An invited talk at the Indo-US 2012 Workshop on Intraplate Seismicity
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Session chaired by Harsh Gupta

Medieval Multihazards and Future Earthquakes in Kashmir

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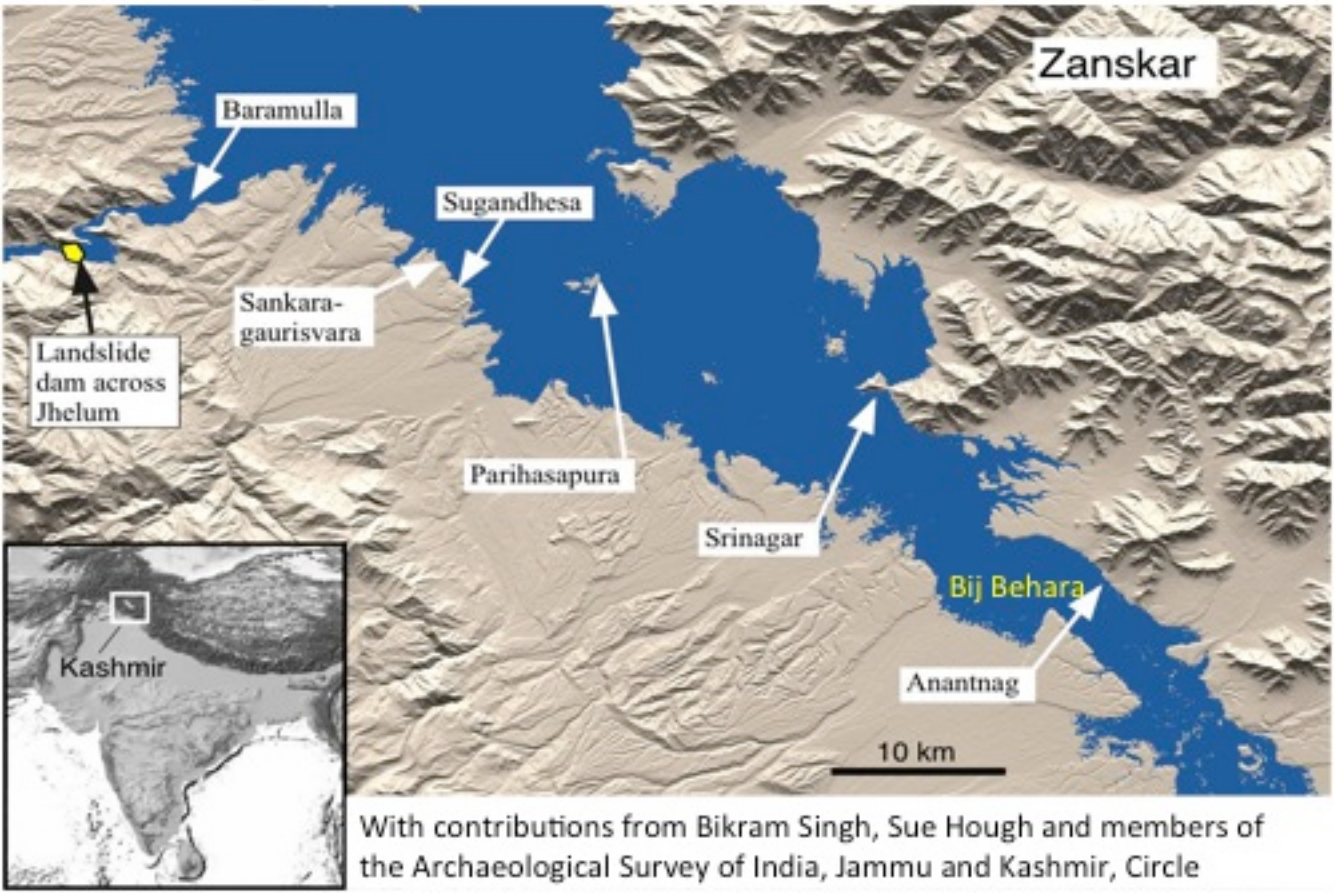
Historical accounts of floods, landslides and earthquakes in Kashmir and new geodetic, archaeological and geological observations relevant to the characterization of future earthquake scenarios in Kashmir.

Summary- Although Mmax=8.9 is calculated to be the maximum credible earthquake for Kashmir based on the probable width of future rupture extending north of the valley below the Zanskar mountains, the most probable future earthquakes based on historical accounts may be as low 7.6<Mw<8.6. Relatively modest earthquakes may trigger landslides that have historically blocked the Jhelum leading to flooding of Srinagar within 18 months, or sooner, depending on prevailing Jhelum discharge rates. The dates of the collapse of Medieval temples provide estimates of the date of historical earthquakes, and almost certainly a record of historical floods is recorded in the valley sediments.

Mile high floods in Medieval Kashmir



With contributions from Bikram Singh, Sue Hough and members of the Archaeological Survey of India, Jammu and Kashmir, Circle

The Suyya legend

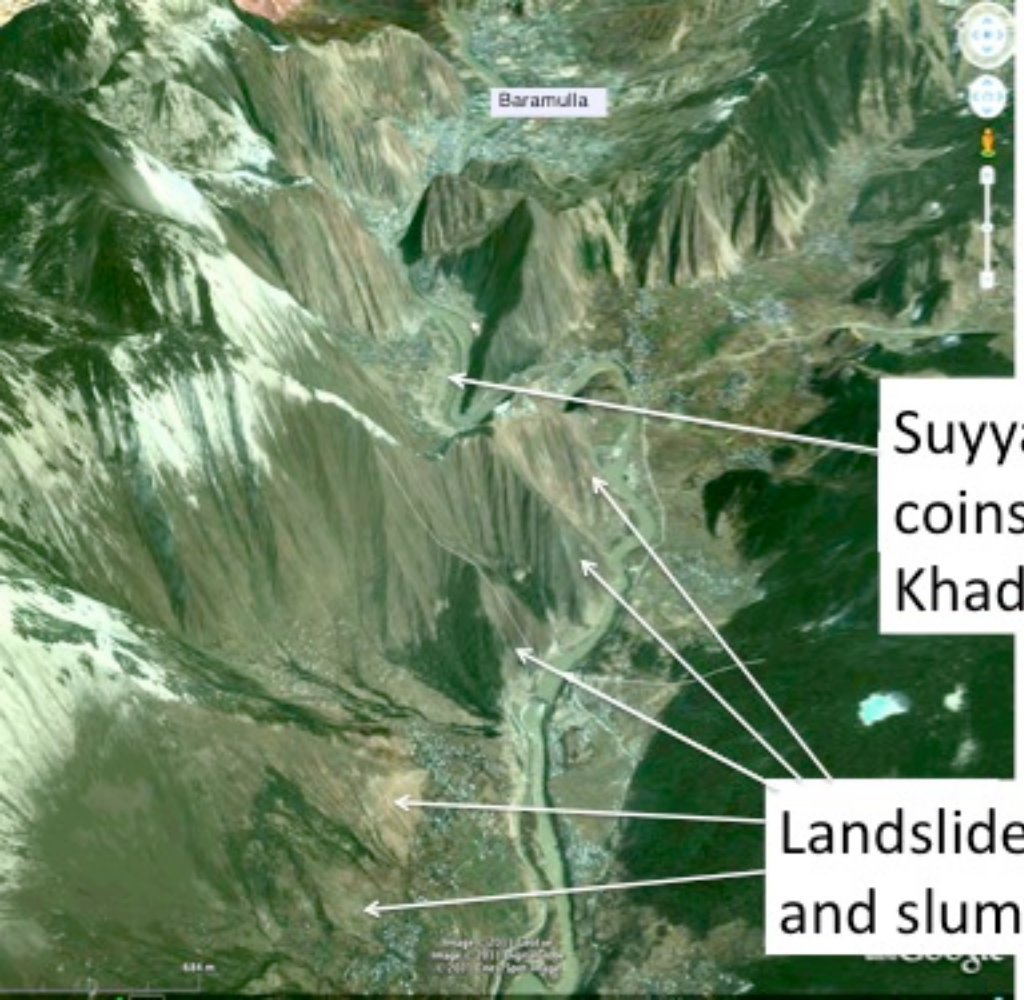
"1. *A nocturnal earthquake occurred during the reign of Avantavarman in 883 AD*

