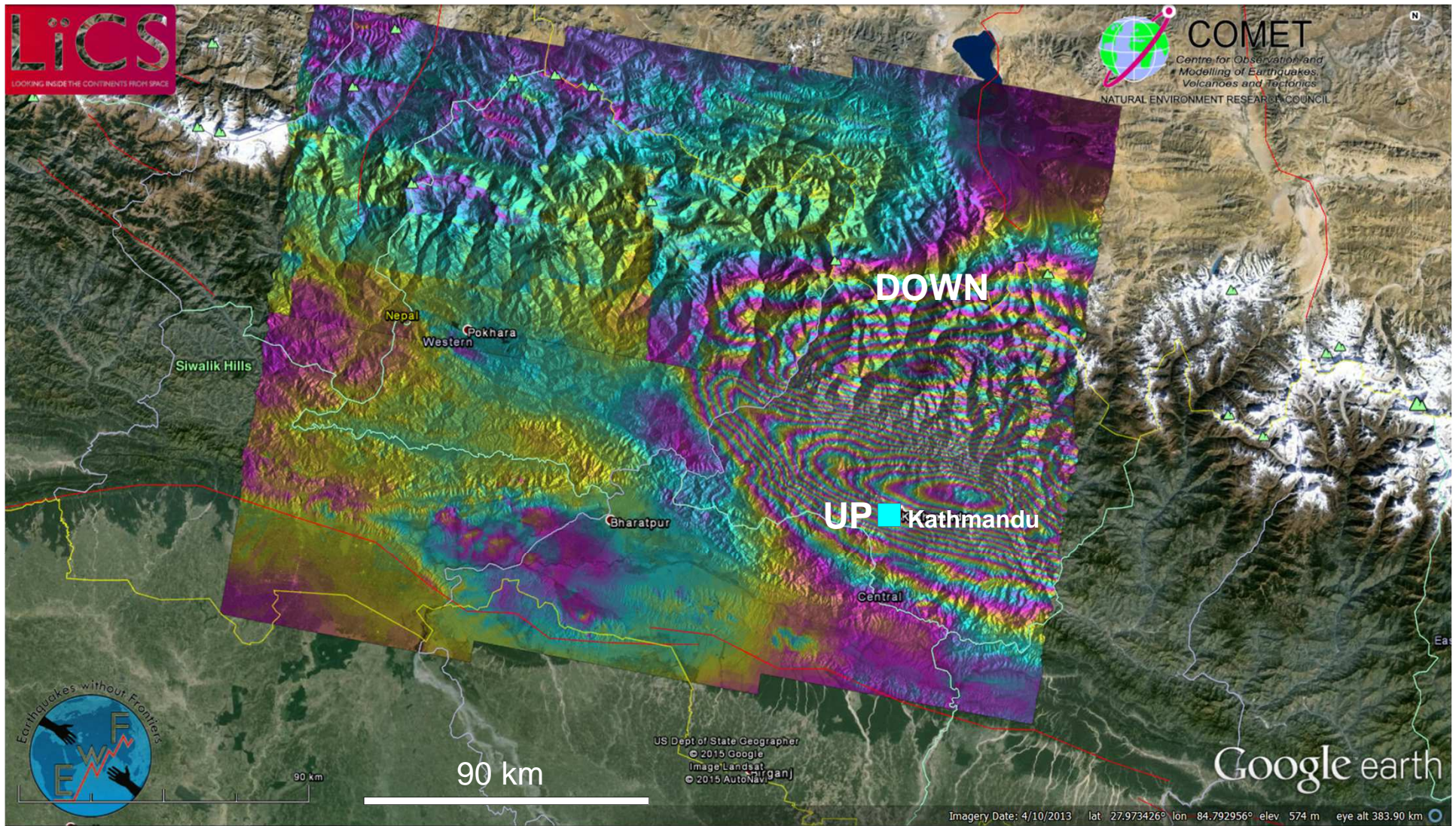
Supriyo Mitra



Aftershocks M>4 until 14 May 2015

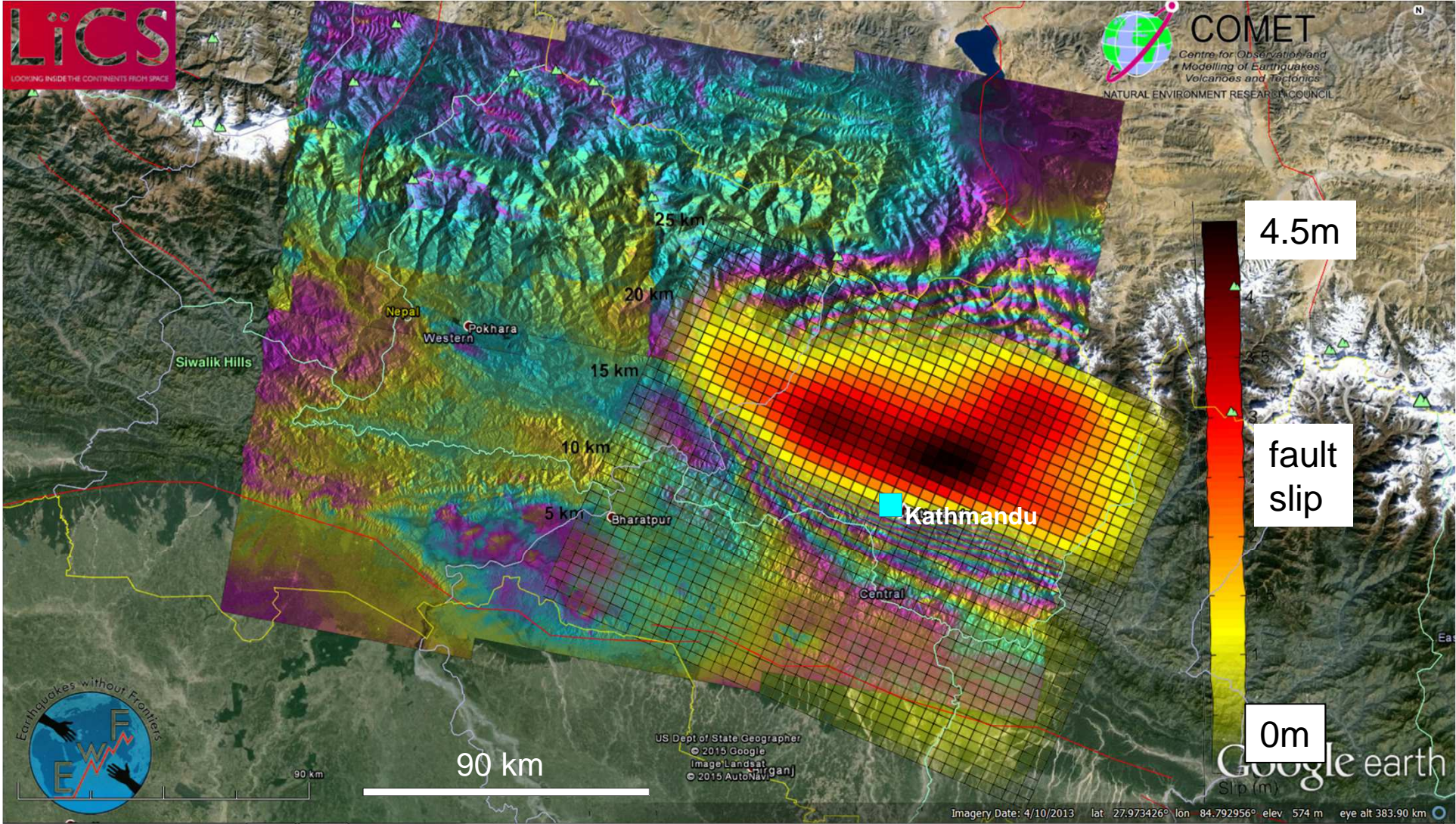
# Radar interferometry



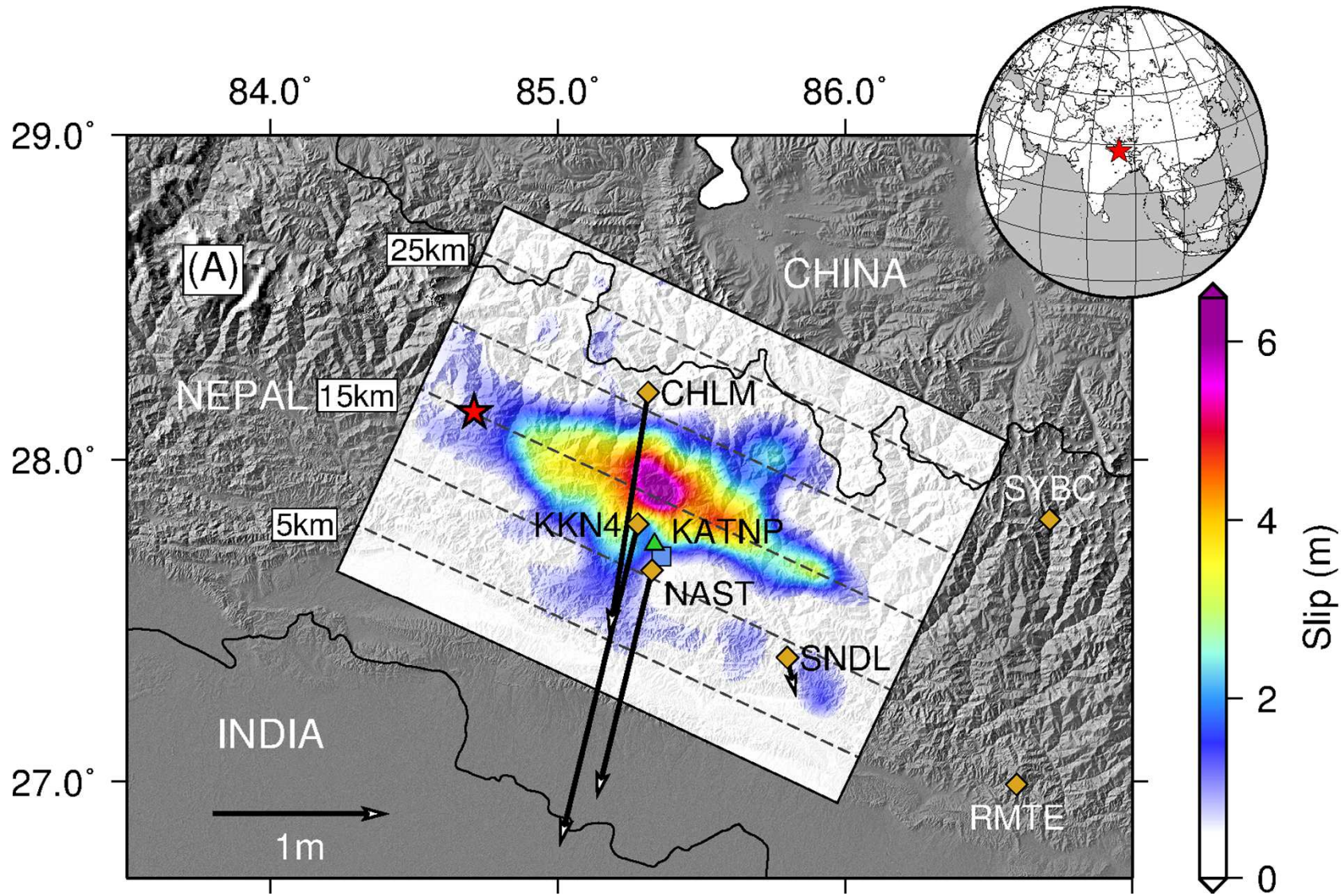


Changes in line-of-sight distance to satellite  
(each fringe = 10cm)

