Indigenous Skills and Practices of Disaster Resistant Construction in Nepal

A Case of Newari Architecture in Kathmandu Valley

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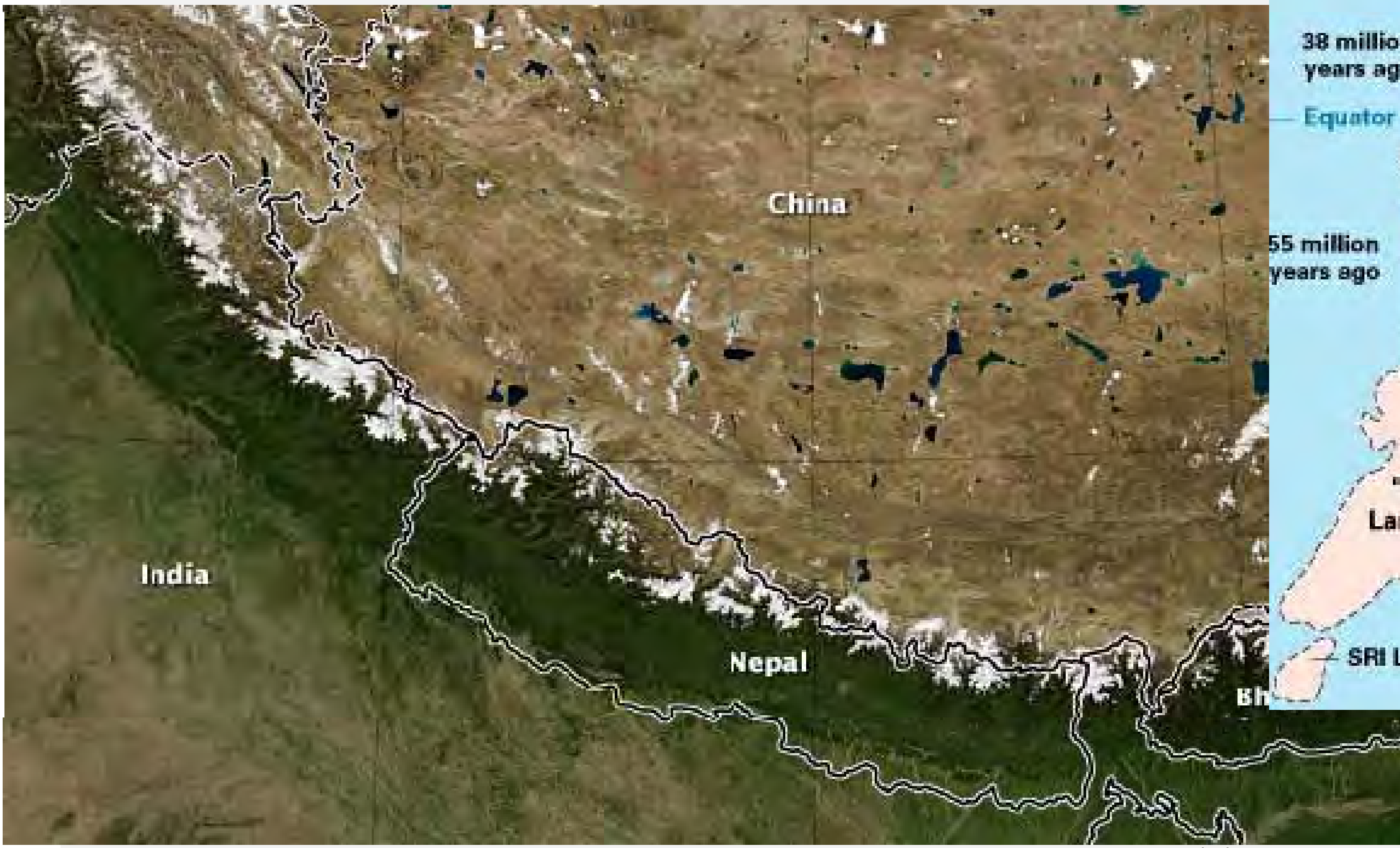
21 Sept. 2017