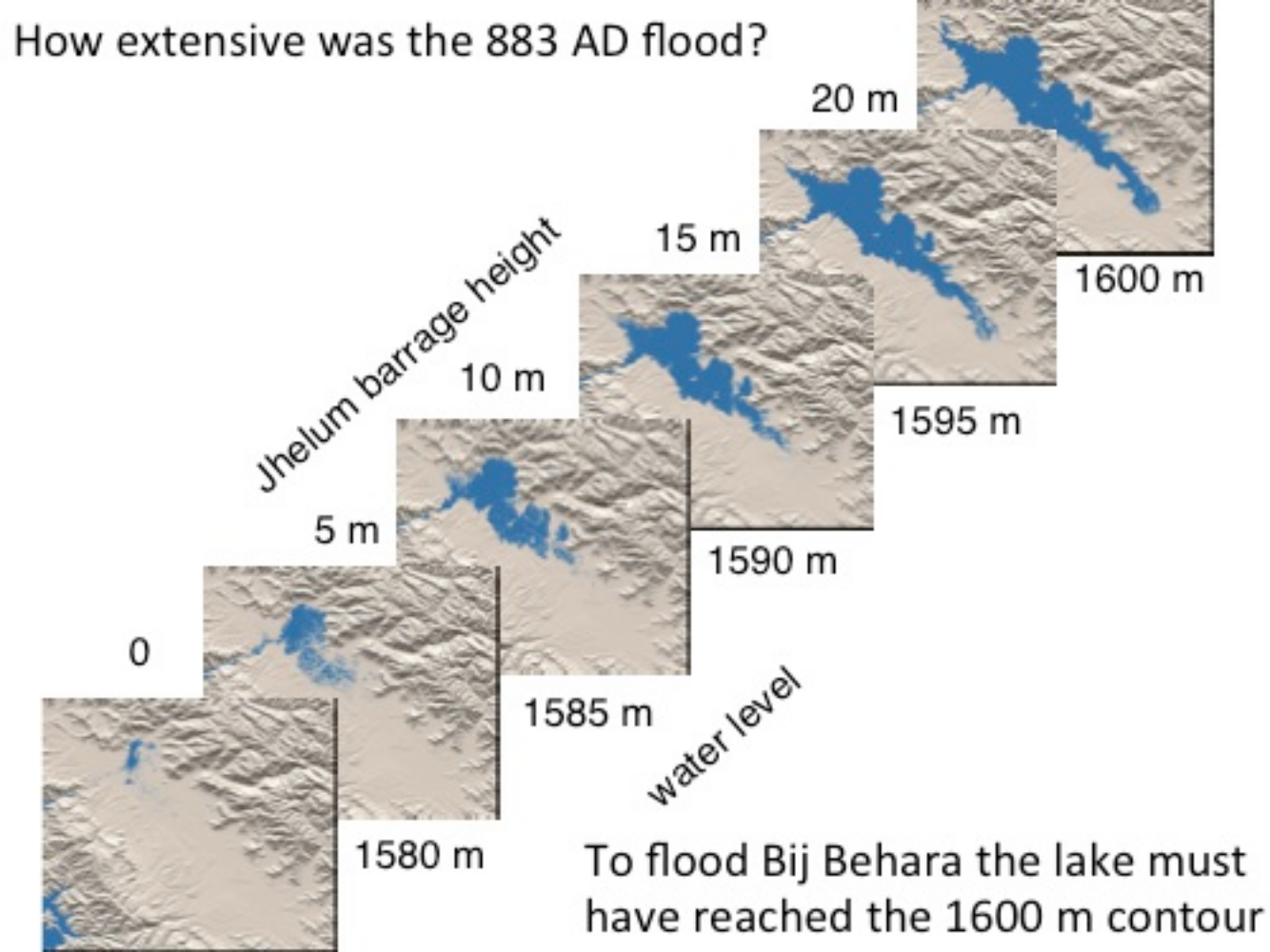
"2. Boulders from the mountainous ridge of Khadniyar on the Baramula side rolled into the bed of the Jhelum and consequently the flow of the river was blocked.

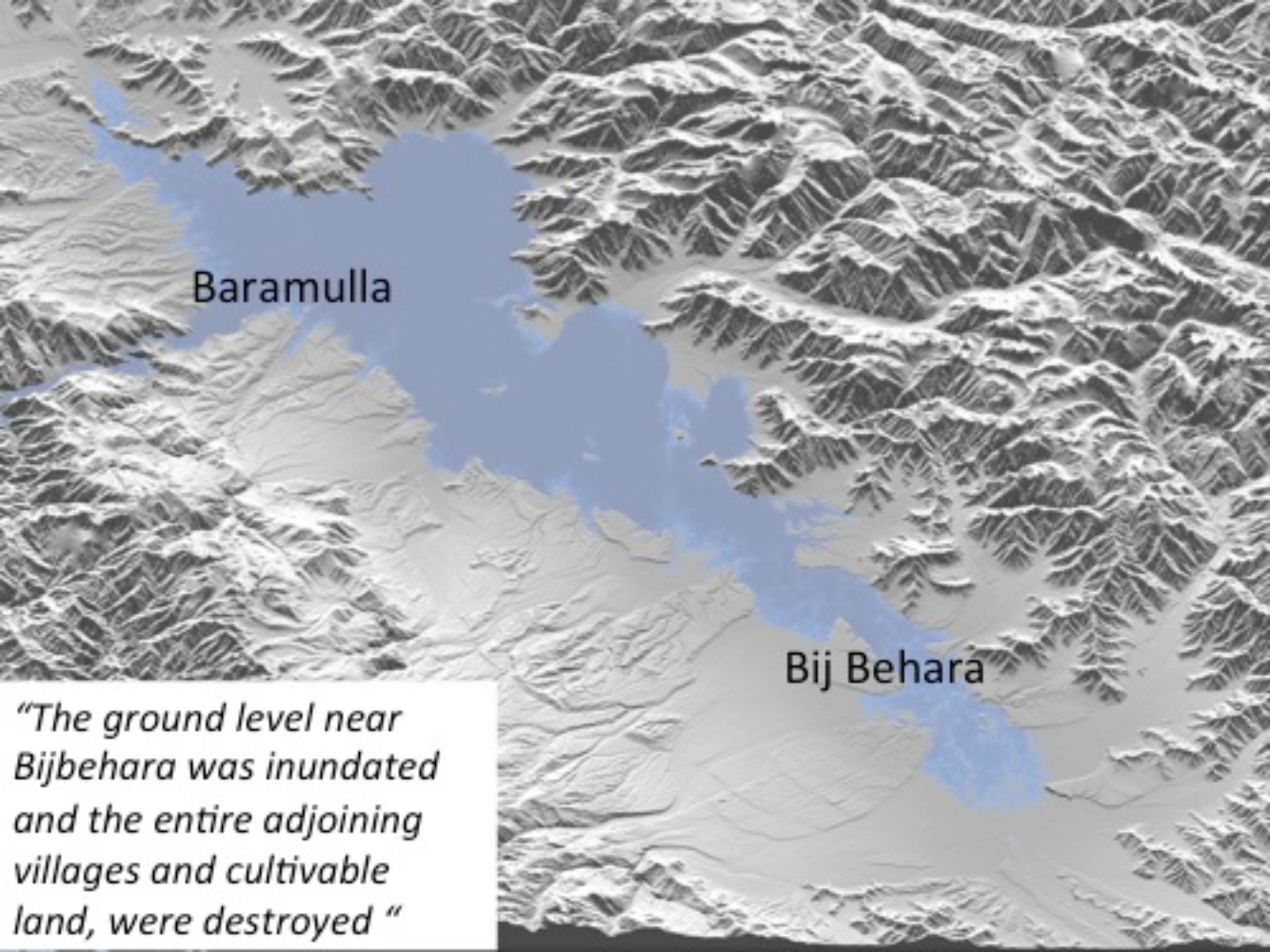
3." The ground level near Bijbehara was inundated and the entire adjoining villages and cultivable land, were destroyed.

4. Then by the efforts of the engineer, Suyya, stone conglomerates of the mountain were removed from the river bed and the water was set free."

Tarik-i Hasan c.1690
Kalhana's Rajatarangini omits the earthquake.

