Comisión Nacional de Investigación Científica y Tecnológica - CONICYT

National Natural Science Foundation of China
国家自然科学基金委员会——NSFC

Chile-China Workshop （2016.08.26）

Some Issues on Strong Earthquake Induced Landslide in China

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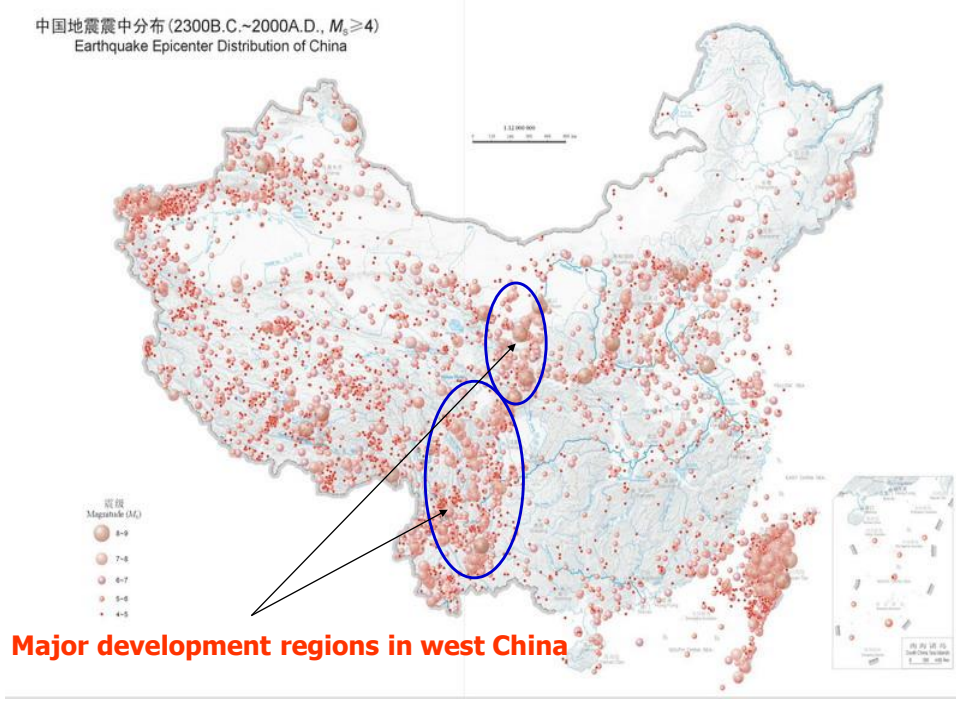
Content

- China is one of countries with numerous active faults and high seismicity in the World