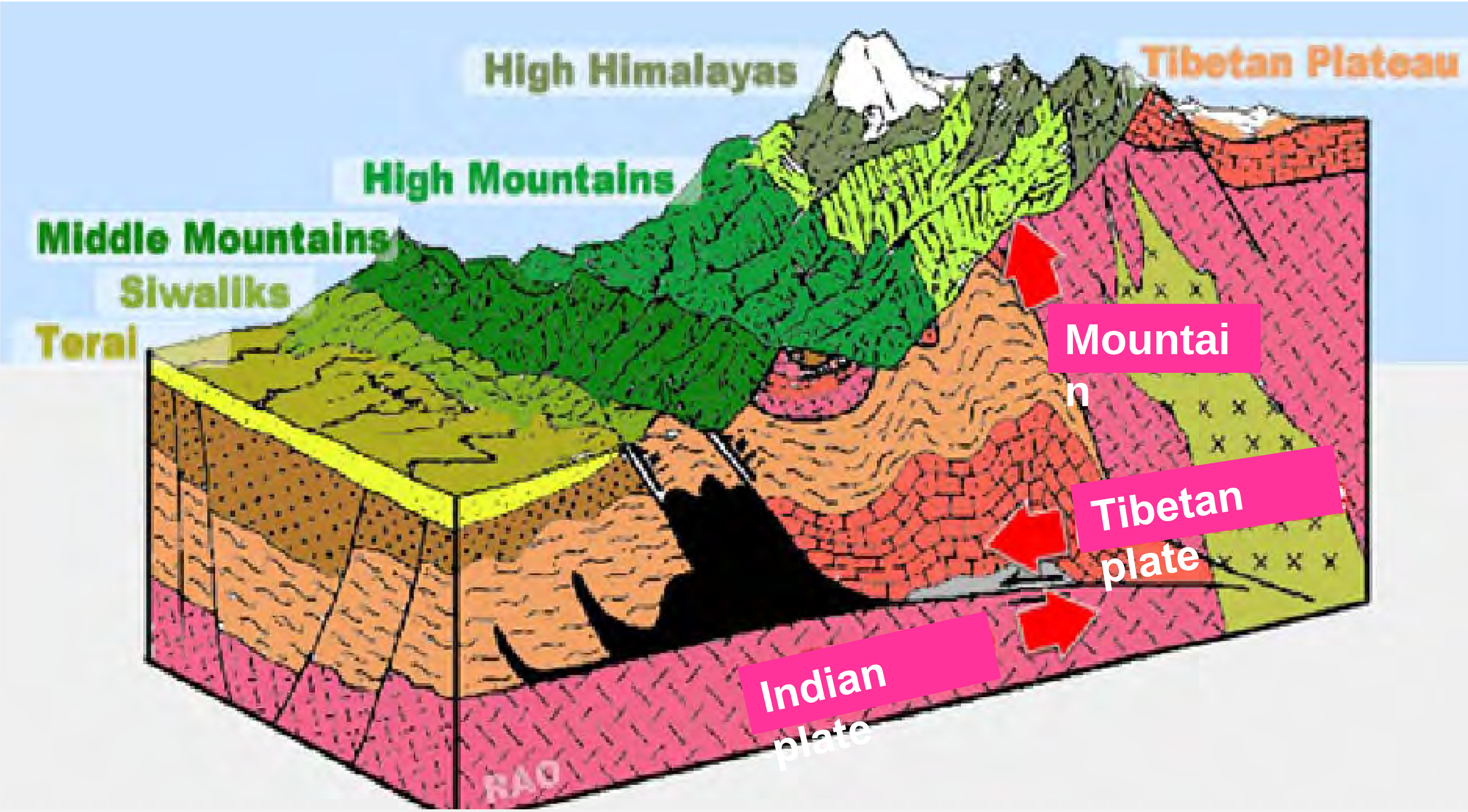
Seismic Vulnerability of Nepal



Source: earthobservatory.nasa.gov

Source: Geolsoc

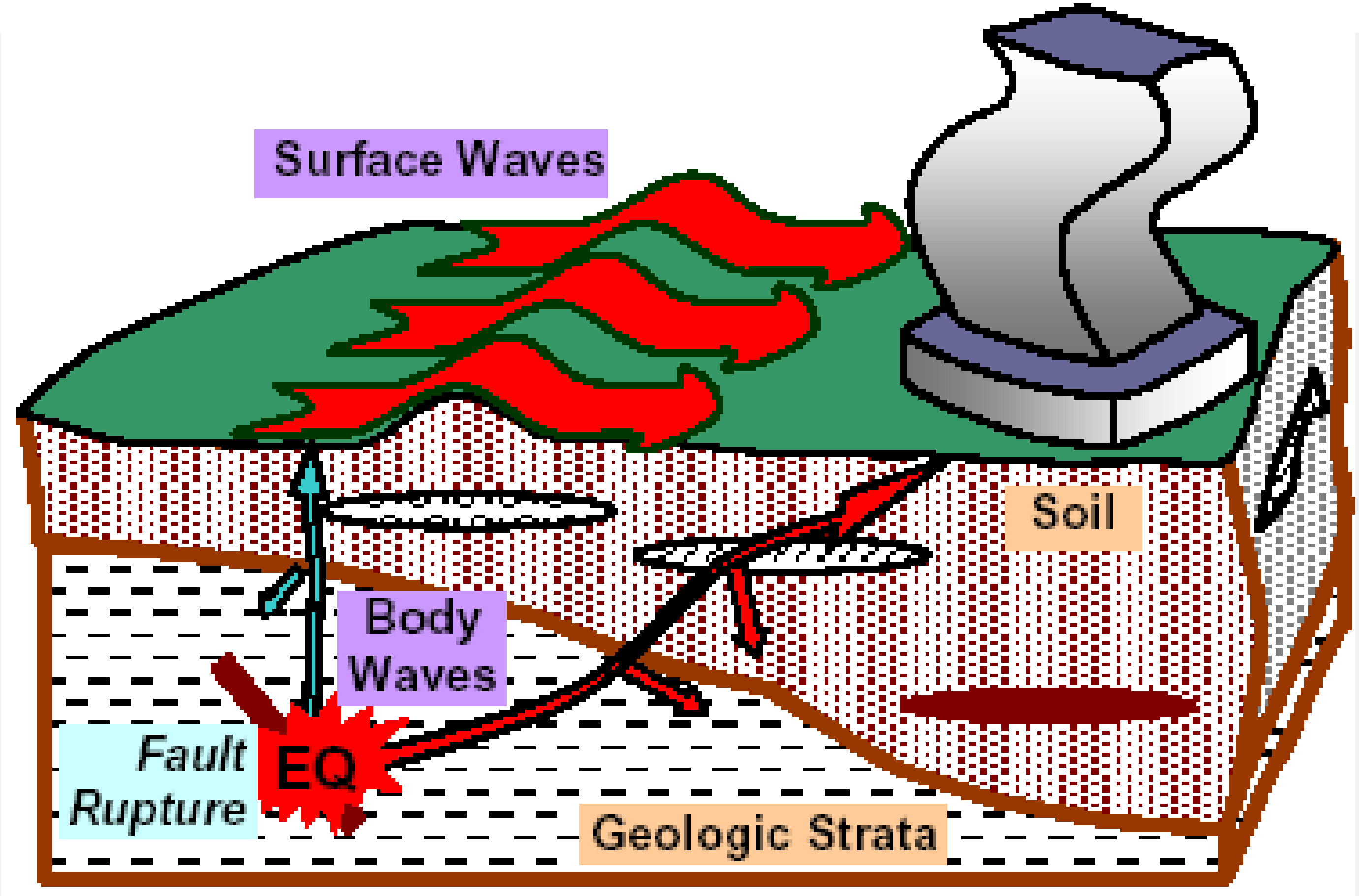
Seismic Vulnerability of Nepal



Source: WWF

Subduction of Indian Plate under Tibetan plate gives rise to the Great Himalayan range

Seismic Vulnerability of Nepal

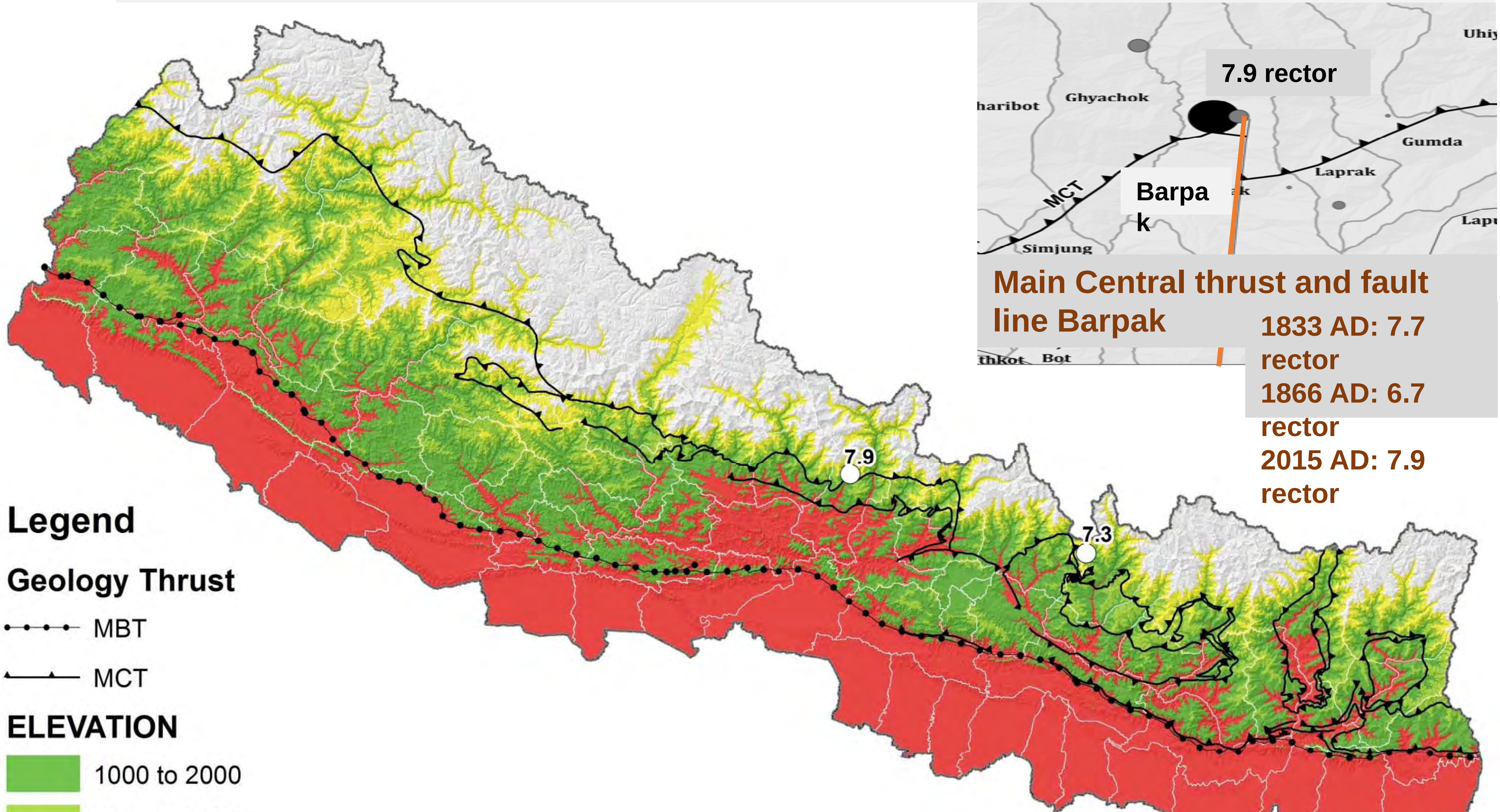


Source: Slideshare.net/ParindPatel

As plate subducts, the frictional force obstructs the process thus accumulating elastic strain energy.

When the bearing capacity of the strata exceed the limit, it ruptures releasing this energy, which transmit in the form of wave that we understand as earthquake.