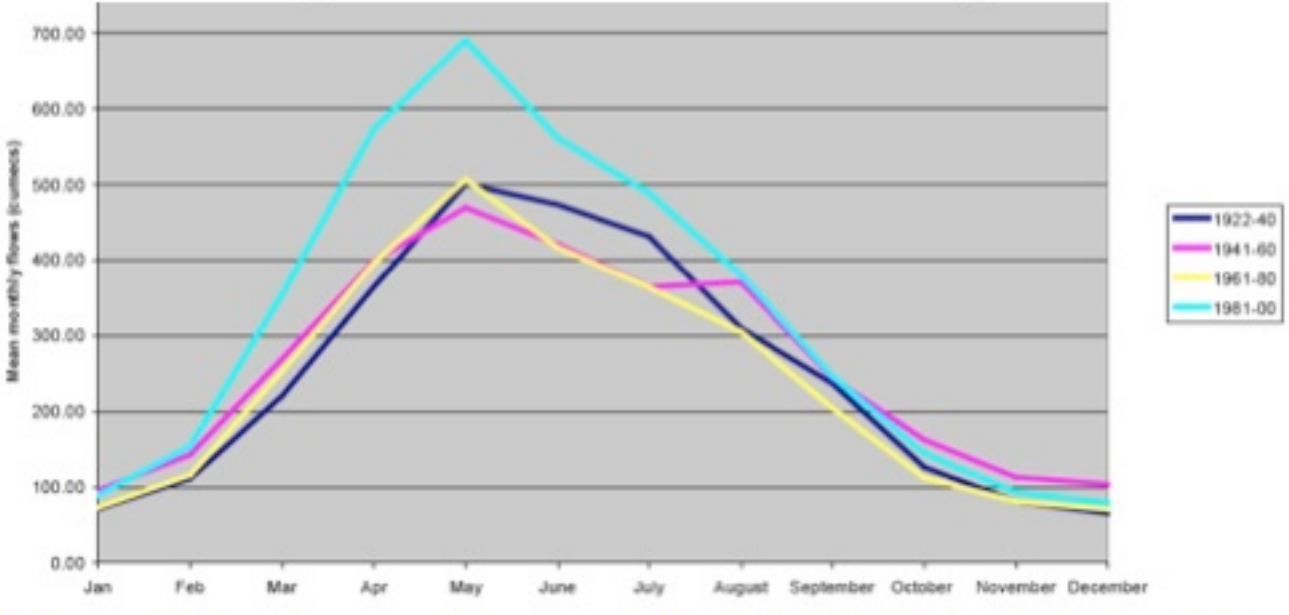

Baramulla
Suyya dumps coins near Khadinyar
Landslides and slumps


How extensive was the 883 AD flood?
20 m
15 m
10 m
5 m
0
Jhelum barrage height
1600 m
1595 m
1590 m
1585 m
1580 m
water level
To flood Bij Behara the lake must have reached the 1600 m contour



"The ground level near Bijbehara was inundated and the entire adjoining villages and cultivable land, were destroyed "

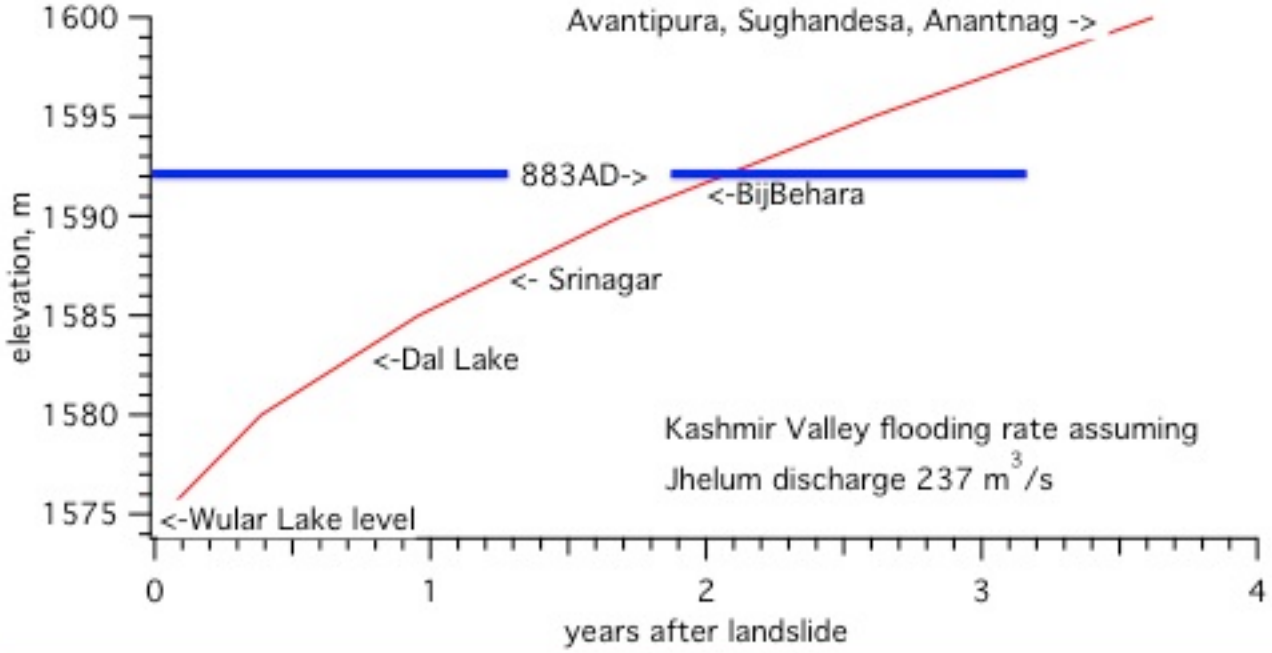
How long to flood the valley?



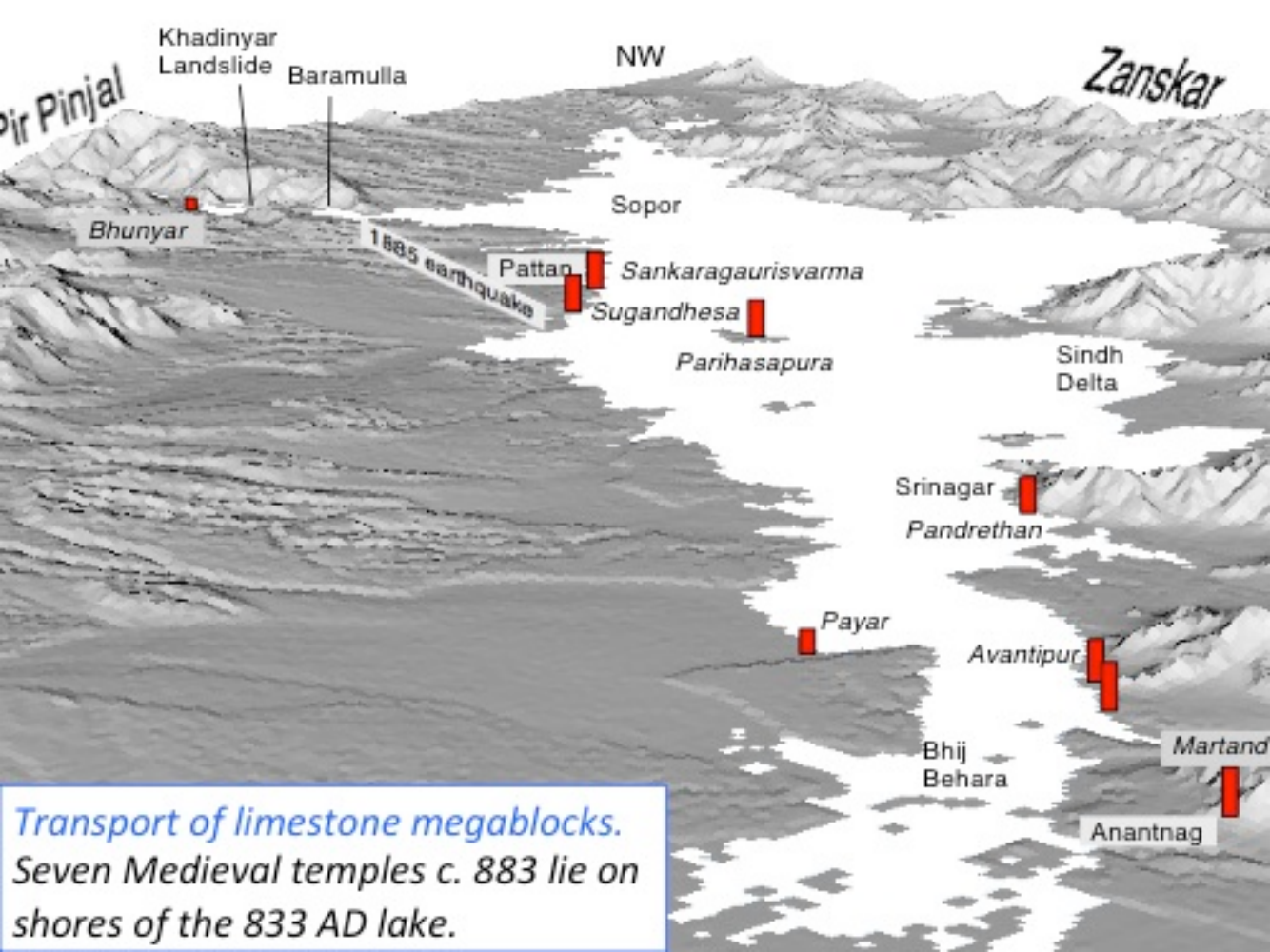
Mean Discharge Jhelum 1922-2000 = 276 m^3/s