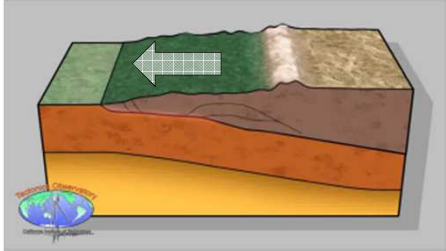
John Elliott



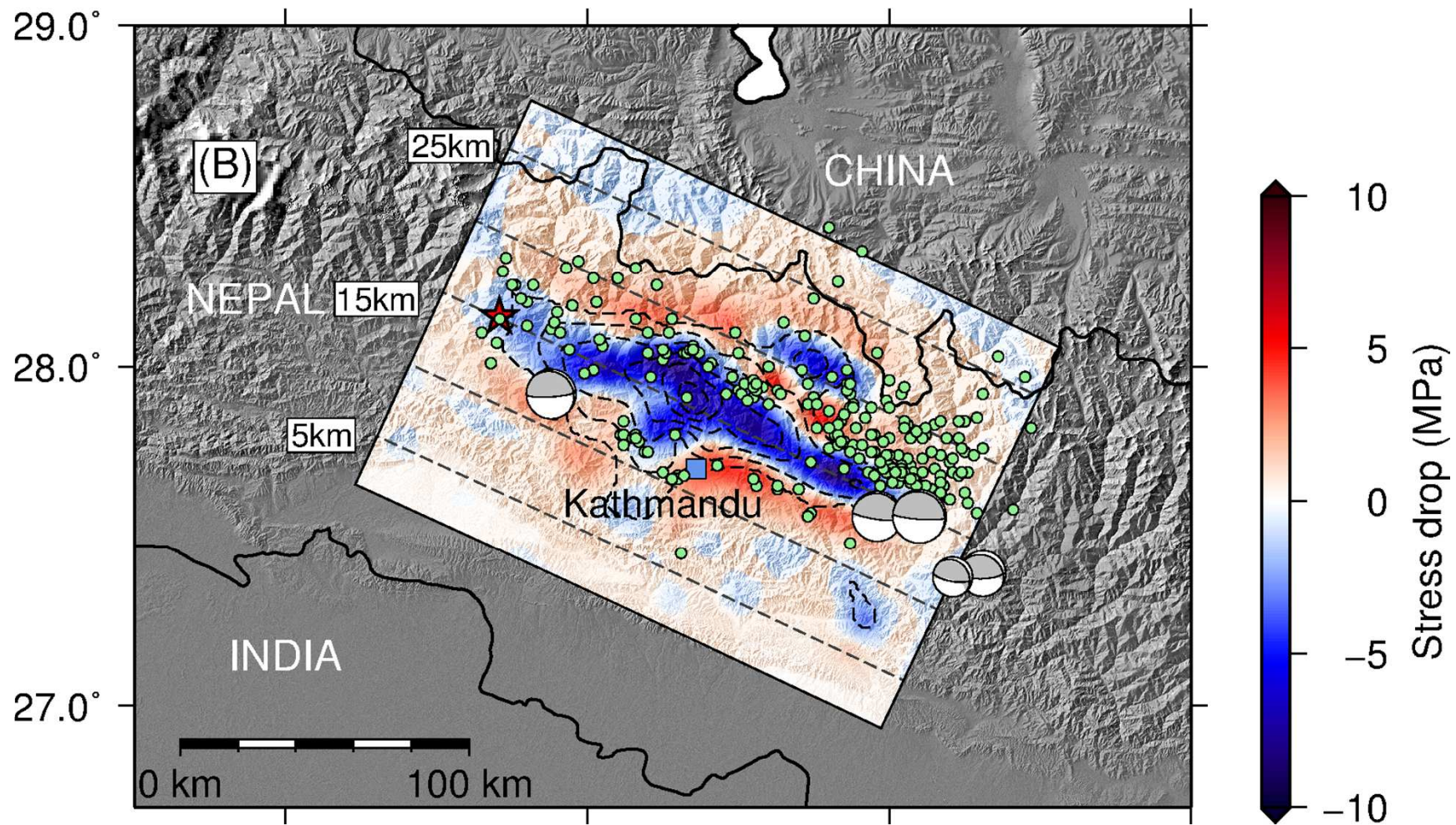
John Elliott



***Fault slip*** in the earthquake





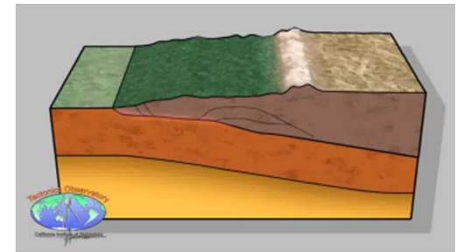
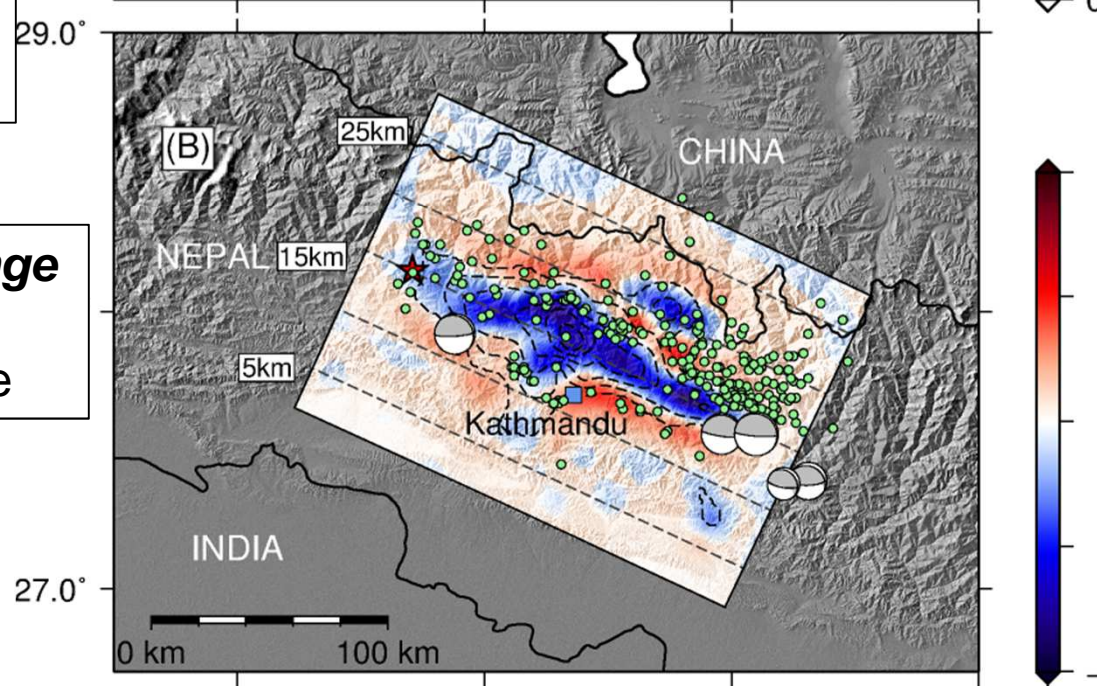
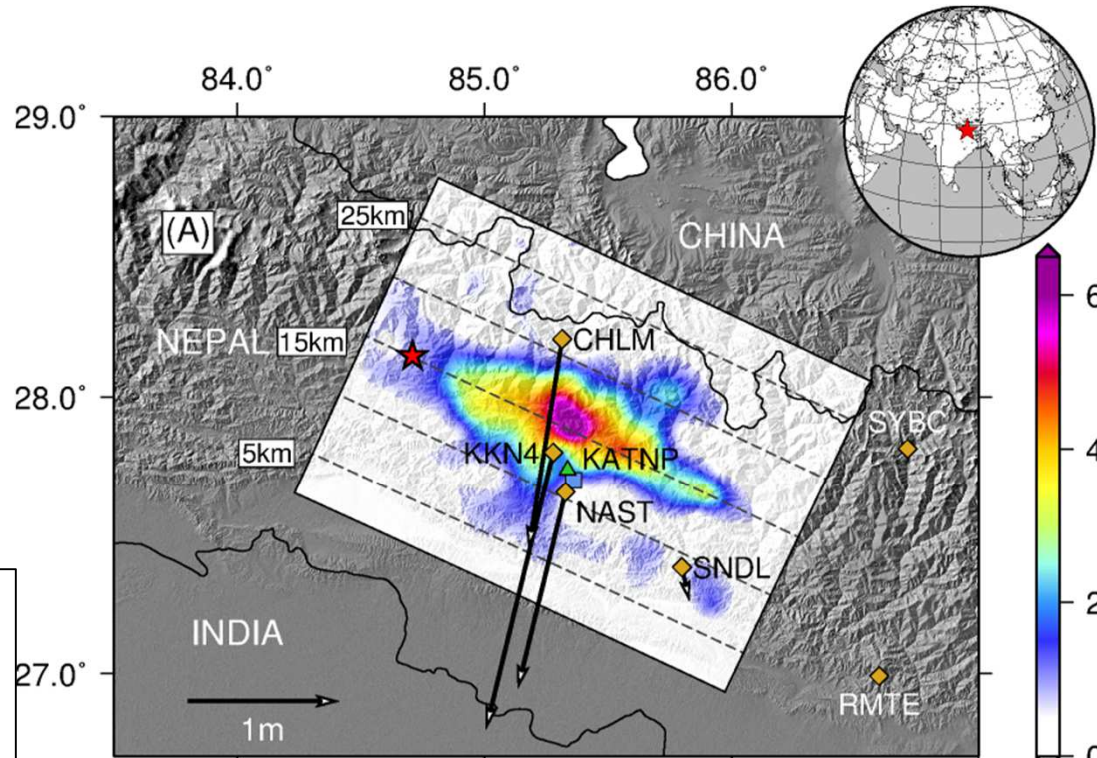