Seismic Vulnerability of Nepal



Main Central thrust and fault line Barpak

1833 AD: 7.7 rector
1866 AD: 6.7 rector
2015 AD: 7.9 rector

MBT: Main Boundary Thrust, where Indian Plate sub-ducts under Tibetan plate
MCT: Main Central Thrust where potential for occurrence of earthquake is high and has innumerous faultlines are

Impacts of the Earthquake

Laprak, Gorkha

Hagam,Sindhupalchowk

Barpak: Before and After earthquake

Source: Sirish Shrestha (left), Darjeeling Chronicle (right)

Impacts of the Earthquake

Kathmandu

Source: mb.com.ph

Kavre

Chautara

Bhaktapur

Impacts of the Earthquake

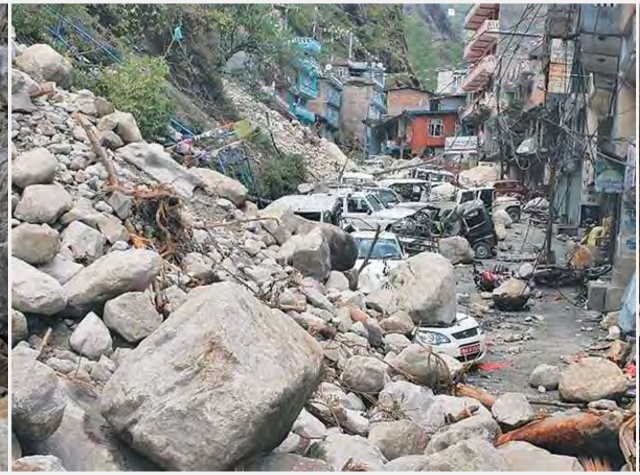
Source: cnn.com

Source: dailymail.co.uk