Max flow 700 m^3/s April-June

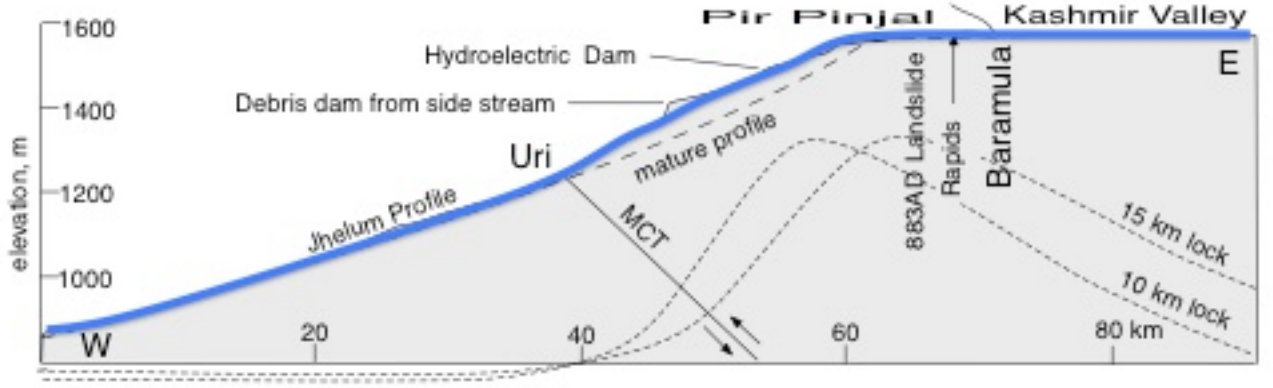
Min Flow 100 m^3/s November-February



Flood reaches BijBehara in 1-2 years.
Onlaps Medieval temples in 3 years



Transport of limestone megablocks.
Seven Medieval temples c. 883 lie on shores of the 833 AD lake.



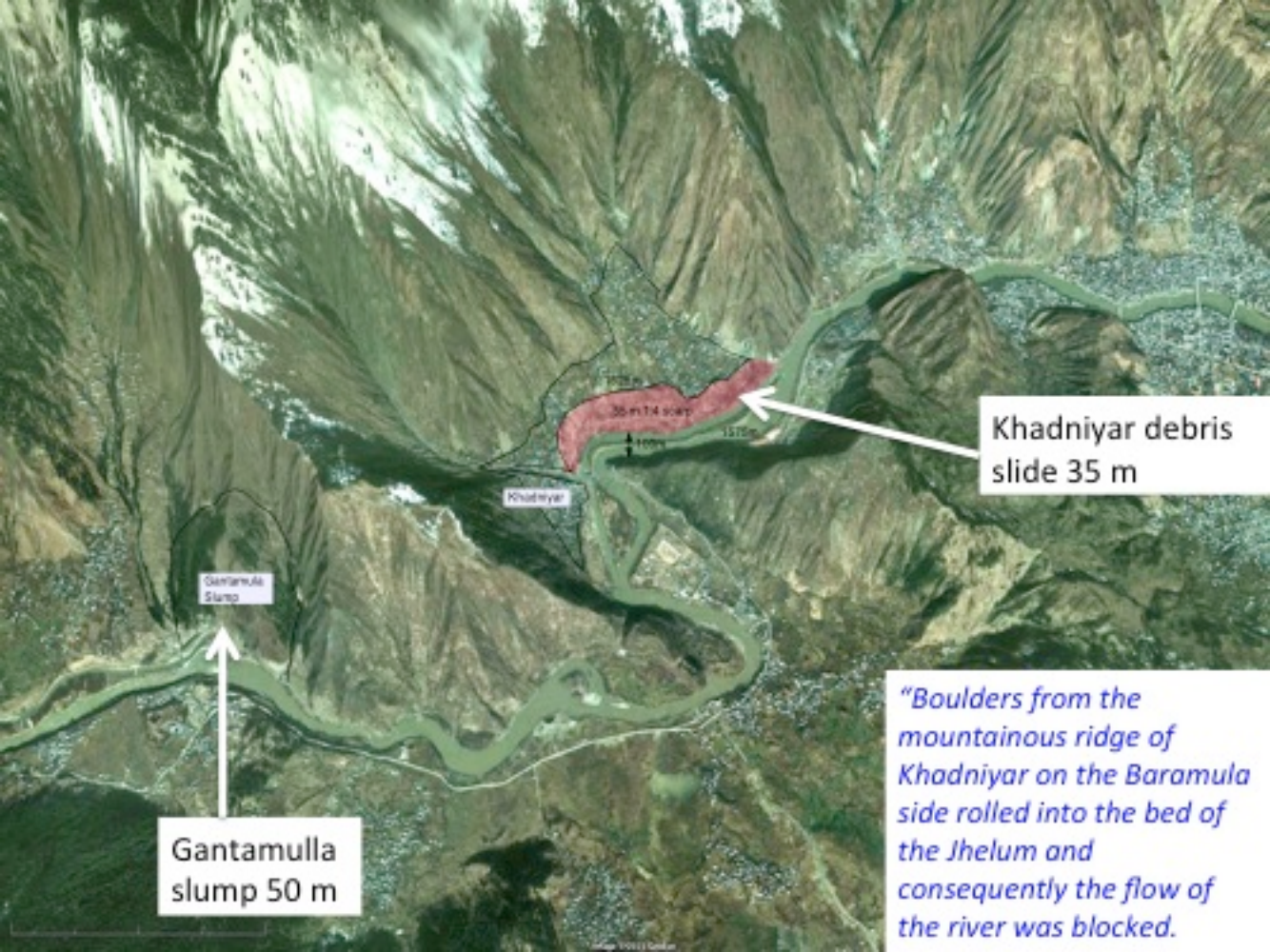
How high was the dam?

First 25 km of Jhelum profile is convex due to uplift.

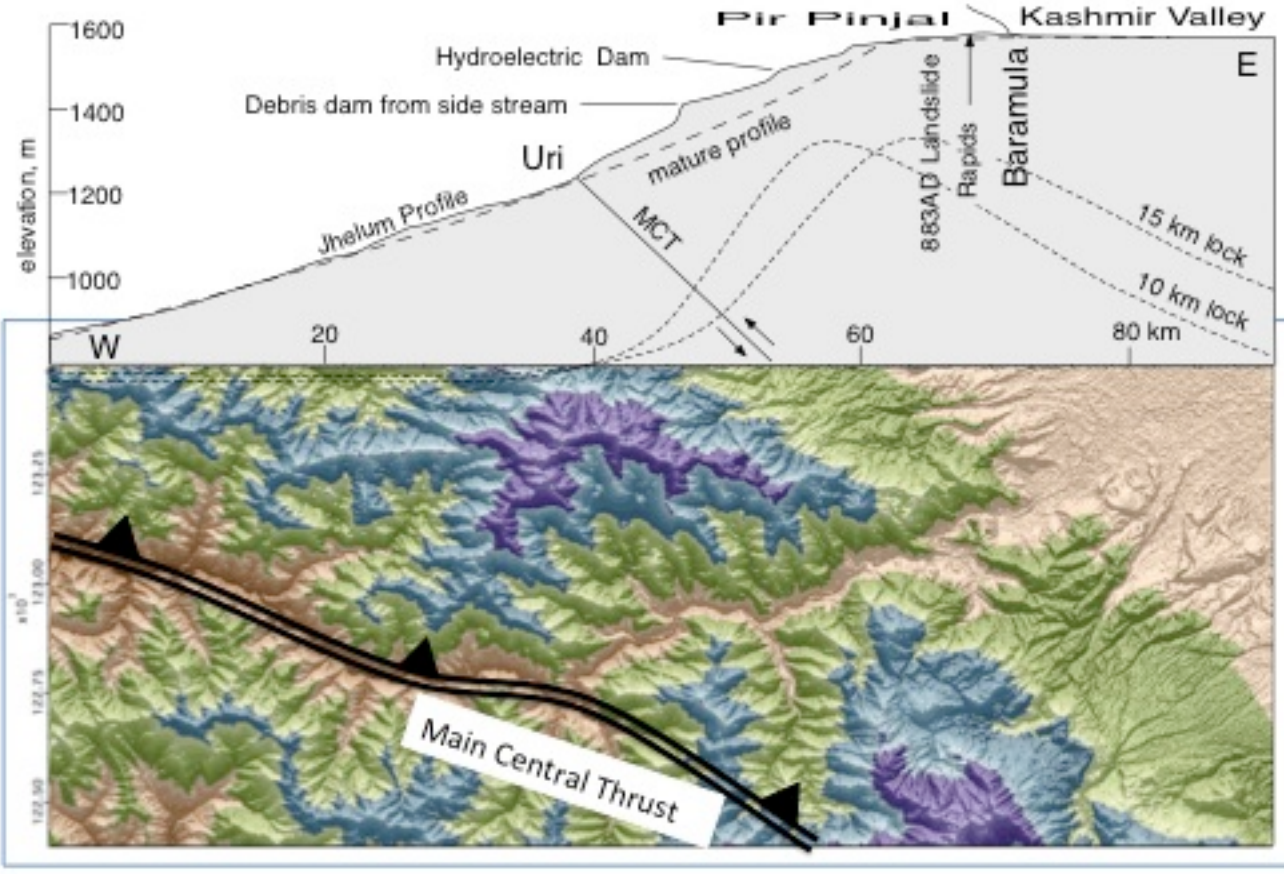
Landslide >400 m if near Uri!