***Change of stress in the earthquake***

**Fault slip**  
in the  
earthquake

**After the  
mainshock,  
before the  
12 May  
aftershock**

**Stress change**  
in the  
earthquake

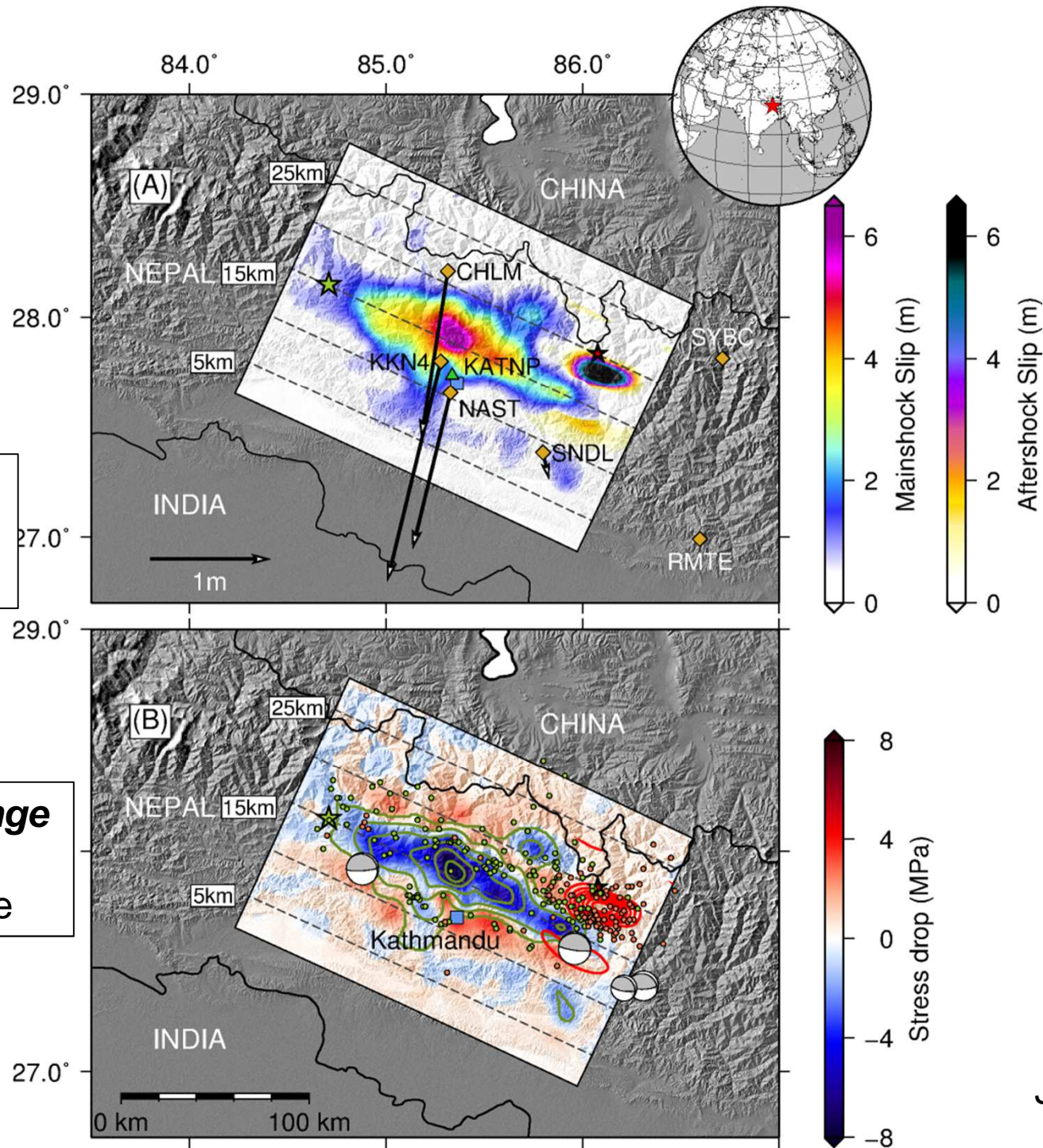


J-P Avouac

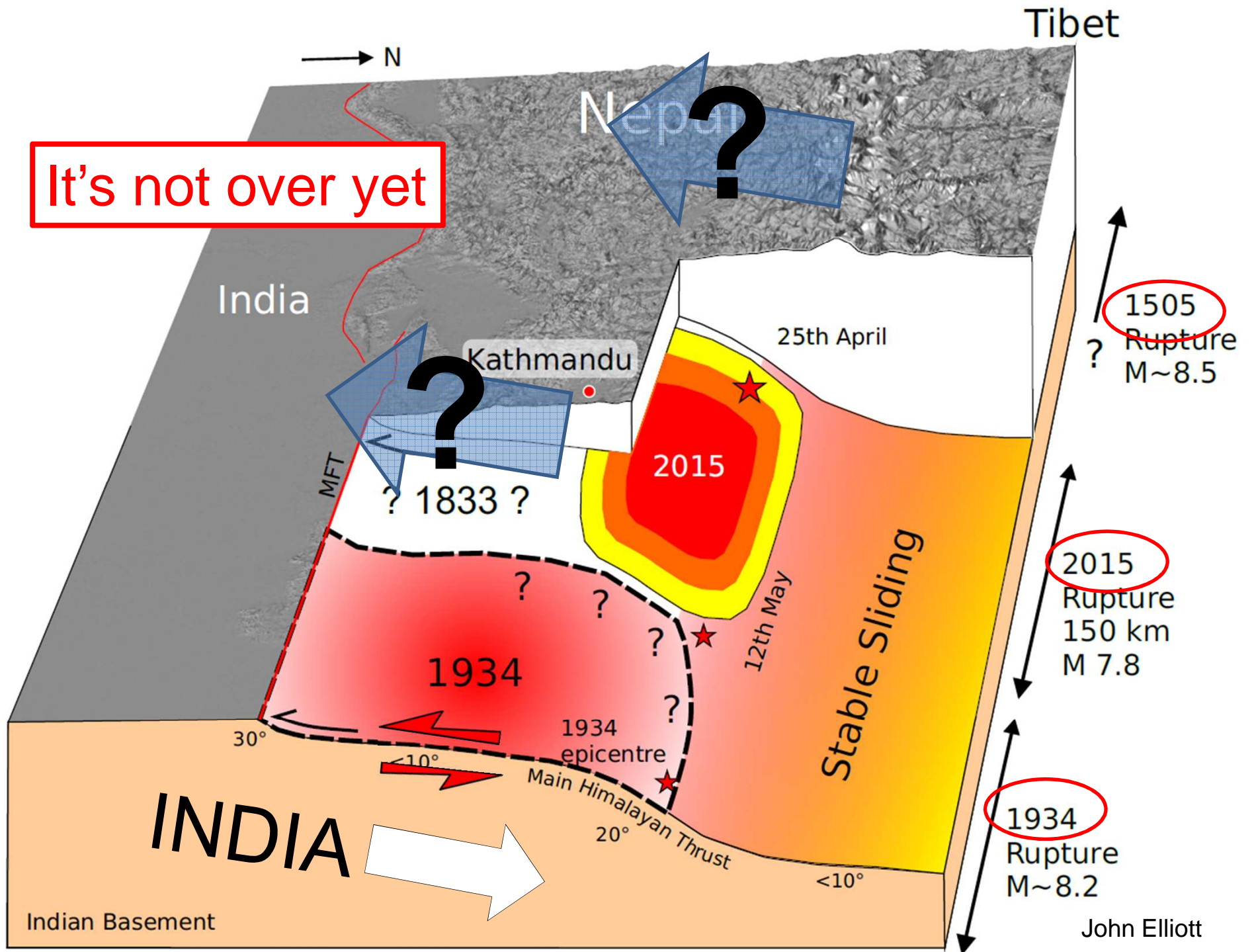
**Fault slip**  
in the  
earthquake

**After**  
the 12 May  
aftershock

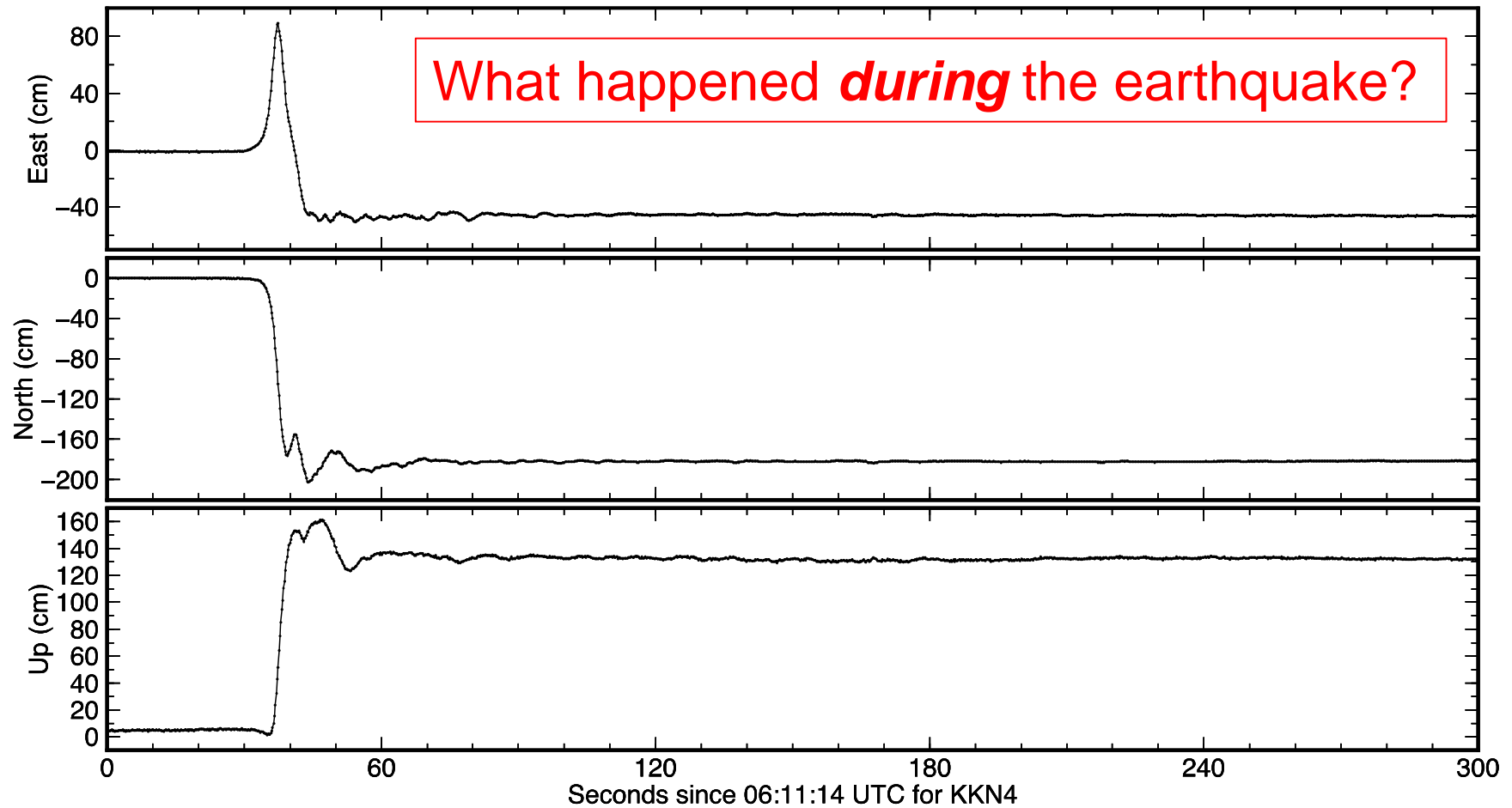
**Stress change**  
in the  
earthquake



J-P Avouac



# Displacement GPS seismogram at KKN4 north of Kathmandu



(5 samples/second)