Impacts of the Earthquake

Landslid

Dunche Source: australiangeographic



Tatopani Source: Kantipur

Rasuwa Source: hyswe

Avalanch

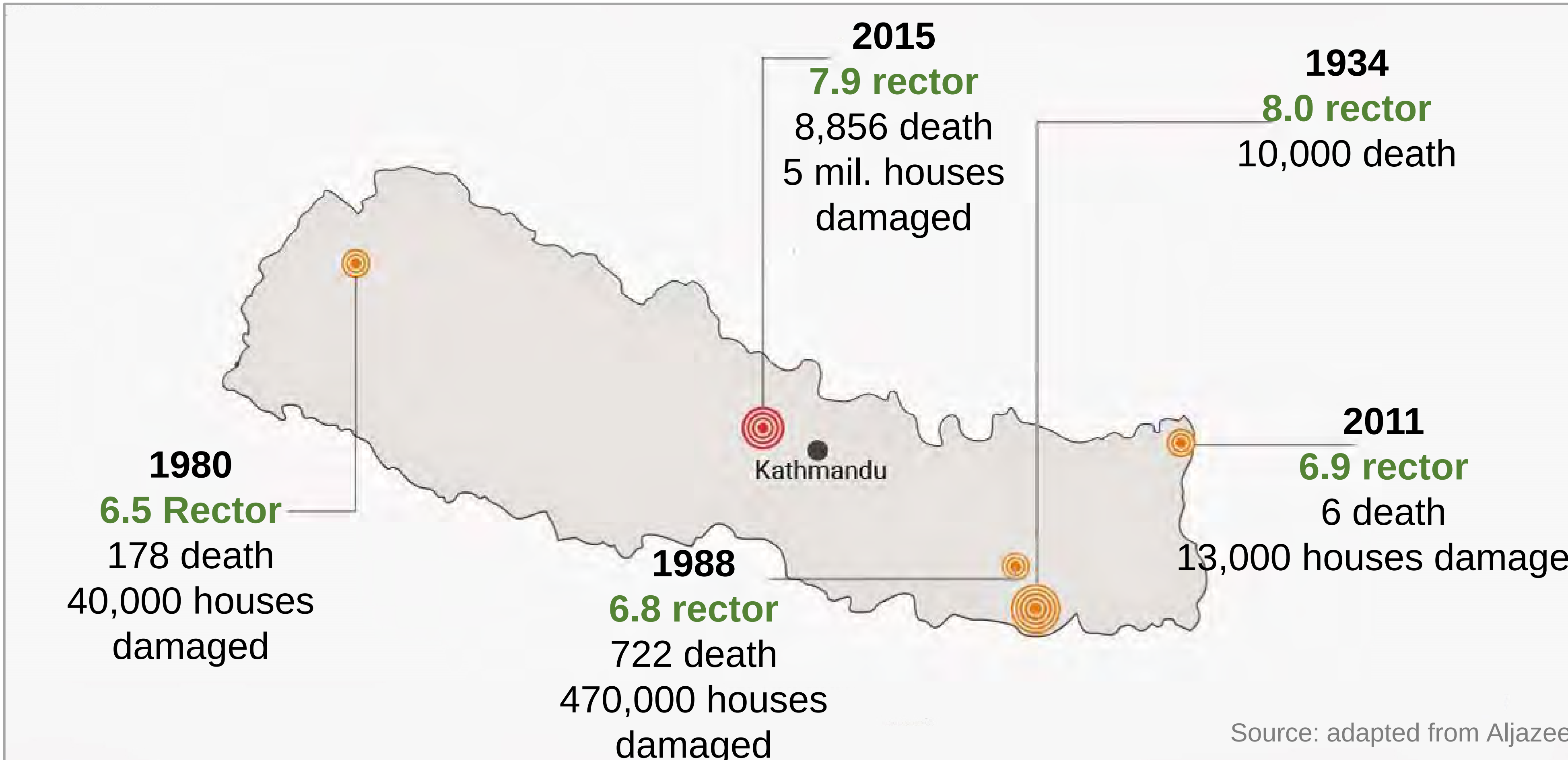
Source: worldpress

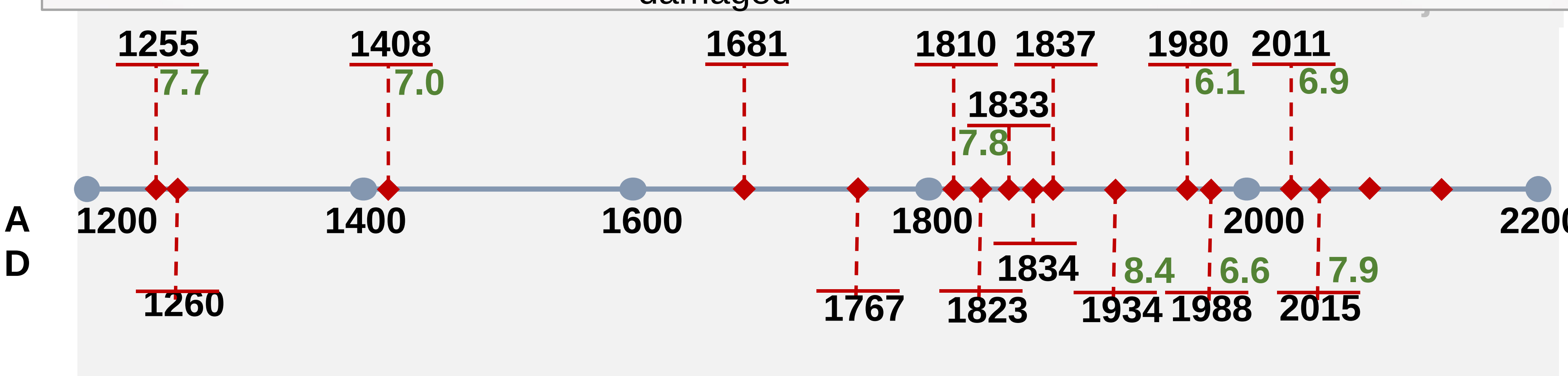
Source: youtube

Source: bbc

Sagarmatha Base Camp

Major Earthquakes in Nepal





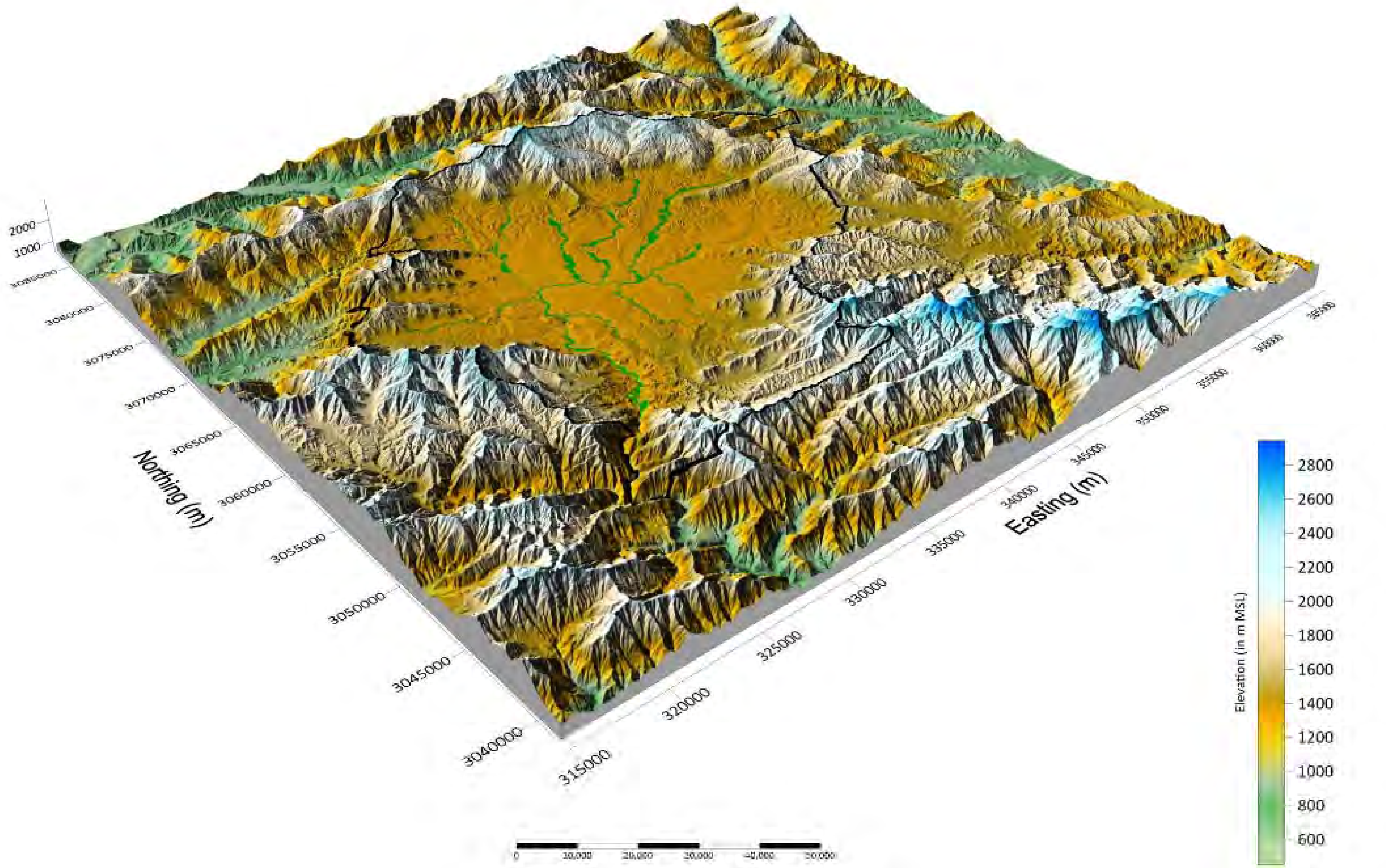
Major Earthquakes in Nepal

Source: Geologyin.com

Earthquake Events from 1911 to 1991 AD

Magnitude (Rector scale)	Events (number)	Recurrence period (year)
5 to 6	41	2
6 to 7	17	5
7 to 7.5	10	8
7.5 to 8	2	40
More than 8	1	81

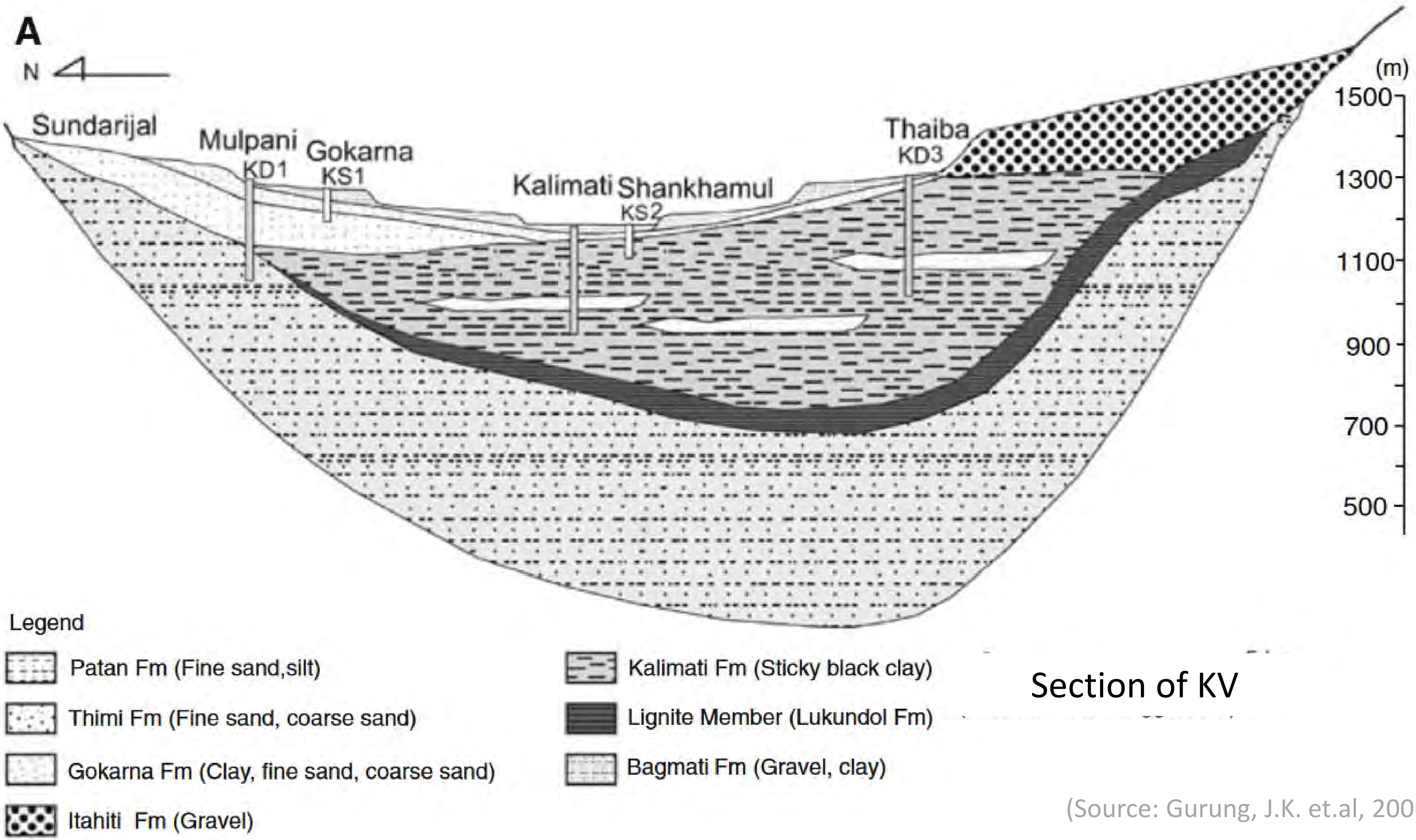
Seismic Vulnerability of Kathmandu Valley