<25 m within 5 km Baramulla

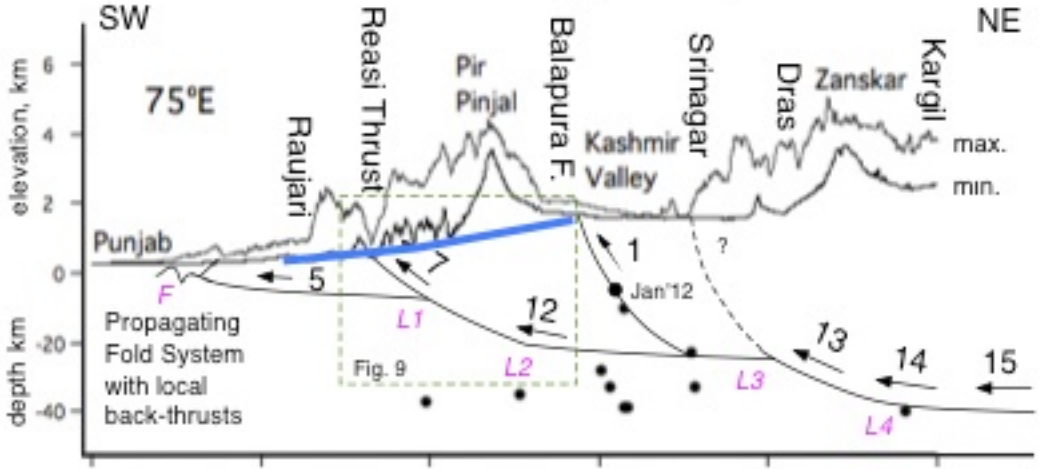
=15 m *at* Baramulla

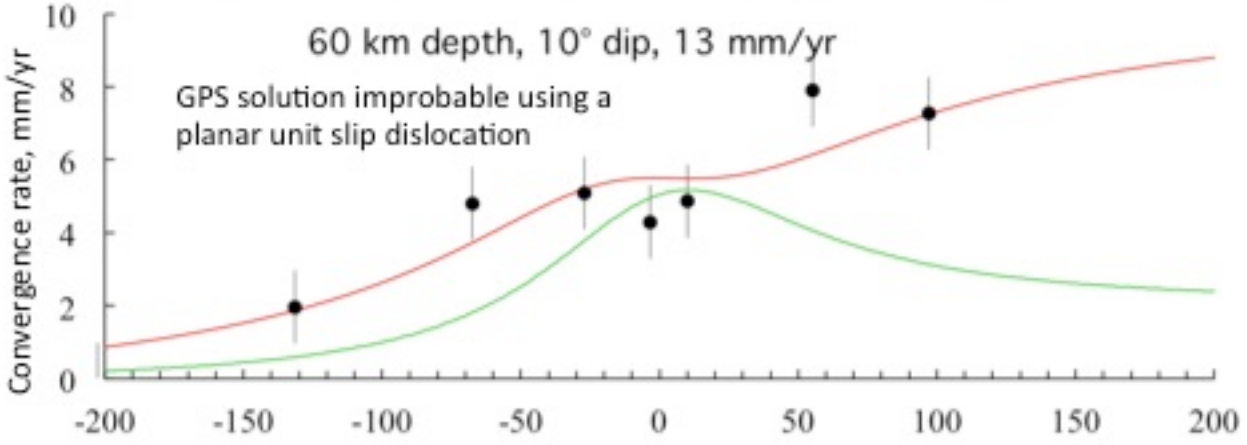

Khadniyar debris slide 35 m
Gantamulla slump 50 m
"Boulders from the mountainous ridge of Khadniyar on the Baramula side rolled into the bed of the Jhelum and consequently the flow of the river was blocked.

Causal Earthquake on MCT? -would explain profile disequilibrium



Current GPS velocities suggest tapered seismic coupling





Historical Sequence for medieval megaflood

Earthquake -> landslide

Jhelum dammed-> flood

Flood waters rise 1 m/month

70% arable land flooded
Crops destroyed, orchards drowned
Sopur and Srinagar under 5-10 m
70% population displaced to high ground
Widespread famine

Sankaravarman (883-902) forms marauding army to plunder neighbouring kingdoms. Arrow through the neck 902AD.

902-950 AD Years of misrule, weak kings, power struggles, corrupt government and famine.

"What if" sequence for megaflood today

09:00 16 January 2012 Mw=7.8 earthquake
09:10 16 Jan Landslide impounds Jhelum
Dal Lake rises 50 cm/day in next 10 days
17-31 January Search & rescue
Feb-March Flood waters now rising 10 cm/day

Railroad/roads impassable. Military crippled. Displaced population. Jhelum Hydropower standstill. Power lines underwater. Airport isolated. Food by helicopter.

Reactive measures

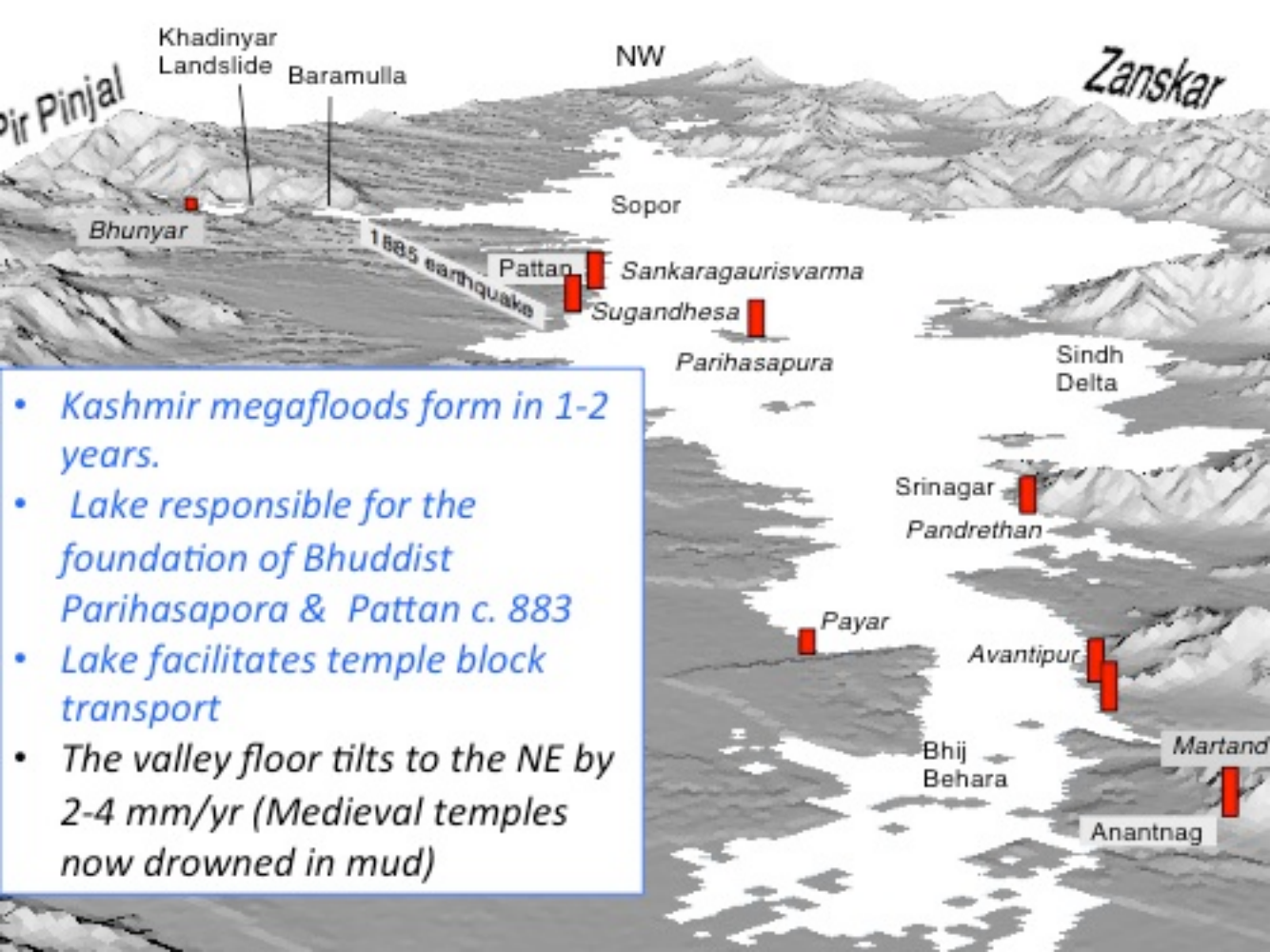
Late engineered breach
Colateral damage to downstream hydropower
Pakistan views bomb induced breach as act of aggression (despite international agreement)