Processed by SOPAC

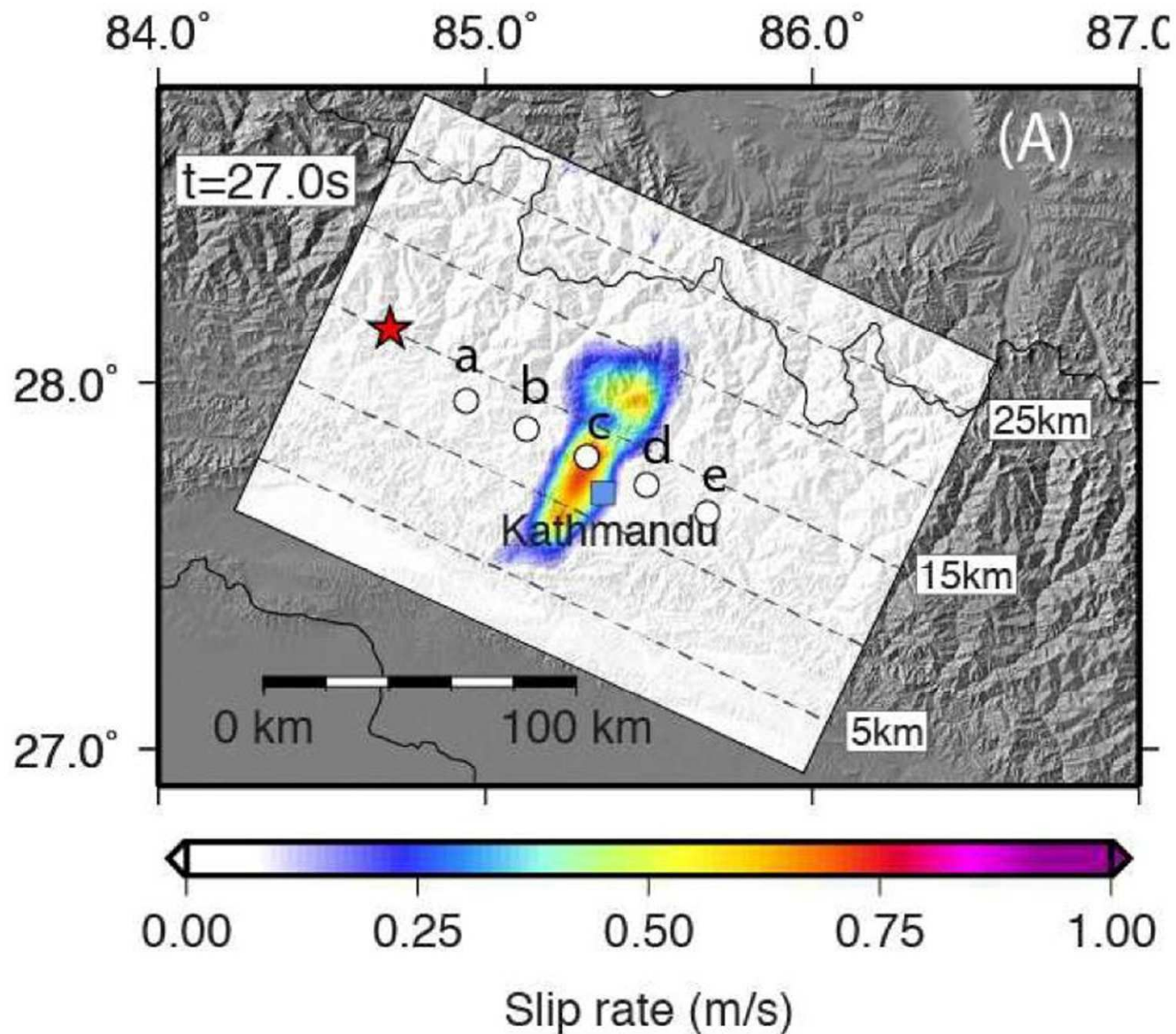


Figure 2 (From Galetzka et al, Science, in review): Image of the propagating slip pulse, 27s after initiation of the earthquake (location of initiation is indicated by the red star). This is the time of intense ground shaking in Kathmandu valley.

Diego Melgar

Kathmandu valley



... a former lake basin



Kathmandu pre-earthquake





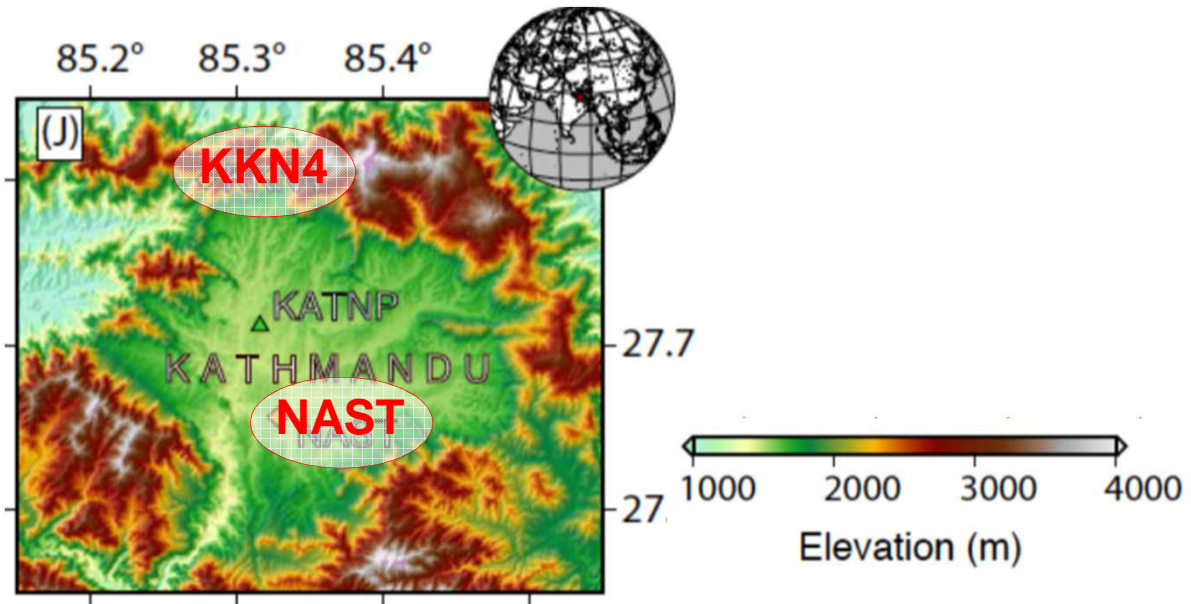
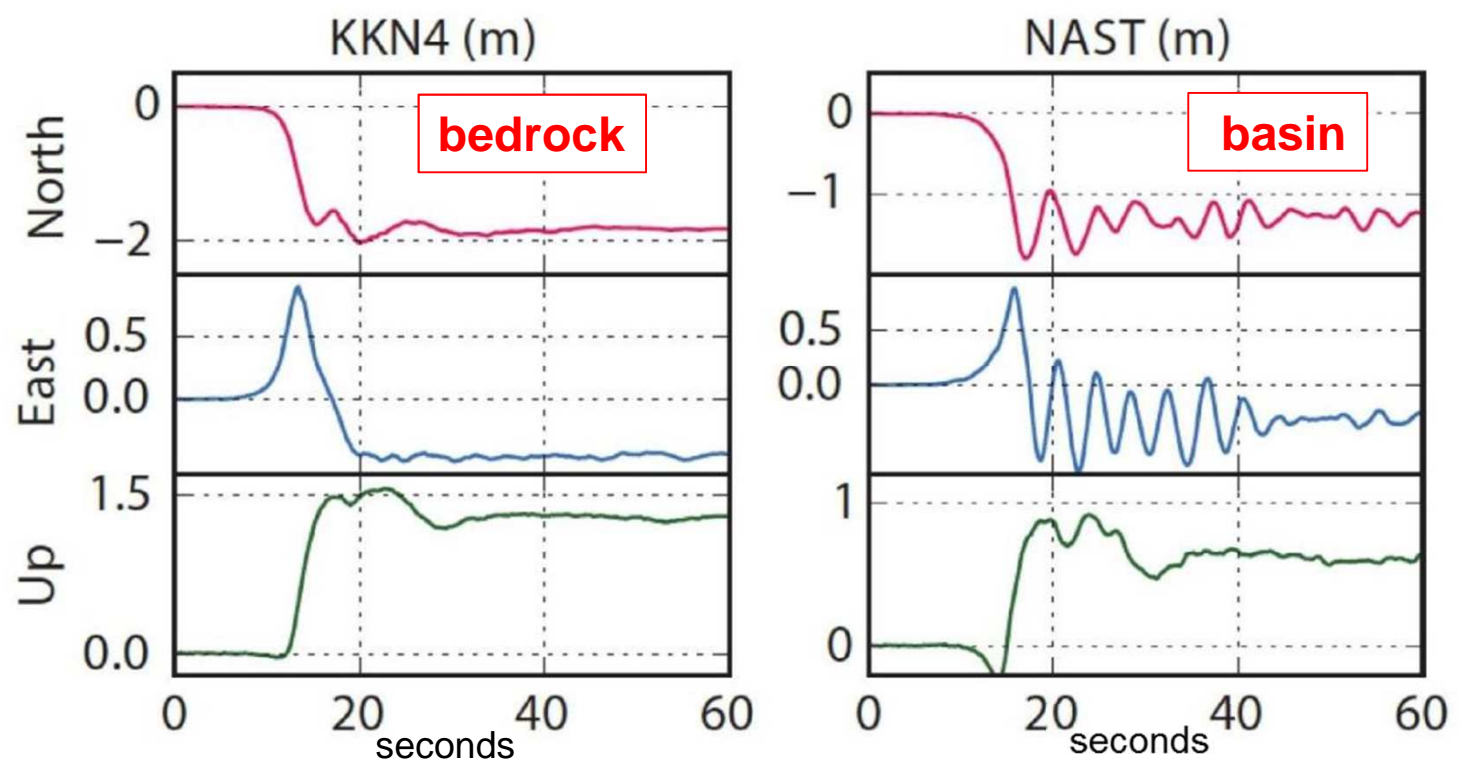
Kathmandu pre-earthquake

Kathmandu  
pre-earthquake

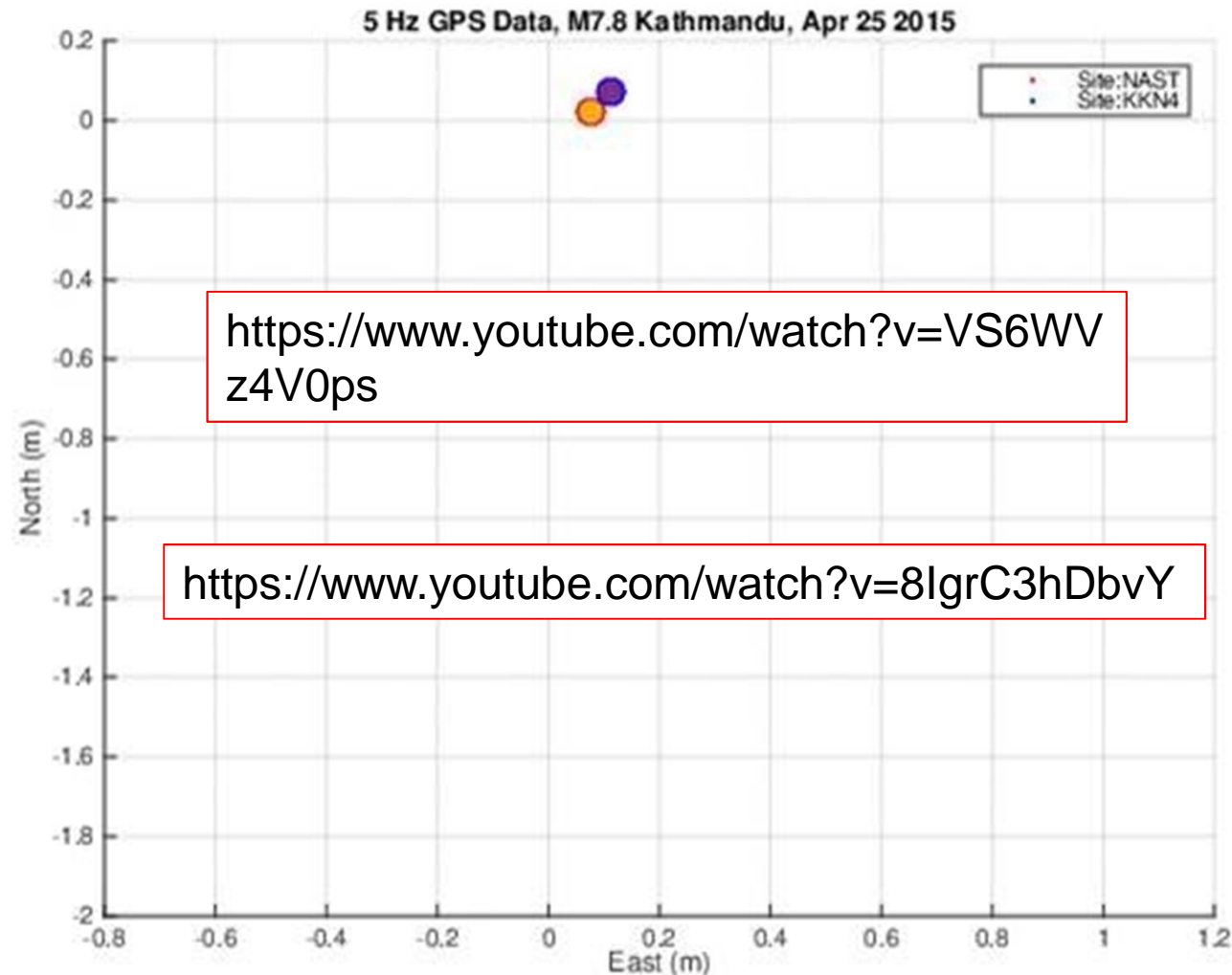


Kathmandu  
pre-earthquake





# Gorkha April 2015 Mw=7.8 earthquake



5 Hz GPS data  
from the  
Kathmandu Valley.  
Speeded up x5

Blue = bed rock  
Orange 650 m  
thick mud

Uplift 1 m  
Translation 2.2 m



Tomijung village



Majgaun (upper village)