Perspective view of KV

Source: UNDP-Nepal

Seismic Vulnerability of Kathmandu Valley

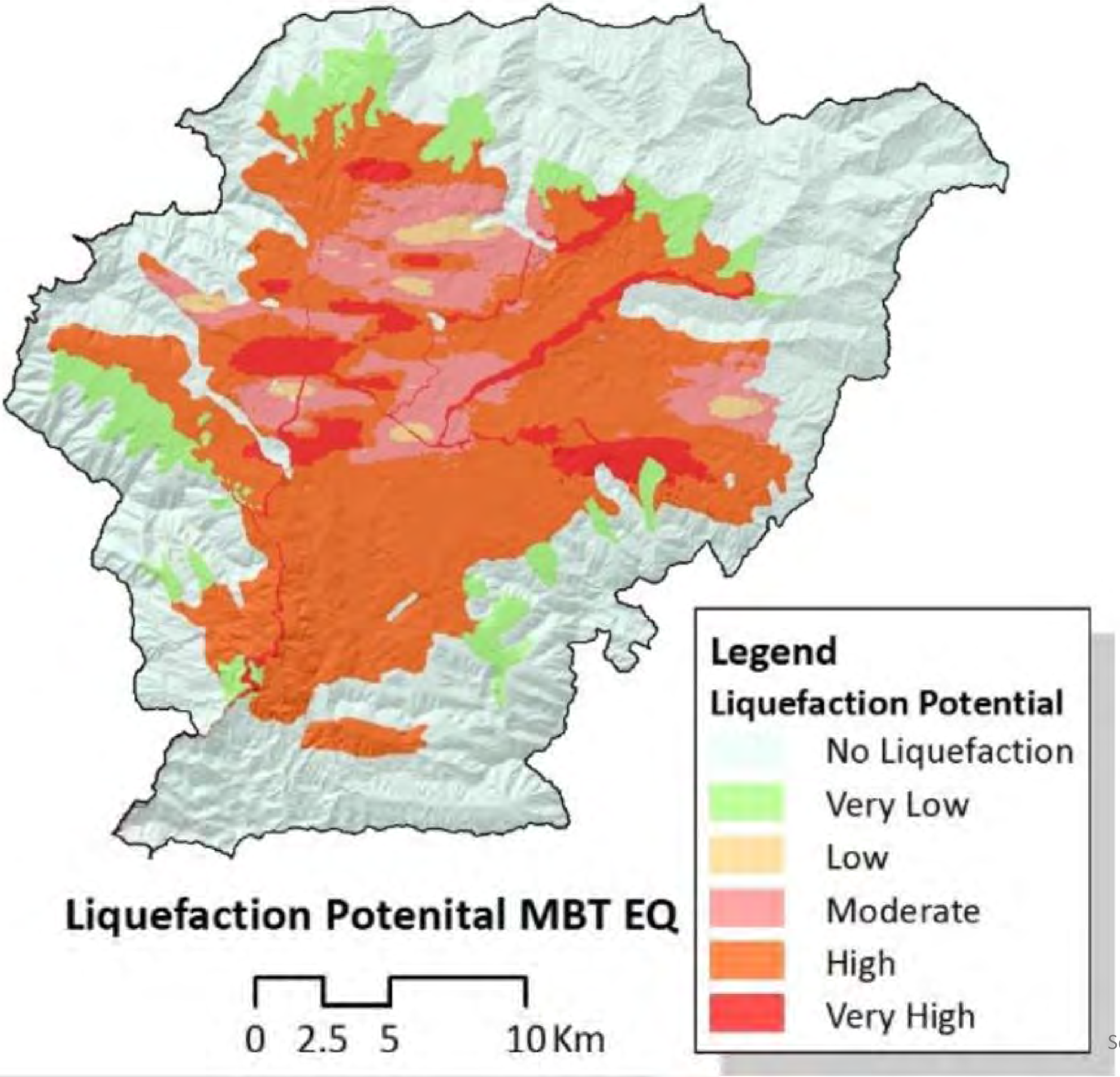


Section of KV

(Source: Gurung, J.K. et.al, 2006)

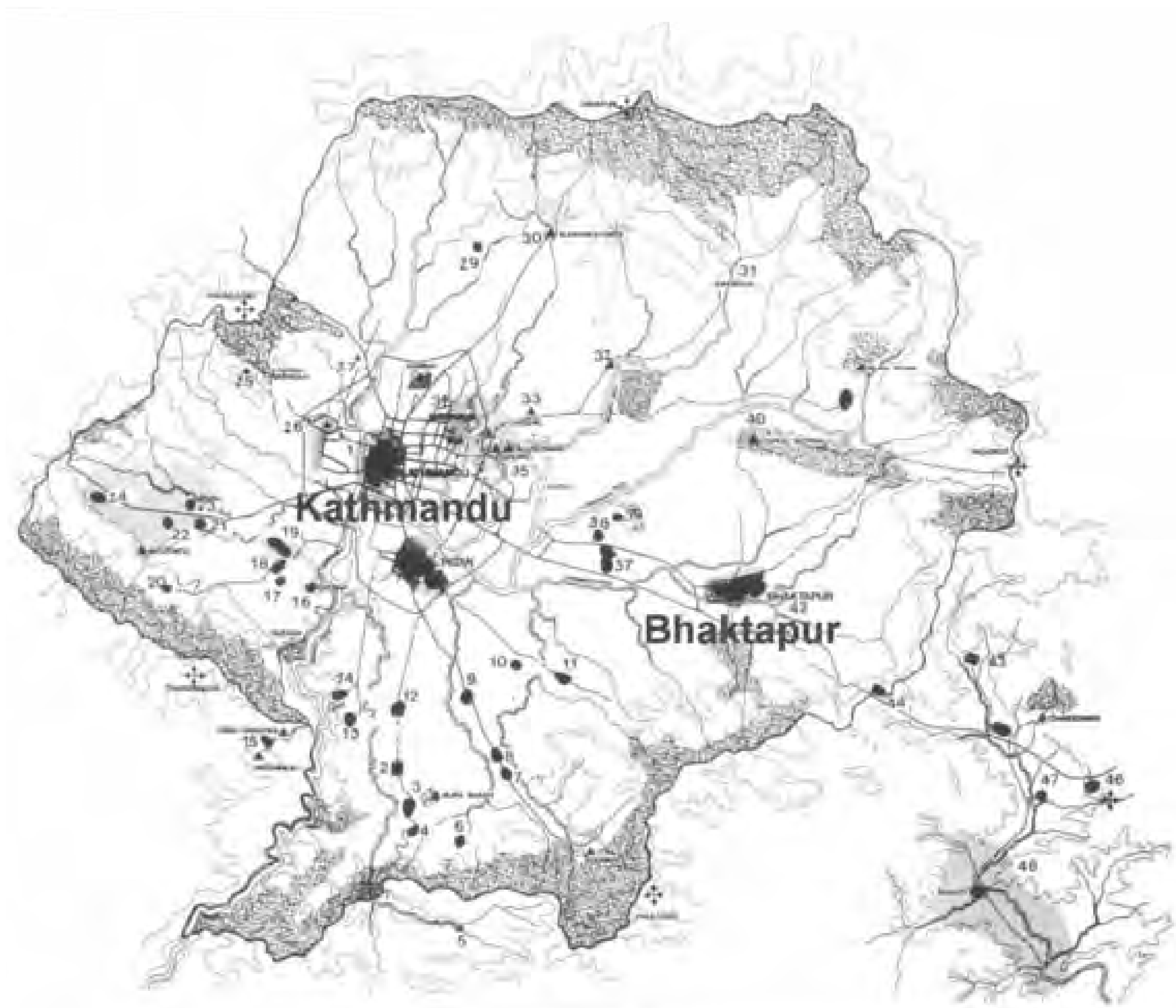
The lacustrine base of the valley gives jelly-bowl effect to the seismic waves

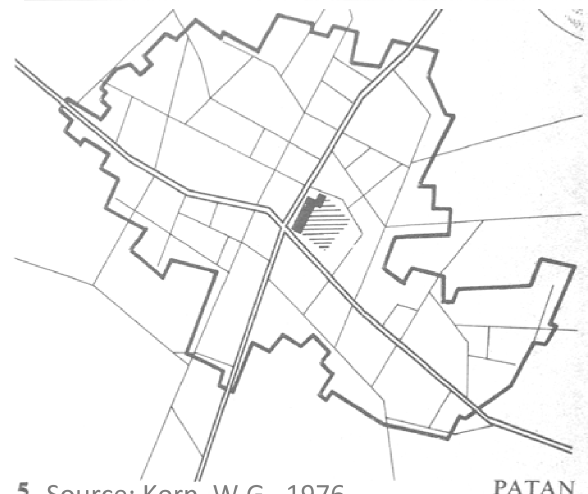
Seismic Vulnerability of Kathmandu Valley