Natural breach
Unpredictable upstream flood
Uncontrollable downstream flood
Debris and rock slide damage to hydropower

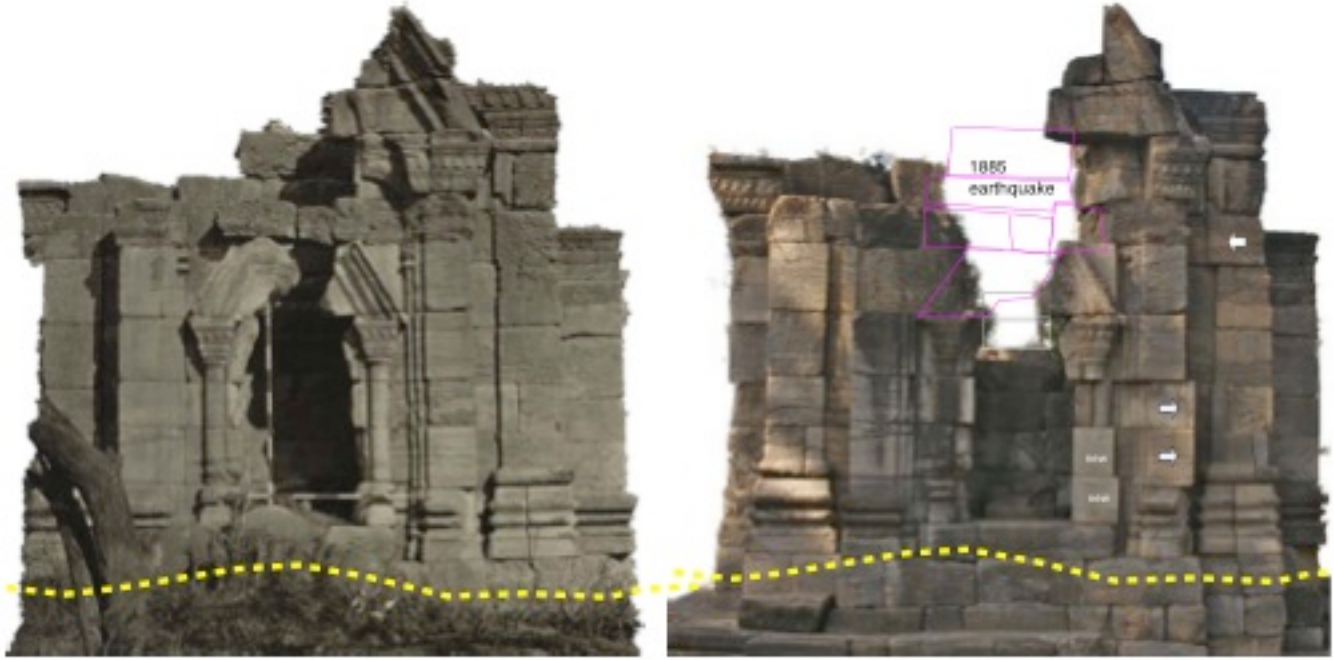
Proactive measures

Early engineered breach
Distraction from earthquake response
Pakistan collaboration (access from east by earth moving machinery)

Pre-emptive bypass tunnel
No Flood
Possible rupture during earthquake



- *Kashmir megafloods form in 1-2 years.*
- *Lake responsible for the foundation of Bhuddist Parihasapora & Pattan c. 883*
- *Lake facilitates temple block transport*
- *The valley floor tilts to the NE by 2-4 mm/yr (Medieval temples now drowned in mud)*

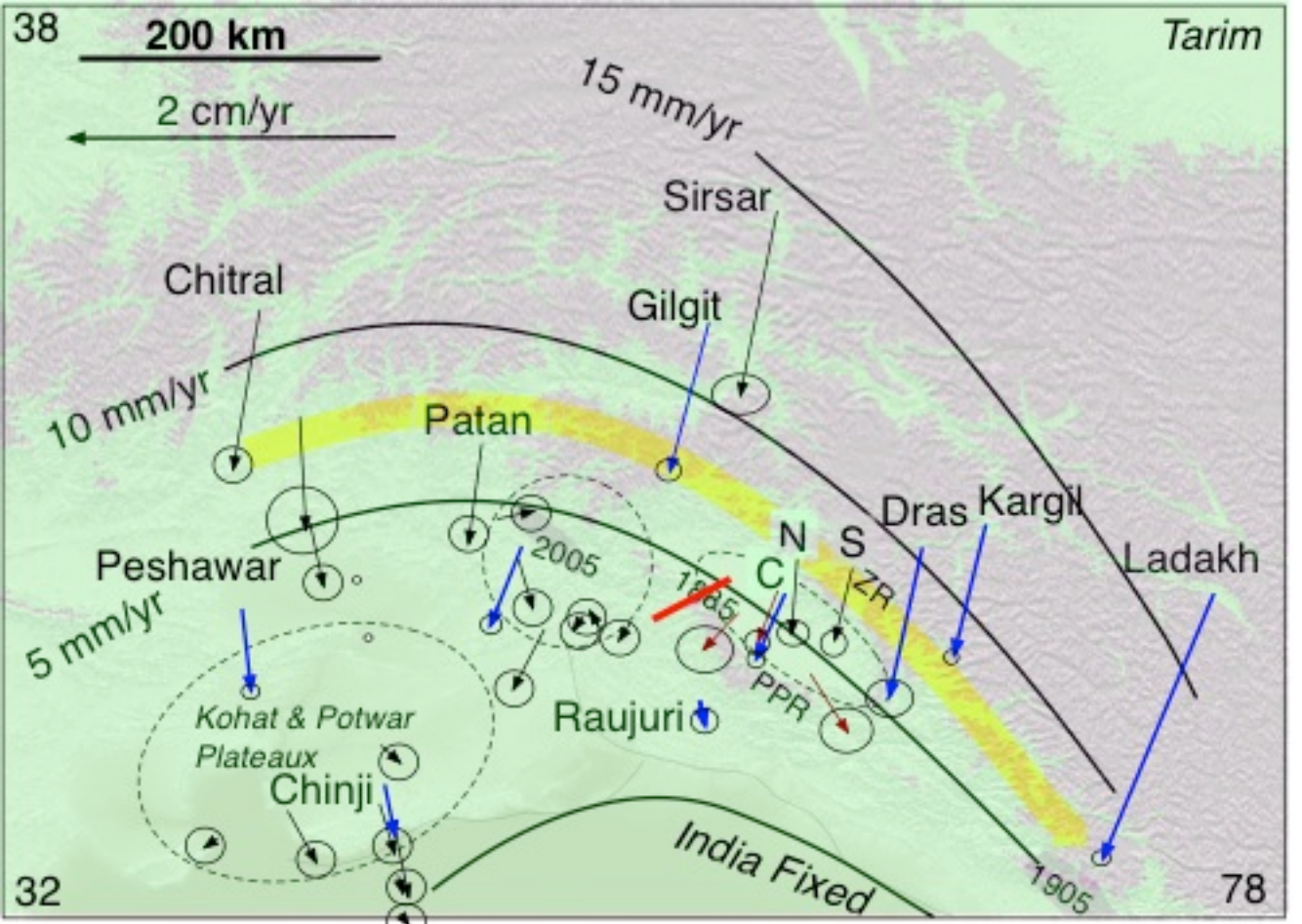


Sequential damage to Kashmir megablock temples during earthquakes

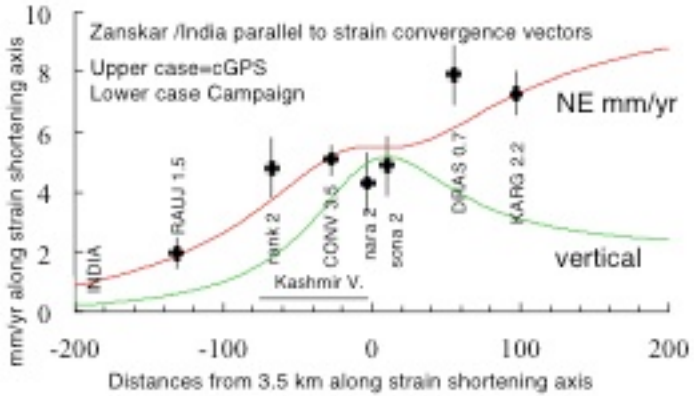
Uppermost blocks toppled

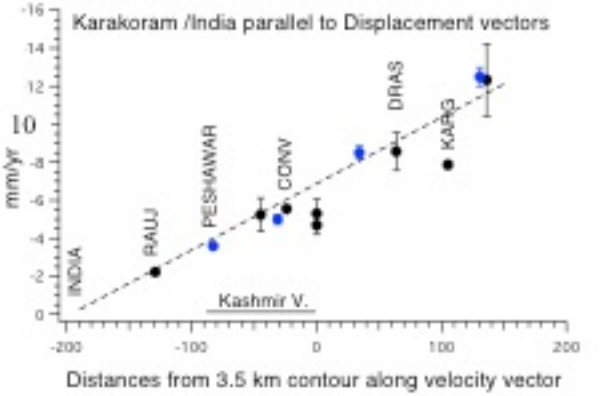
Intermediate blocks jostled

In collaboration with the Archaeological Survey of India we are dating incremental block collapse reconstruct history of shaking in the valley.