Thulo Sabro

Roger Bilham

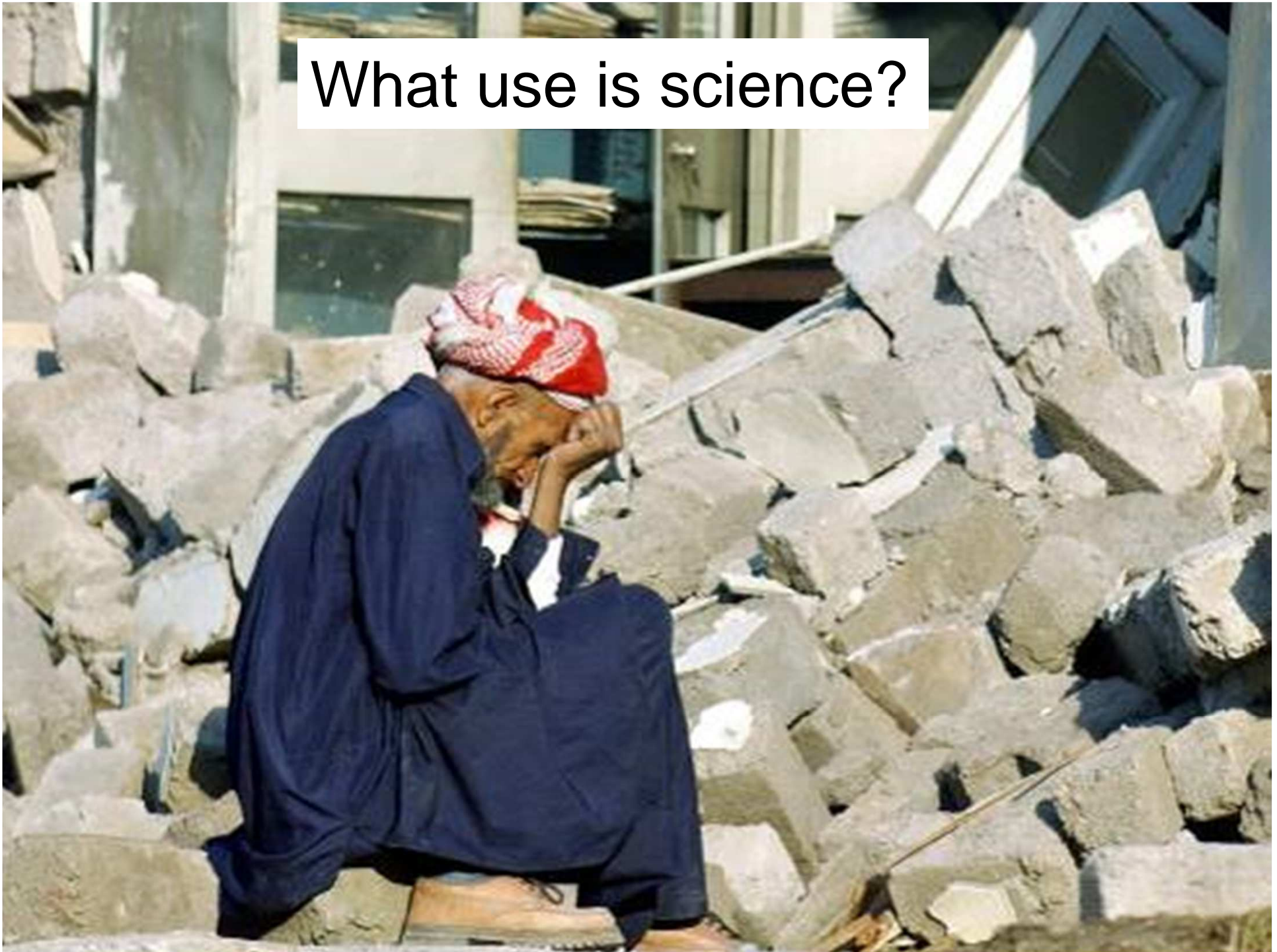


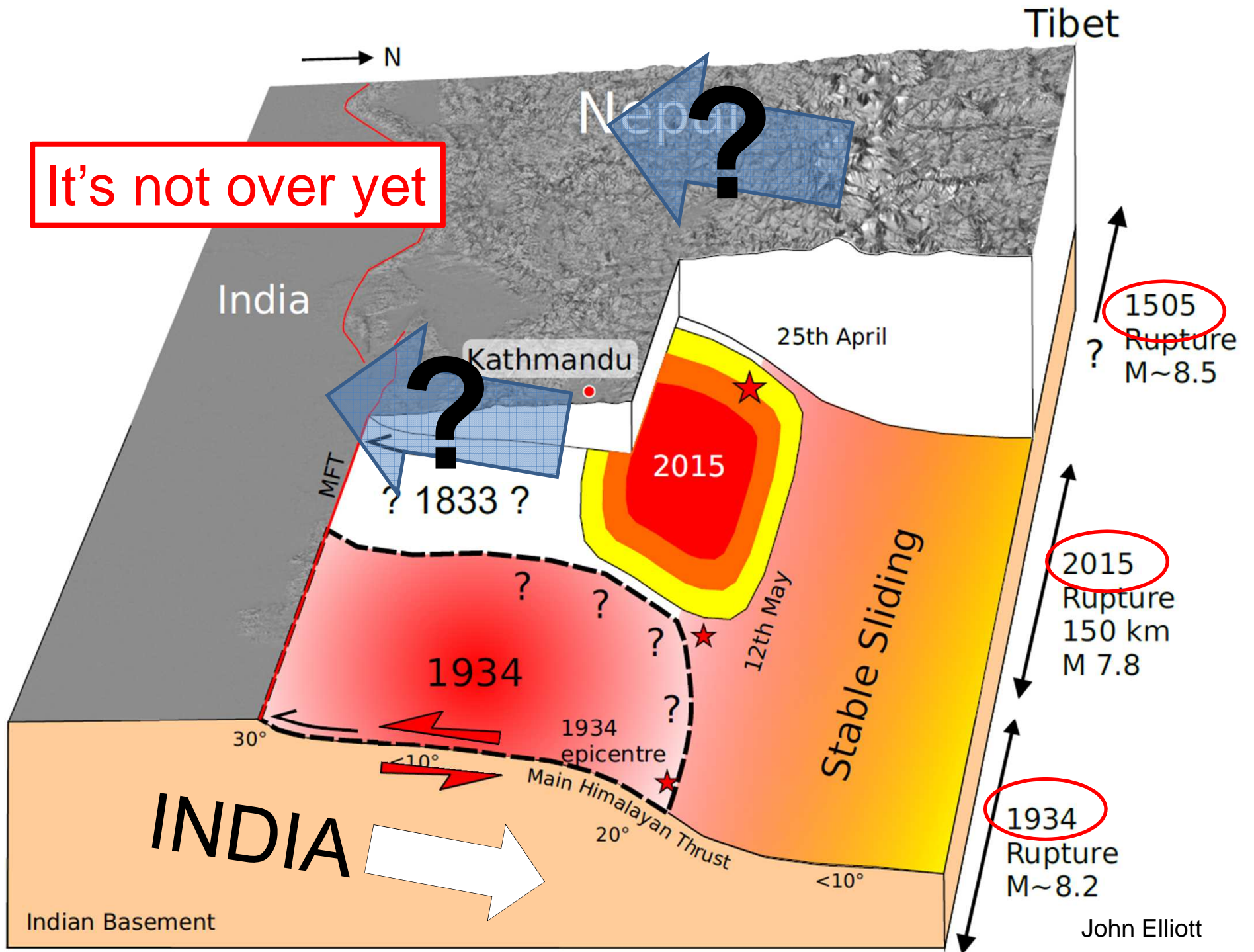


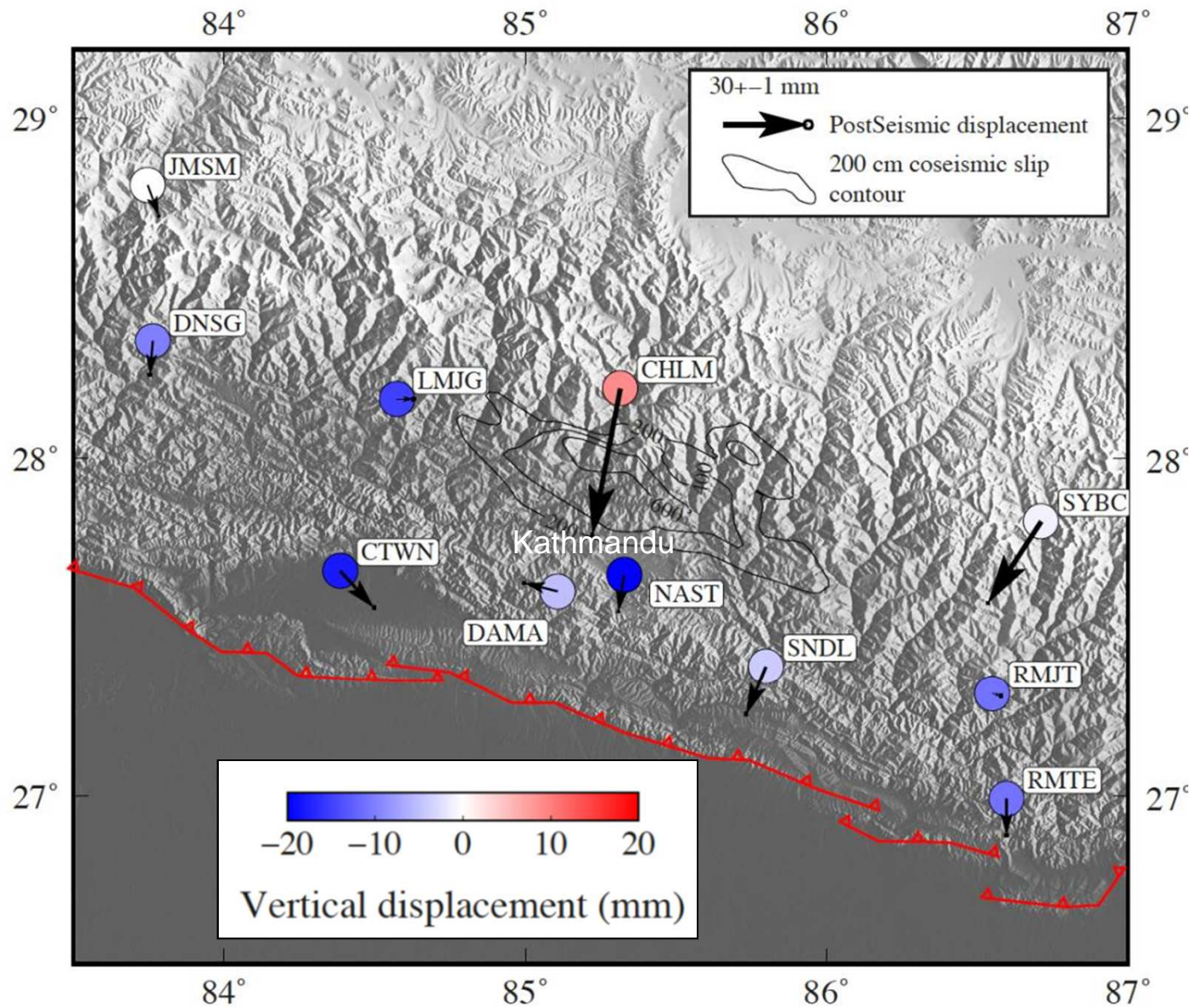
Gogne

Roger Bilham

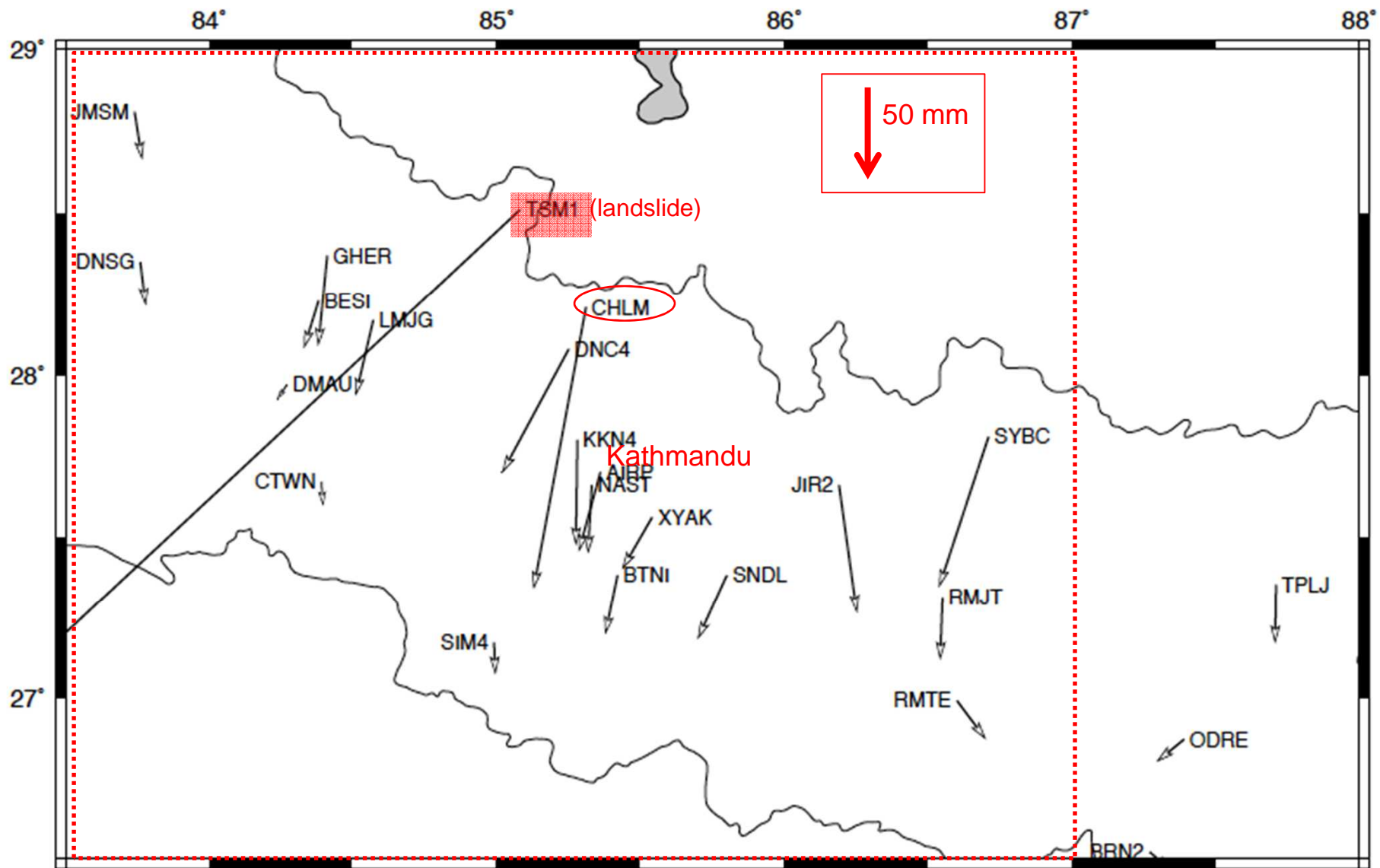
What use is science?



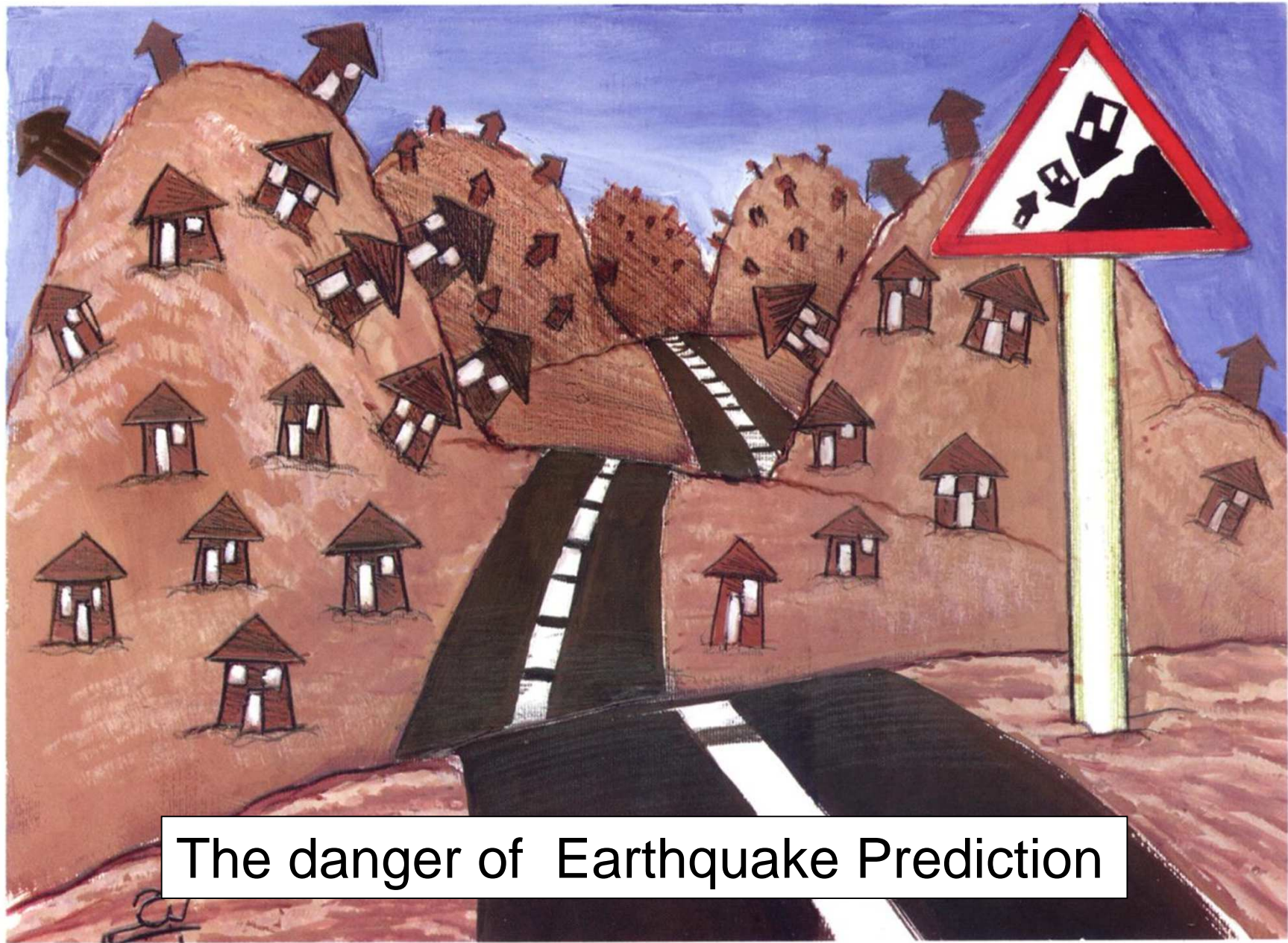




Post-mainshock GPS displacements 25 April to 1 July



Post-mainshock GPS displacements 25 April to 15 September