Source: UNDP-Nepal

Newari Settlement in **Kathmandu Valley**





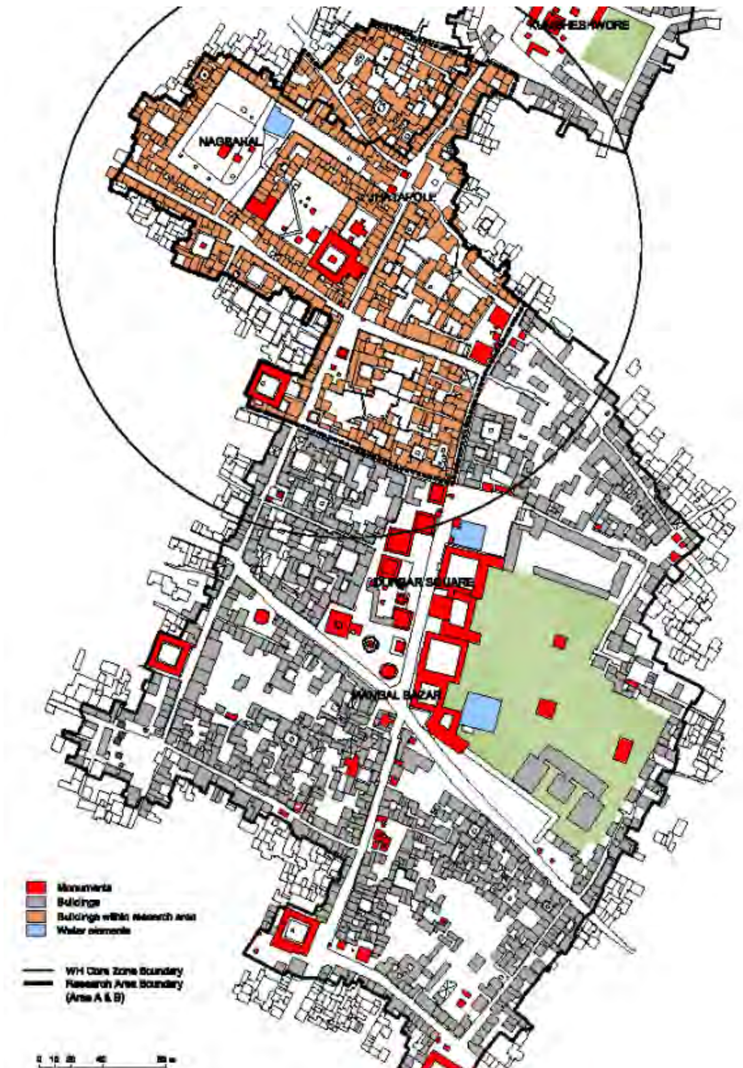
Source: Korn, W.G., 1976

- Newari art and architecture flourished between 13-18 century
- Characteristic of compact rich fabric of houses, temples, open spaces, monasteries intrinsically arranged at the cross section of trade routes

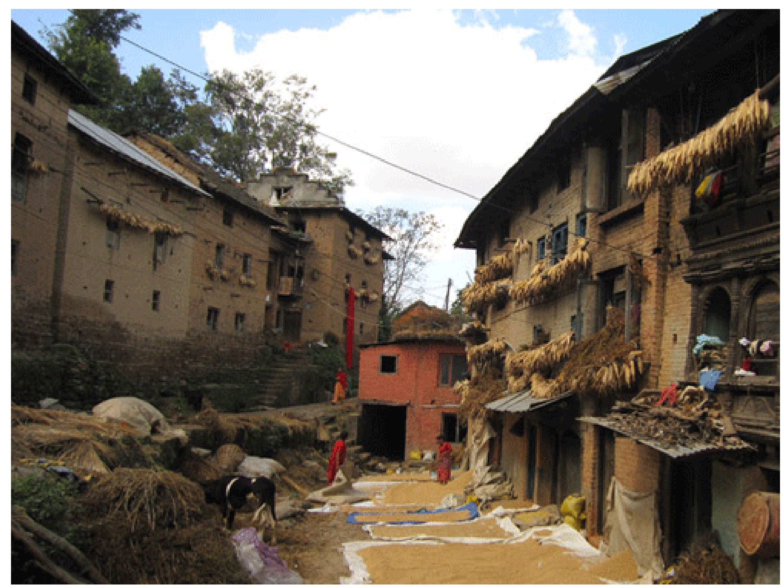
Newari Settlement in Kathmandu Valley

Morphology of the towns:

- Dense / compact building stock of regular height.
- Hierarchy of public, semi-public and private open spaces linked by streets.



Ritsumeikan University, 2012



A Newari House in Kathmandu Valley

A typical traditional Newari House

- Uniformity in plan and height
- Uniformity in function of spaces
- Symmetry in facade
- Uniformity in construction technology and material

Kitchen Space

Living Room with decorative window

Bed Room Space

Store or shop

A Newari House in Kathmandu Valley

Building Material

Two basic materials:

- Mud- In abundant quantity, used as bricks, tiles, mortar as major structural element
- Wood – Used as post, joist, rafter, struts, door and windows to increase dampening for absorbing substantial movement and adding flexibility of the structure

Two locally available natural materials used in close association, blended with joinery of wood, intriguing carving and technical details

A Newari House in Kathmandu Valley

Indigenous knowledge and practices for mitigation of earthquake risk

1. Building configuration
2. Load bearing structure
3. Ring ties
4. Openings: door and windows
5. Flooring system
6. Wooden Joinery
7. Roofing system

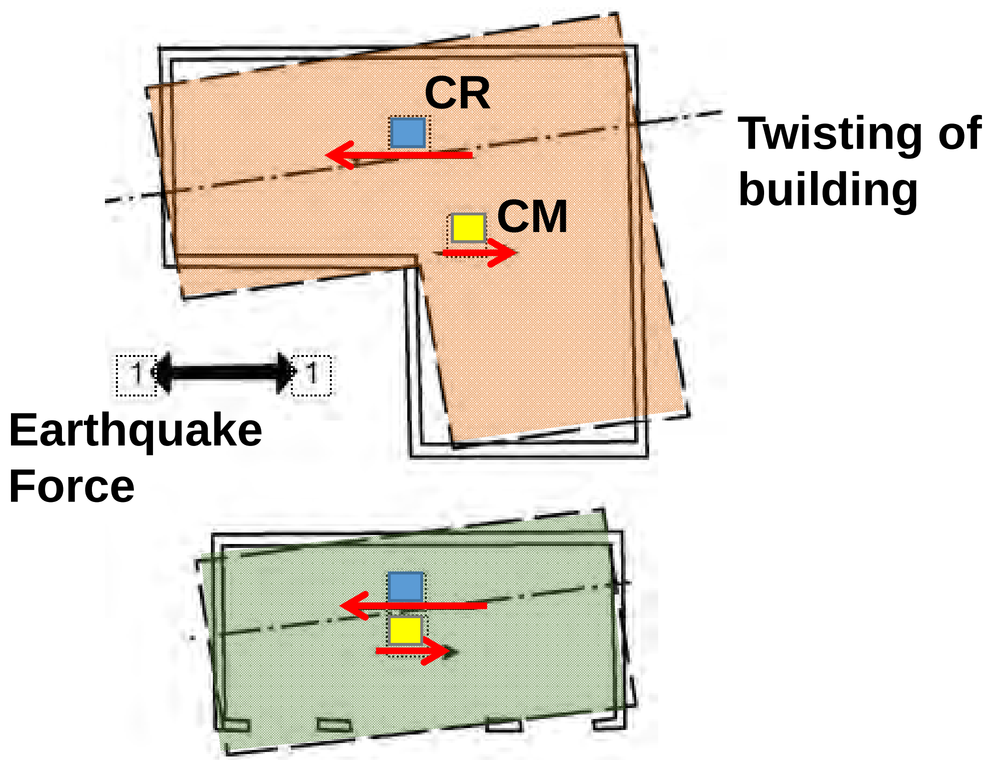
Brick masonry with limited capacity to take lateral force, requires stable plan, placement and size of openings, thickness and height, connection details and workmanship