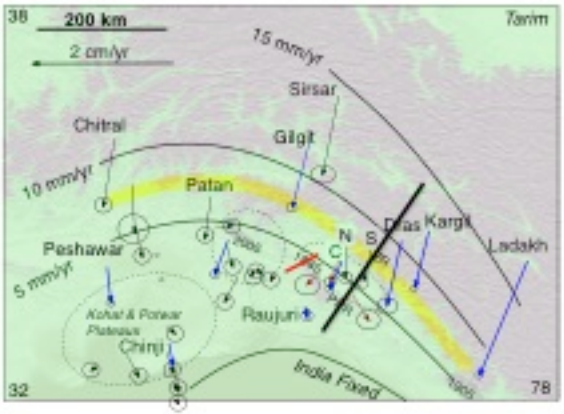


GPS convergence vectors 2005-2011. India Fixed. University of Kashmir and Peshawar

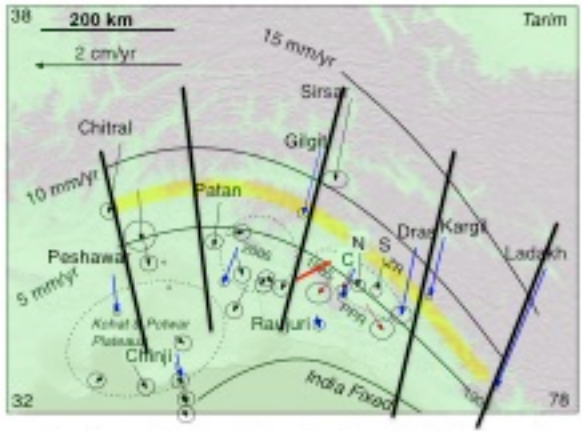




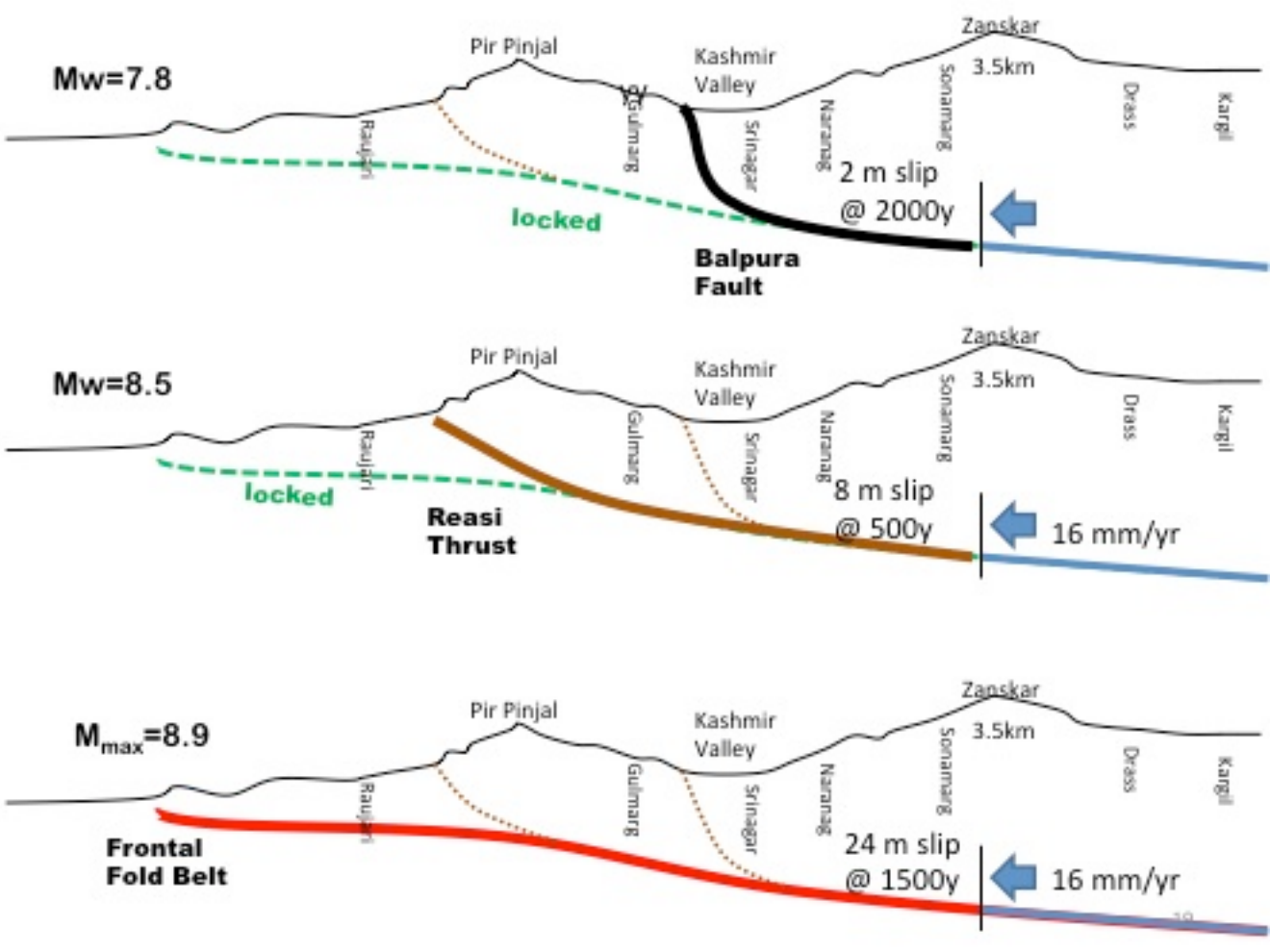
Arc Normal velocities



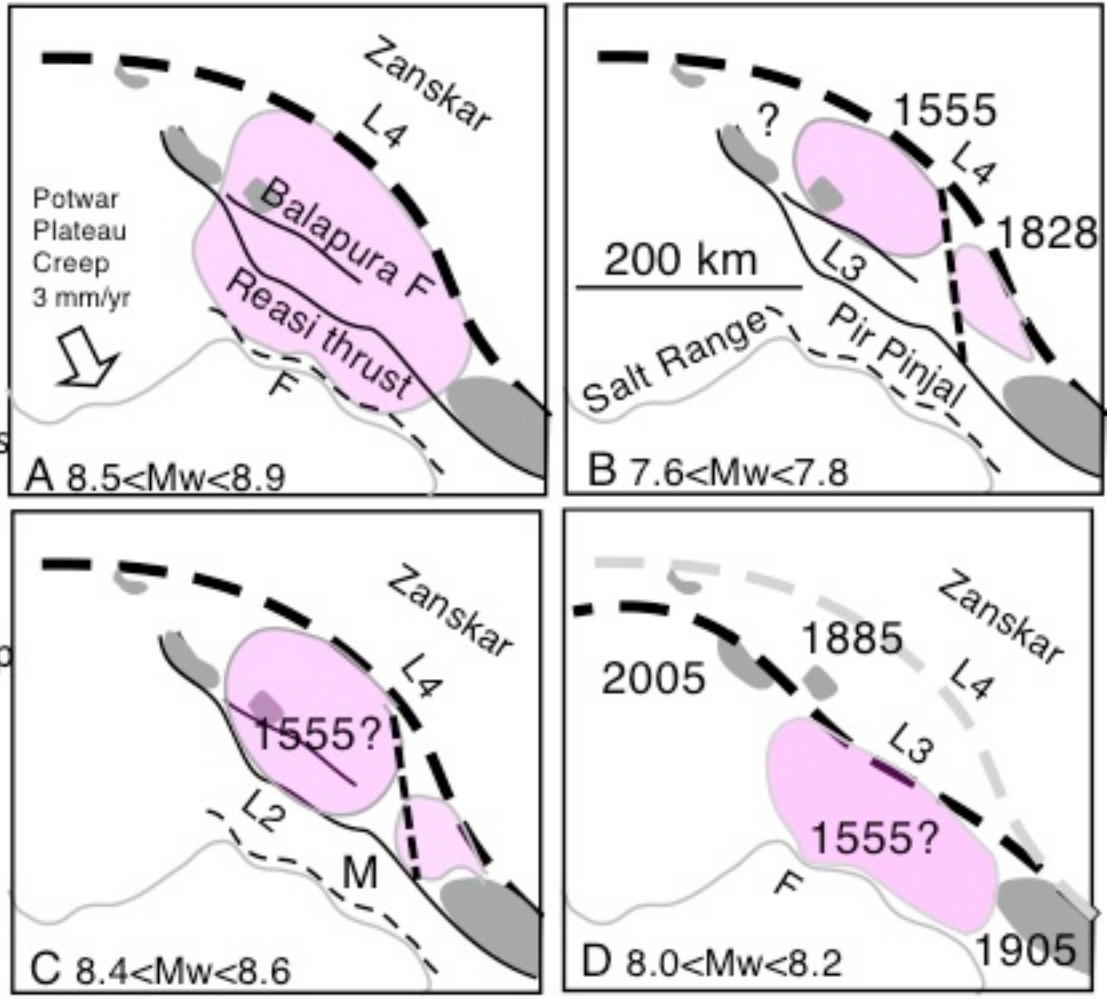
Vector parallel velocities

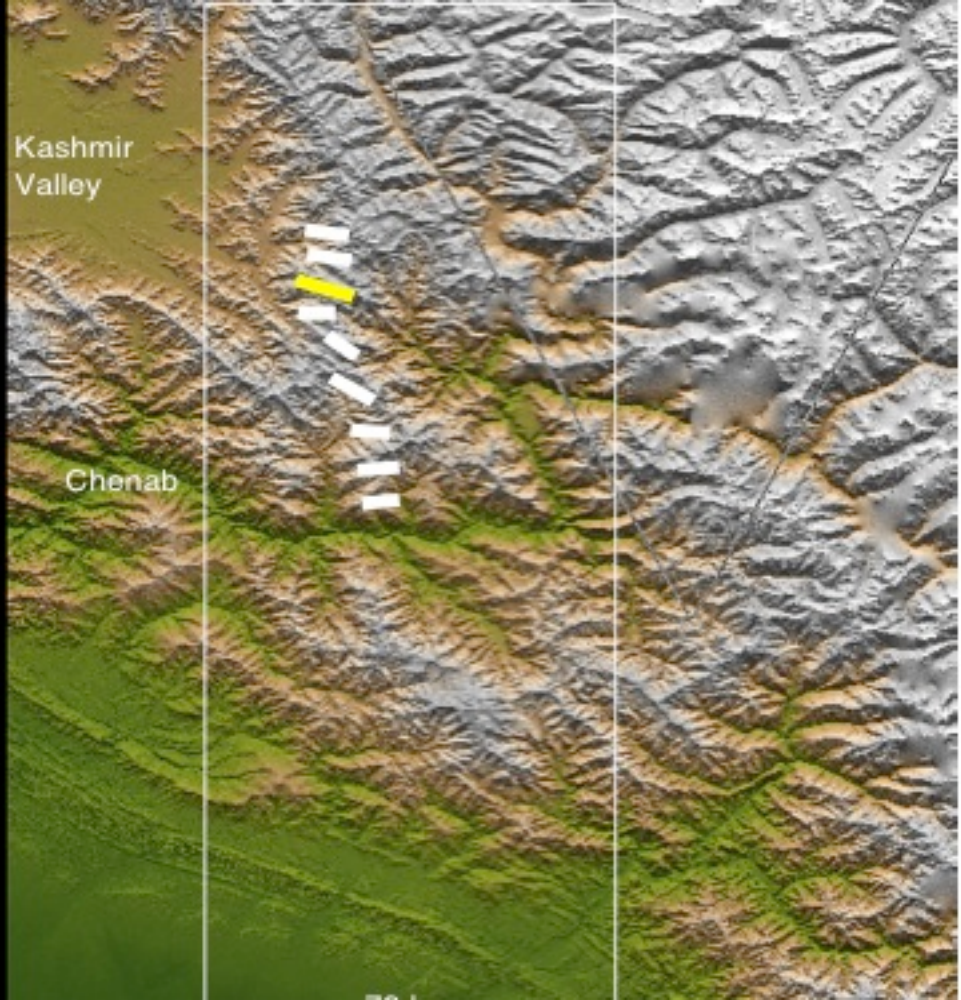


GPS does not fit planar dislocation. Apparently tapered seismic coupling loaded by 15mm/yr.


Mw=7.8
Pir Pinjal
Kashmir Valley
Zanskar
3.5km
Rajouri
Gulmarg
Srinagar
Naranag
Sonamarg
Drass
Kargil
2 m slip
@ 2000y
locked
Balpura Fault
Mw=8.5
Pir Pinjal
Kashmir Valley
Zanskar
3.5km
Rajouri
Gulmarg
Srinagar
Naranag
Sonamarg
Drass
Kargil
locked
Reasi Thrust