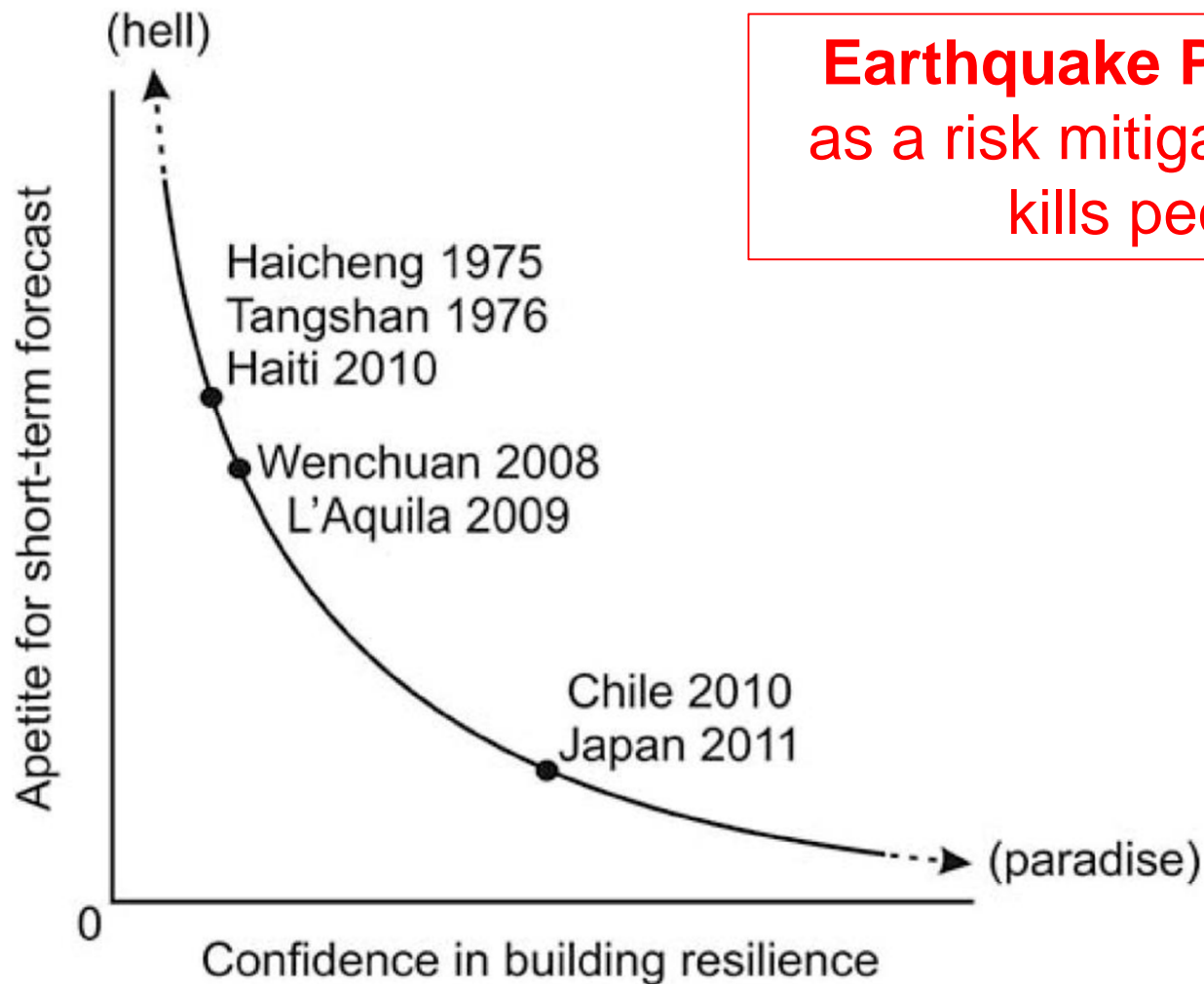
The danger of Earthquake Prediction

*Reza Jangi - Iran*

Zarand

Earthquake prediction is NOT the answer





**Earthquake Prediction,  
as a risk mitigation policy,  
kills people**

▲ **Figure 1.** Graph illustrating how perceived need for short-term forecasting is inversely related to public confidence in the resilience of our built environment to earthquake shaking.