A Newari House in Kathmandu Valley

Indigenous knowledge and practices for mitigation of earthquake risk

1. Building configuration:

- Symmetric plan
- Rectangular in shape
- Length breath ration less that 1:3
- Center of mass and center of rigidity close enough to reduce risk of torsion



A Newari House in Kathmandu Valley

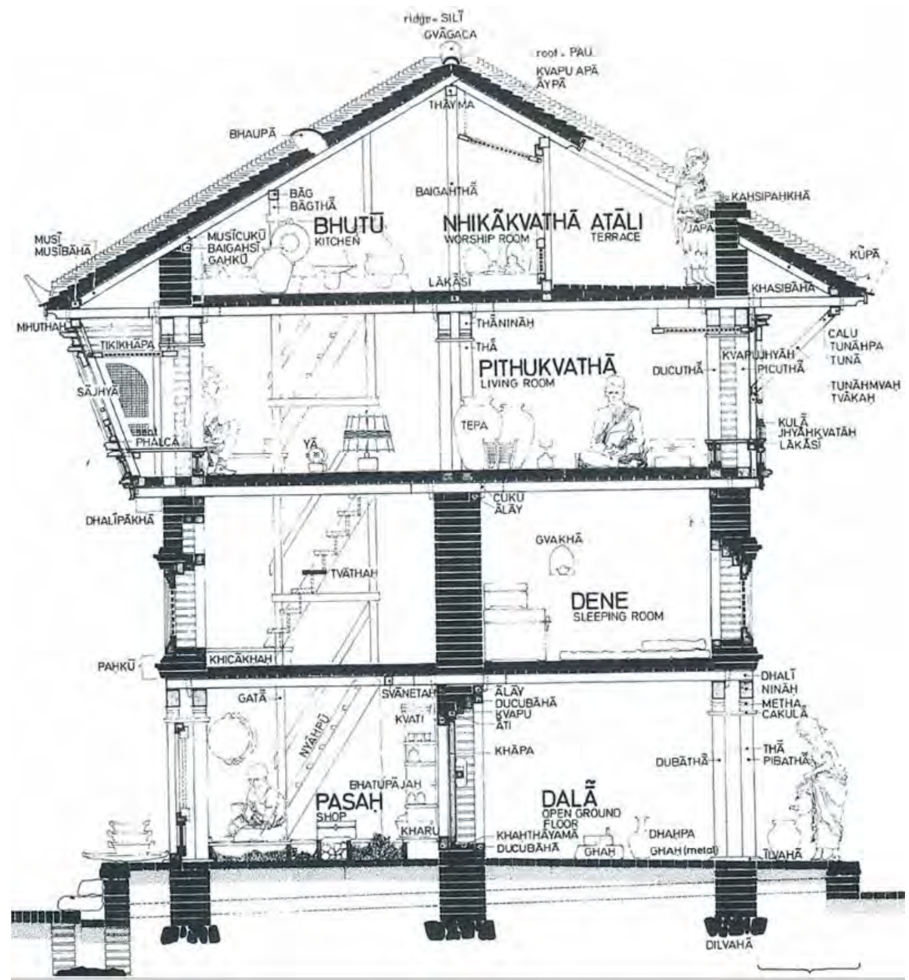
Indigenous knowledge and practices for mitigation of earthquake risk

2. Load bearing structure

- Brick by nature is brittle, good at compressive but with limited capacity against lateral force

- Triple wall with internal spine wall that increases redundancy, provides clear load path

- Thickness of the wall in minimum 45 cm, which is thick enough to reduce the possibility of shear failure under horizontal stress



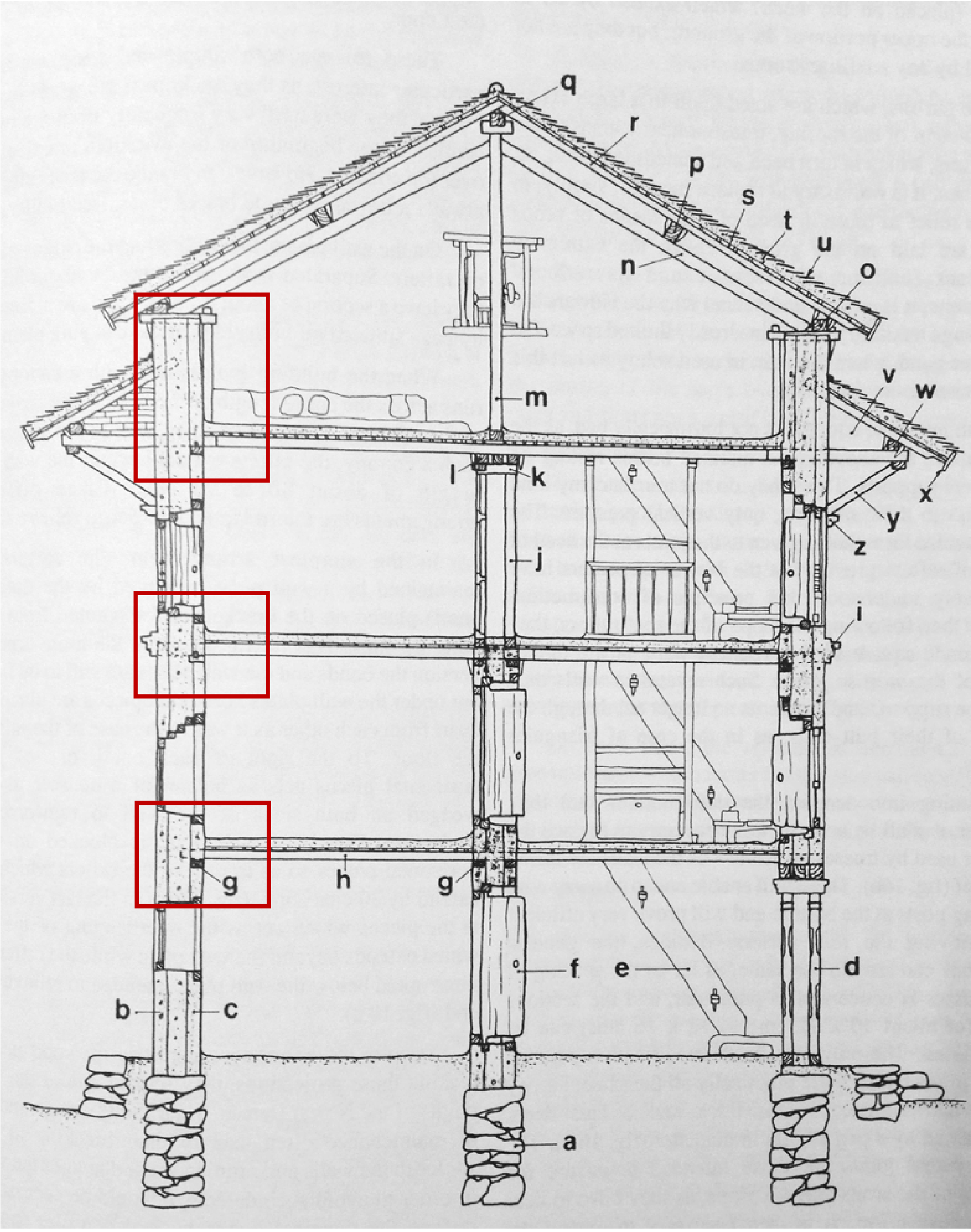
Source: Murty, C.V.R. Source: Gutschow, N., 1982

A Newari House in Kathmandu Valley

Indigenous knowledge and practices for mitigation of earthquake risk

3. Ring ties

- Use of timber to counter brittle failure of mud wall
- Used at sill, lintel and floor level to reduce slenderness of the masonry by splitting mass
- Preventing out of plane failure by building integrity between elements.