8 m slip
@ 500y
16 mm/yr
Mmax=8.9
Pir Pinjal
Kashmir Valley
Zanskar
3.5km
Rajouri
Gulmarg
Srinagar
Naranag
Sonamarg
Drass
Kargil
Frontal Fold Belt
24 m slip
@ 1500y
16 mm/yr

Alternative Kashmir scenario-earthquakes based on assumed rupture area and slip





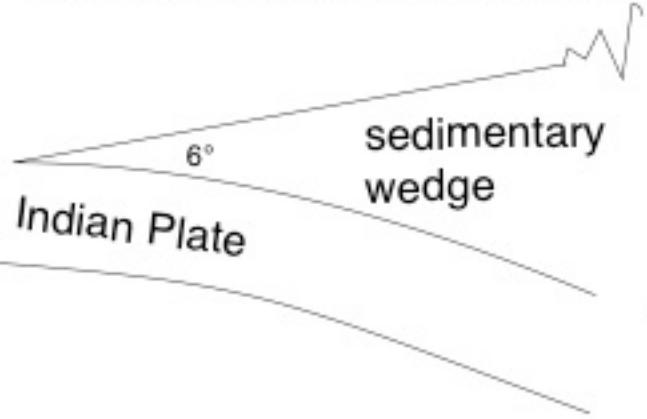
Possible segment boundary SE Kashmir underlying linear sequence of normal faults

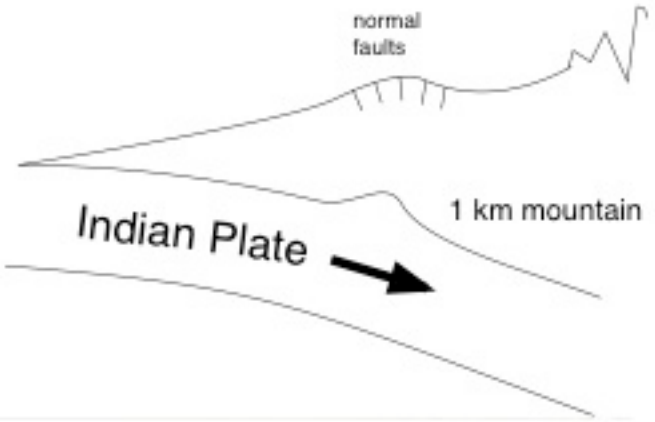
WNW normal fault slipped 700-400 BC

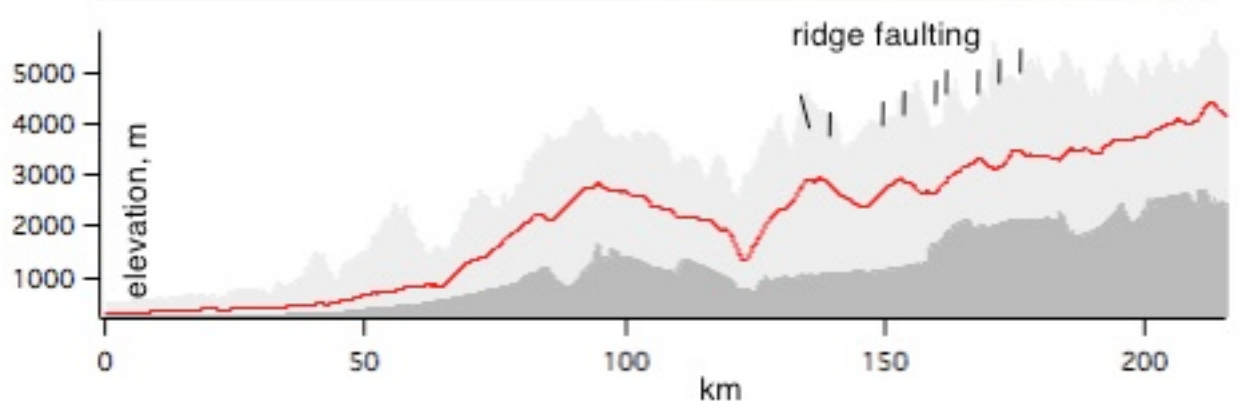
^{14}C sag pond samples

courtesy Shabir Ahmad

Ancient Punjab mountain pushed beneath the Himalaya?







Preferred Kashmir rupture scenarios based on historical Record
A and D considered unlikely