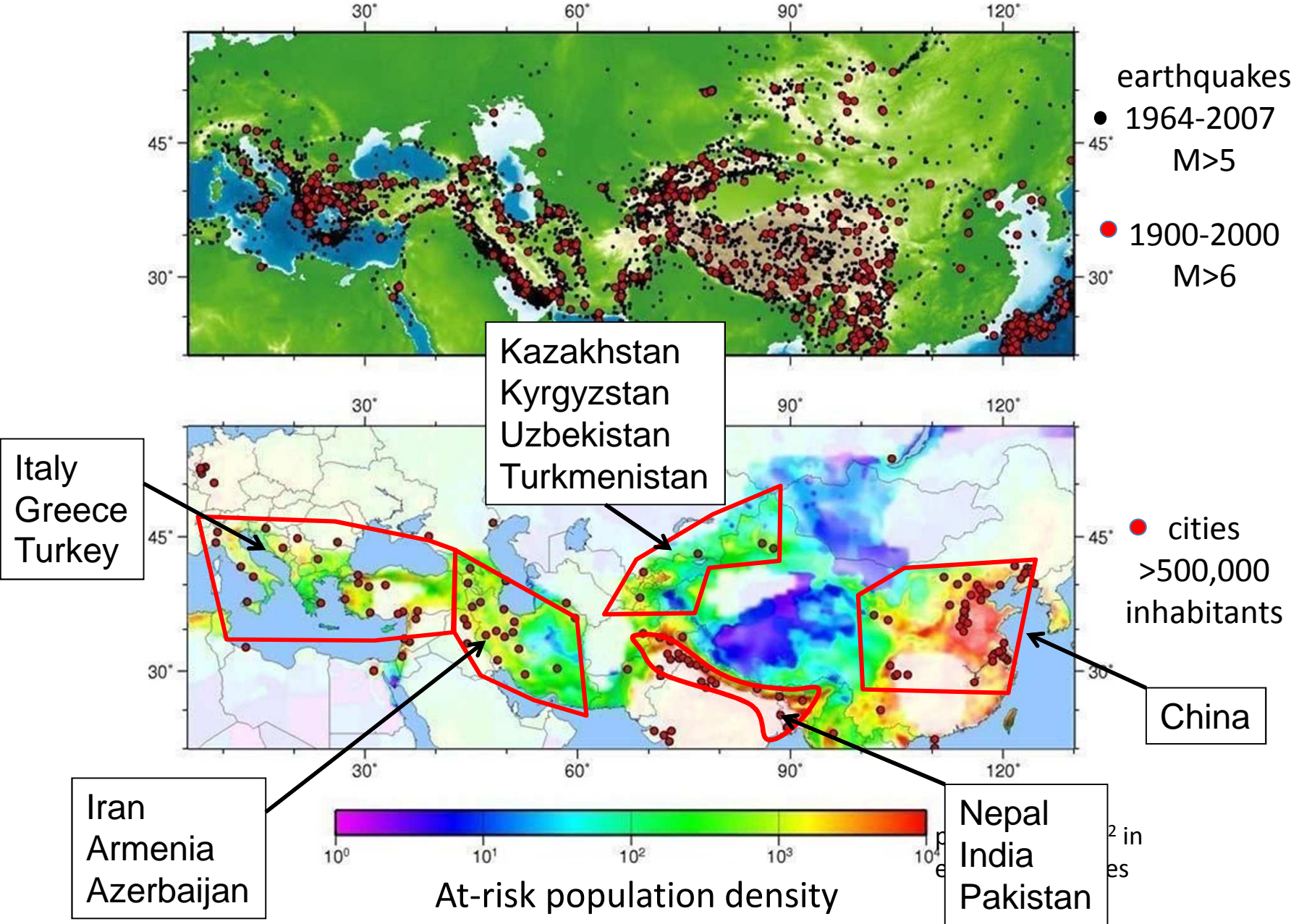


Supporting other scientists



Tabriz, Iran

# Earthquakes without frontiers



# Earthquakes without frontiers

## *Vision*

Better knowledge of  
the hazards and their context

Find effective pathways to resilience  
in each country

More Mortezas and not alone:  
increasing local capability

Bam 2003; 30,000 killed out of 100,000 population



Amod Dixit





EwF meeting at NSET



“Earthquakes don’t kill people: buildings do” (N. Ambraseys)

Barpak reconstruction

Roger Bilham



# You can make your NEW HOUSE safe against EARTHQUAKE !

## FOLLOW 10 RECOMMENDATIONS For Single Storey Masonry Houses in Cement Sand Mortar

1

### Site Selection

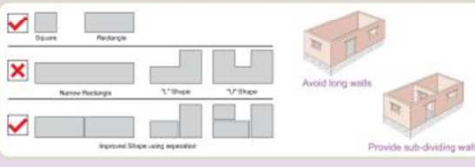
- Avoid steep & unstable slopes;
- Avoid areas susceptible to landslides and rockfall;
- Avoid construction on loosely filled grounds;
- Place house away from the river banks;
- Avoid construction too close to visible, permanent, deep and active faults;
- Distance between house and tree or with adjoining house be preferably at least equal to the height of tree or house, whichever is larger.



2

### Shape of House

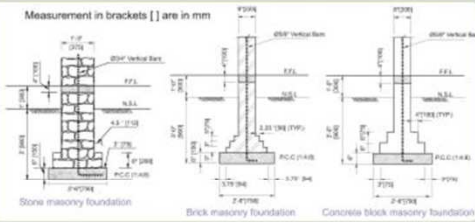
- Construct regular shaped houses like square, rectangular or circular;
- Subdivide complex shaped buildings by providing gaps at appropriate locations;
- Avoid long and narrow structures;
- Construct compact box type layout with all building components such as floor, walls and roof tied-up with each other;
- Maximum room size should be limited to 15ft x 15ft.



3

### Foundation

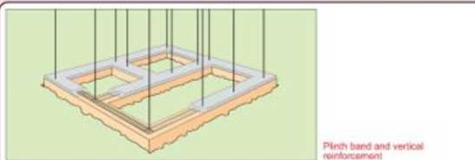
- Use continuous strip footing;
- In case of soft soil, the depth of foundation below existing ground level should be at least 3 ft. For rocky areas minimum depth should be 1.5 ft.;
- Minimum width of footing should be 2.5 ft.;
- Make the excavated surface level before laying the foundation;
- In case of loose soil, provide some nominal reinforcement in foundation bed concrete;
- If stone soiling is used under foundation reduce the thickness of foundation strip to 3";
- Foundation Details: Foundation for various masonry options should be as shown in the figure.



4

### Plinth

- Plinth should be at least 1 ft above the ground level
- Provide a reinforced concrete band at plinth level, as shown in figure. Where foundation is placed on rock, no plinth band is required.
- Minimum thickness of plinth band should be 3 to 4 inch and width should be equal to wall thickness. Main reinforcement should be 2 Nos. 3/8" (3 sutar) bars with 1/8" (1 sutar) rings @ 6". Hook length should be 2.5 inch. Bars shall have a clear cover of 1"



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### Walls

- Masonry should be laid staggered so that the vertical joints don't form a continuous line.
- At corners or wall junctions, through vertical joints should be avoided by properly laying the masonry. Never make vertical "teeth".

#### Stone Wall

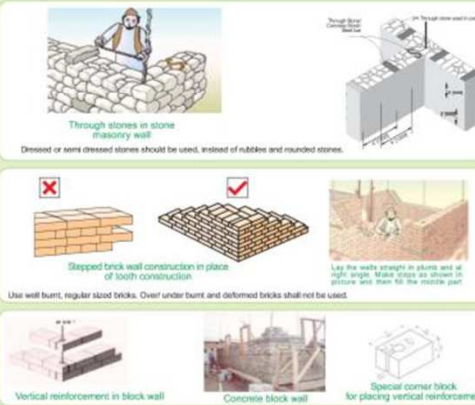
- Wall Thickness: Min. 15 inch
- Boulder stone should not be used in its natural shape. Boulders should be dressed or semi-dressed before they are laid.
- The inner and outer wythes of the wall should be interlocked with through stones. No large space between two wythes should be left for filling with pebbles or mortar.
- Through Stone: Through stone of full length equal to wall thickness should be used in every 2ft. lift at not more than 4ft. apart horizontally, placed in staggered position. A through stone could be a stone, concrete block or an S-shaped steel bar of min. 3/4" (2 sutar) well packed with mortar.

#### Brick Wall

- Wall Thickness: Min. 9 inch
- Stepped Construction: Stepped wall construction is better than toothed, when there is a need for future extension or continuation of work.

#### Concrete Block Wall

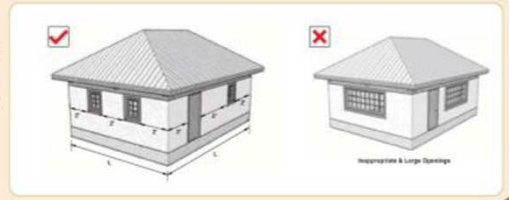
- Wall Thickness: Min. 8 inch
- Solid blocks are preferable as compared to hollow blocks.
- Special corner blocks with side hole are required for placing vertical reinforcement.



6

### Doors & Windows

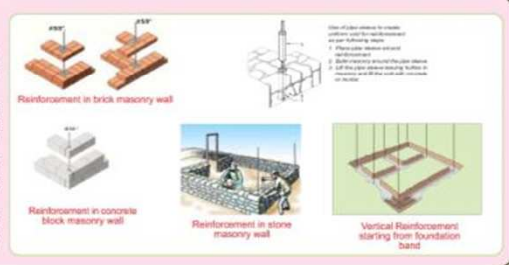
- Location of Doors & Windows: Doors and windows should be placed at least 2 ft. away from the wall corner.
- The total length of doors and windows in a wall should not be more than 50% for single storey construction;
- Gap between two openings: Wall length between any two openings (doors and/or windows) should not be less than 2 ft.;
- Keep lintel level same for doors and windows.



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### Vertical Reinforcement in Walls

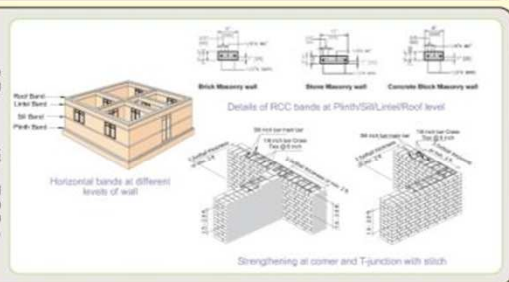
- Place vertical steel bars in the wall at all corners, junctions of walls and adjacent to all doors and windows;
- Anchor all vertical steel bars in the foundation and roof band;
- Use 5/8" (5 sutar) or min. 1/2" (4 sutar) steel bars in case of brick and concrete block masonry. Provide 3/4" (6 sutar) or min. 5/8" (5 sutar) steel bars for coursed stone masonry;
- Fill the pocket around steel bars with 1:2:4 concrete for brick and concrete block masonry. Cement sand mortar 1:3 may also be used for concrete block masonry;
- For stone masonry place 2" dia. PVC pipe around the steel bars, and build masonry around it. Extract the pipe and fill the hole with 1:3 c/s mortar or 1:2:4 concrete.



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### Horizontal Bands and Corner Strengthening

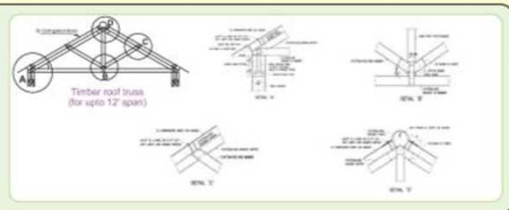
- Horizontal bands should be provided throughout the entire wall with minimum thickness of 3 to 4 inches at following locations:
  - Plinth Band at Plinth Level (DPC Level);
  - Lintel Band above Doors & Windows;
  - Roof Band at Wall top;
  - Sill Band - below window level (Sill level) - Optional;
  - In case of window size more than 3ft, provide min. 6" lintel above the window;
  - Provide 3 to 4 ft long steel dowels at corners and T-junctions comprising 2 Nos. 3/8" (3 sutar) bars with 1/8" (1 sutar) ties @ 6" apart or expanded metal mesh at vertical spacing of 18" to 24". If room sizes are small, dowel bars may be made continuous.