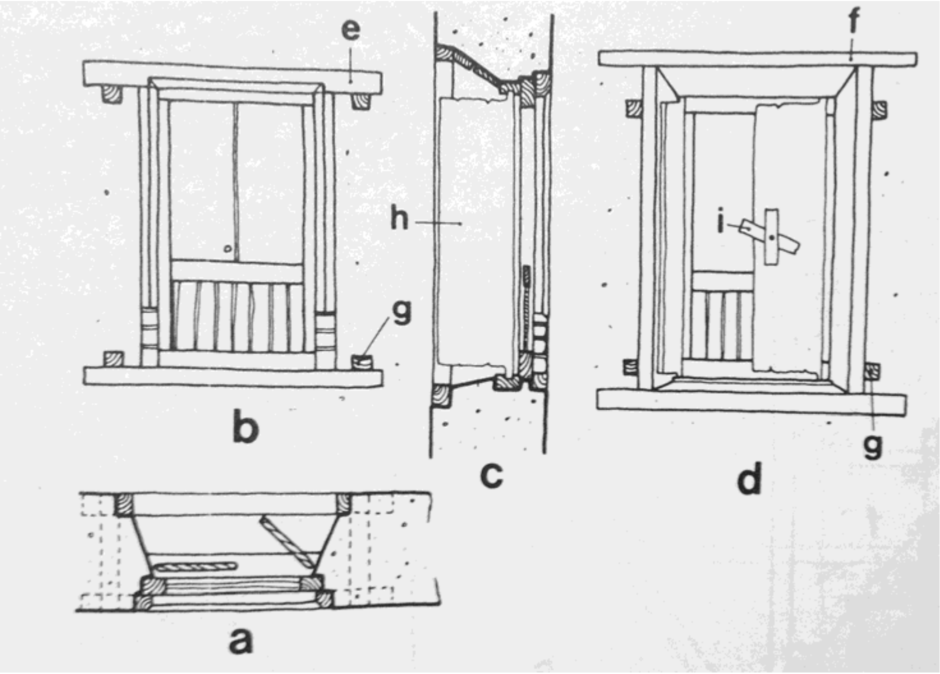
Source: Toffin, G., 1991

A Newari House in Kathmandu Valley

Indigenous knowledge and practices for mitigation of earthquake risk

4. Openings: door and windows

- Small in size with symmetric placement
- Short opening ratio providing large shear area near opening to prevent shear failure or collapse
- Double frame of timber all around the opening across both sides of the thick wall, counter lateral force to smoothen transfer of energy



A Newari House in Kathmandu Valley

Indigenous knowledge and practices for mitigation of earthquake risk

5. Flooring system:

- Joists of 50x100 mm closely spaced and rests over continuous wall plate to support floor of timber plank with layer of mud in sub-floor
- Average height less than 2.5 meters → reduce slenderness with limited unsupported length.

6. Wooden Joinery

A Newari House in Kathmandu Valley

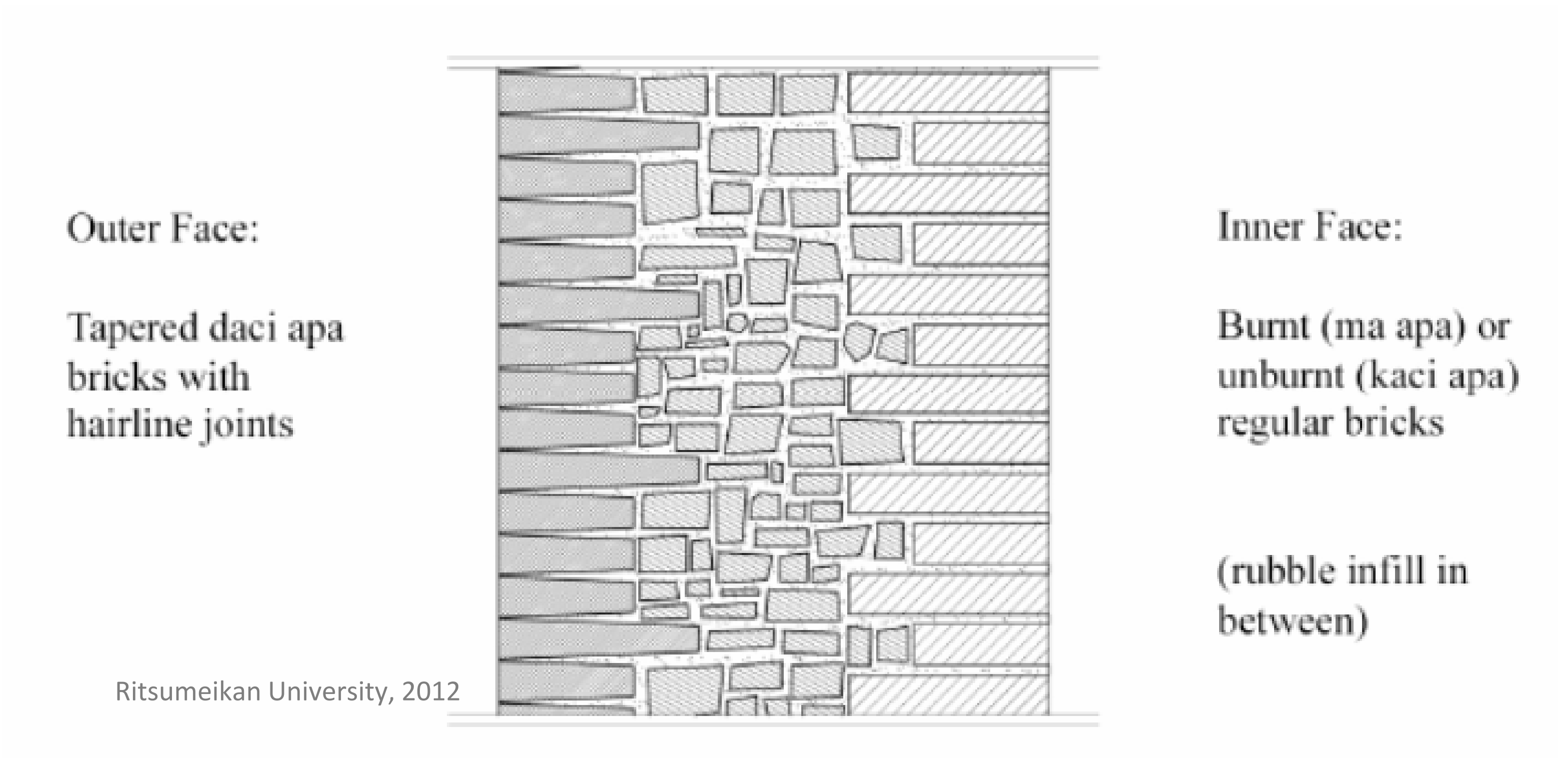
Indigenous knowledge and practices for mitigation of earthquake risk

6. Roofing system:

- Timber rafter and purlin support layer of timber plank and mud which is covered by terracotta.
- Roof projection of above 1 m to project the external wall from rain and deterioration. It is supported by wooden struts to transfer load to vertical load bearing wall.

Deficiencies of the structure

- The 45cm wall has two faces: baked bricks on the outside and crude brick on the inside. Both laid on runner and internal spacing filled with crude bonding of brick pieces which is usually disconnected.
- Rc … as ea
- He … ie re … ke fo



Ritsumeikan University, 2012

Indigenous knowledge and practices for mitigation of earthquake risk

- Indigenous solutions have been developed using local materials and expertise.
- The big earthquake's recurrence rate is a century while medium level earthquake is frequent so the building must have been developed for shorter recurrent cycle.
- The caste system limited building construction to a social group. The knowledge was stored in their minds, refined based on experience. Skill and knowledge was transferred from one to another generation, with continuous innovations leading to a significant accumulation of design, detail and practice of construction systems that could undertake great earthquake force. (Source: Tiwari, 1998)

Indigenous knowledge and practices for mitigation of earthquake risk

Vernacular architecture is wide spread outside Kathmandu Valley as well.

Level of details and complexity varies, still people have used technologies that would add flexibility and stability to the structure to resist lateral force.

House in Kaski

House in Surkh

Oldest house in Dolakha

Indigenous knowledge and practices for mitigation of earthquake risk

While these buildings are rapidly replaced by modern RC structures in both urban and rural areas.

- Confidence on traditional material and technology
- Transition to new technology, supposedly related to status
- Availability of material, specially timber

Additional floors in traditional building

RC structures in historic core area of Lallitpur

In Bajhang, price of brick and cement is double due to transportation

Indigenous knowledge and practices for mitigation of earthquake risk

GI wire containment technology:

Traditional technology is retained by using new material.

UNDP's initiative in reconstruction

Thank you!