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### Roof

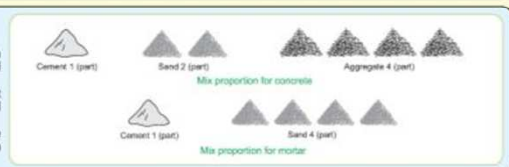
- Use light roof comprising wooden or steel truss covered with CGI sheets;
- All members of the timber truss or joists should be properly connected as shown in figure;
- Trusses should be properly cross-tied with wooden braces as shown in figure;
- Well seasoned hard wood without knots should be used for roofing. Timber treatment such as use of coal tar or any other preservative can prevent timber from being decayed and attacked by insects.



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### Materials

- Mortar:** Cement sand mortar should not be leaner than 1:4 (1 part cement and 4 parts sand) for masonry and 1:6 for plaster.
- Concrete:** The concrete mix for seismic bands should not be leaner than 1:2:4 (1 part cement, 2 parts sand and 4 parts aggregate)
- Reinforcement:** Reinforcing Steel shall conform to Grade 40, having minimum yield strength of 40,000 psi. Plain steel shall not be used except for ties.



This publication has been prepared for assisting in rural reconstruction of earthquake affected areas and is believed to be helpful in assuring the enhanced earthquake safety of rural houses. This will provide easy and ready to use solutions for common rural houses. This construction checklist is for single storey rural housing units, the provisions mentioned here are only for such houses, if the house is other than this, standard provisions for those specific types should be followed. For further details related to the provisions mentioned in this checklist, detail guidelines can be followed.



Lumle, Nepal, 2015

Importance of  
variability in local  
construction and  
design



Pattan, Pakistan 1974





7000 schools were damaged or destroyed



Retrofitted school, Lalitpur



Retrofitted school, Lalitpur

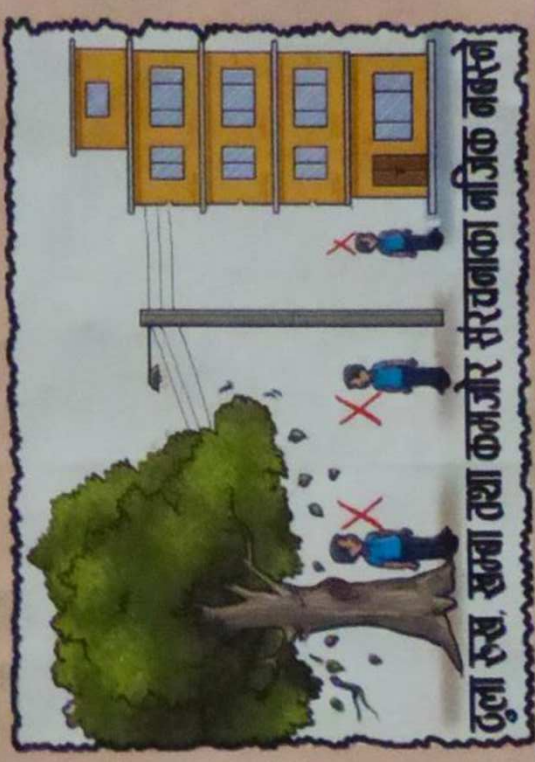
सोधी नबोली आउंछ भूकम्पीय विपदा जागौ जुटौ बघाउन सुष्टिको सम्पदा १६ औ मूकम्प सुरक्षा दिवस २०७०

## भूकम्पको समयमा अपनाउनु पर्ने सतर्कता

“धुंदा टेकी गुडुल्की ओत लागी  
समात” को विधि अपनाएर टाउको र  
शरिरको संवेदनशिल अंग जोगाउने



हतारमा घरबाहिर ननिस्कने

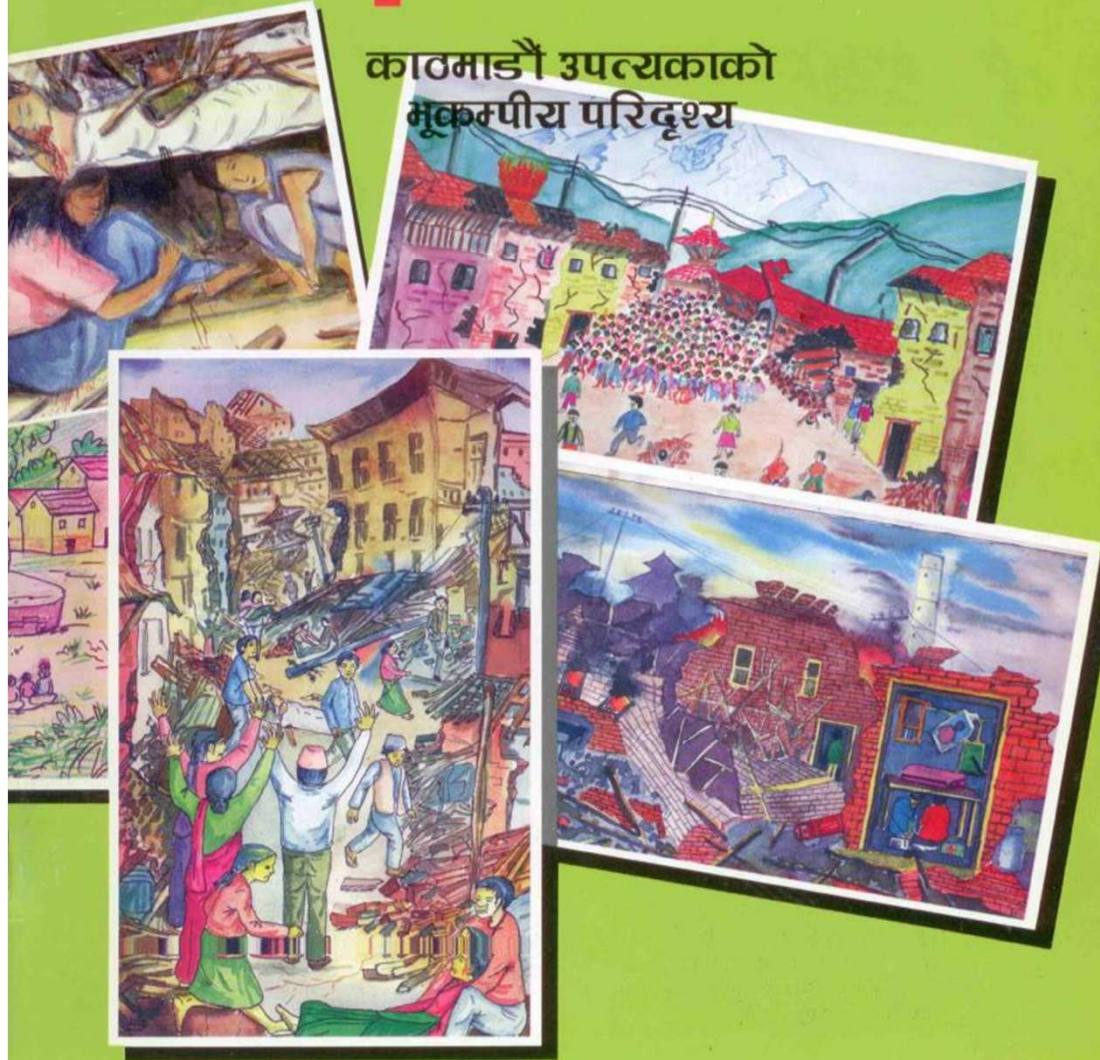


पुला रुख, खम्बा तथा कमजोर संरचनाका नजिक नबस्ने

KATHMANDU VALLEY'S

# Earthquake Scenario

काठमाडौं उपत्यकाको  
मूकम्पीय परिदृश्य



A product of the Kathmandu Valley Earthquake Risk Management Project implemented by National Society for Earthquake Technology-Nepal (NSET-Nepal) and GeoHazards International (GHI)

NSET



Women's group, Kirtipur



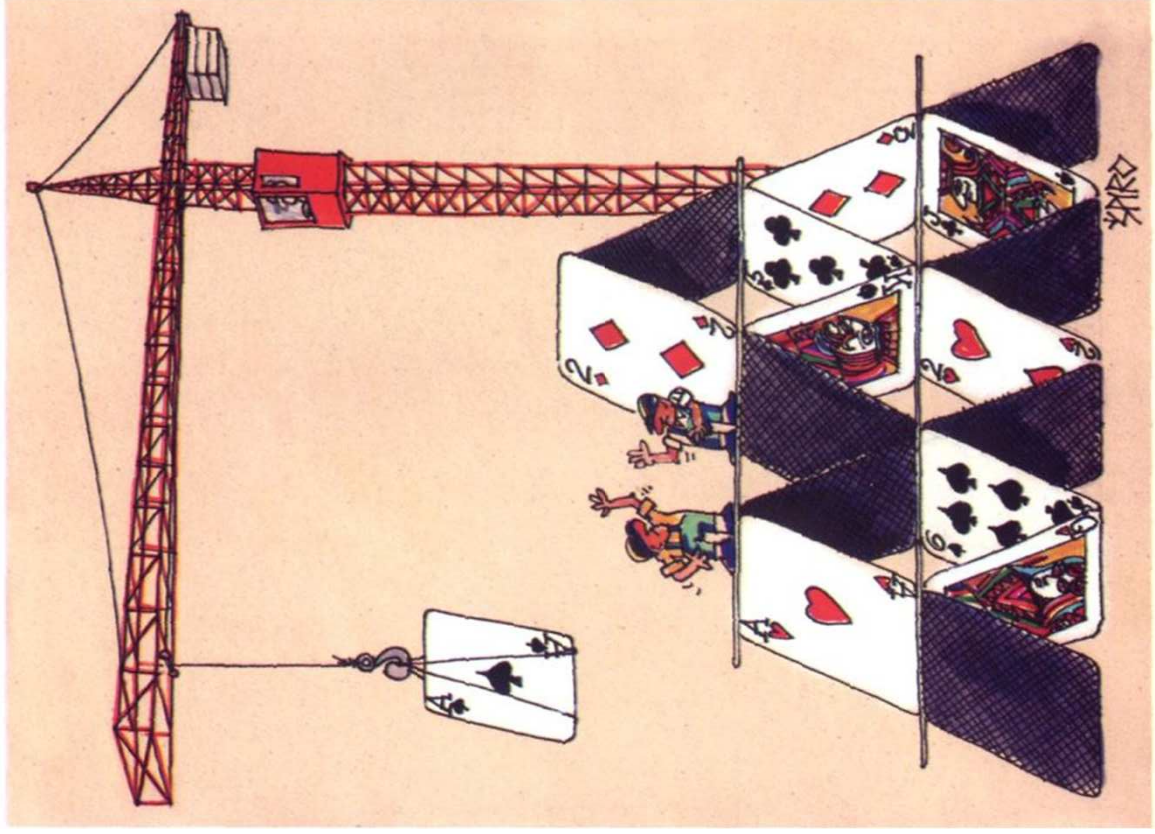
Vice Chairman, BSDMA  
Shri Anil Kumar Sinha, IAS(Retd.)



बिहार राज्य आपदा प्रबंधन प्राधिकरण  
BIHAR STATE DISASTER MANAGEMENT AUTHORITY



Women's group, Kirtipur



Spiro Radulovic - Serbia





Leninakan, Armenia 1988



Skopje, Macedonia 1963



# The problem: daily difficulties of urban life in Asian cities

Congestion

+

Traffic

+

Pollution

+

Air quality

+

Water supply

+

Health

+

Poverty

+

+ ...

**+ earthquakes!**

Tabriz, Iran