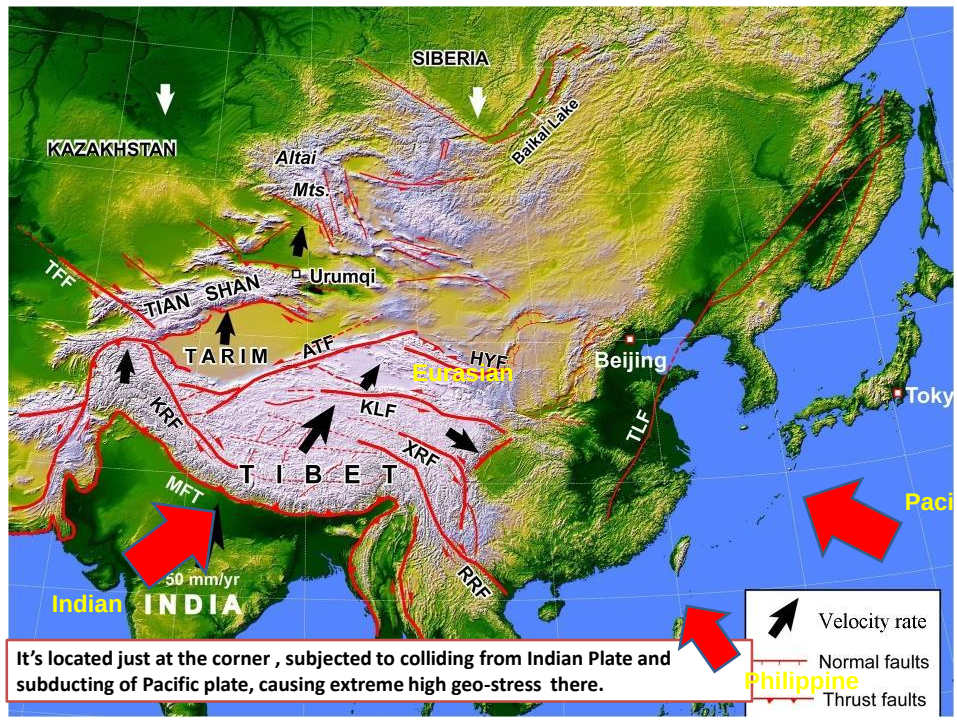
Major development regions in west China

Seismic disasters since 1900 in China mainland

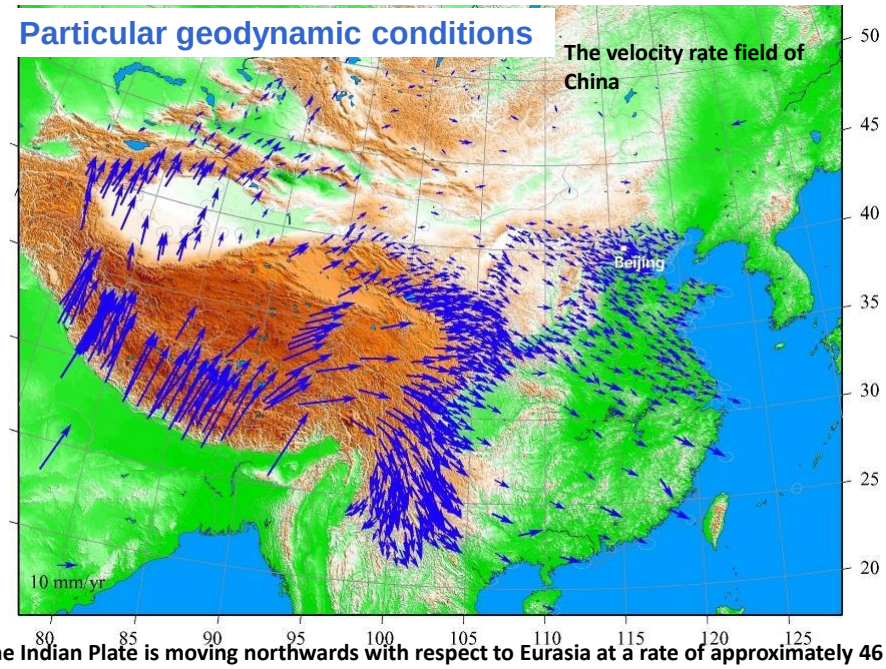
No.	Year	Place	Magnitude	Intensity	Fatalities
1	1902	Ashitu, Xinjiang	8.25	XI	1,000
2	1904	Daofu, Sichuan	7	IX	>400
3	1906	Shawanxi, Xinjiang	7.7	X	>300
4	1908	Qiling Lake, Tibet	7	IX	<100
5	1920	Haiyuan, Ningxia	8.5	XI	240,000
6	1927	Gulong, Gansu	8	XI	40,000
7	1932	Changma, Gansu	7.6	X	70,000
8	1933	Maoxian, Sichuan	7.5	X	20,000
9	1950	Chayu, Tibet	8.5	XII	4,000
10	1966	Xintai, Hebei	7.2	IX	8,064
11	1970	Tonghai, Yunnan	7.7	X	15,621
12	1975	Haicheng, Liaoning	7.3	IX	1,328
13	1976	Tangshan, Hebei	7.8	XI	242,000
14	1988	Lancong, Yunnan	7.6	IX	743
15	2008	Wenchuan, Sichuan	8.0	XI	87,419
	Since 1900, over 750,000 killed, over 7,000 per year				

- Why the China land is of such high seismicity?
- Are there are any particular geodynamic conditions?

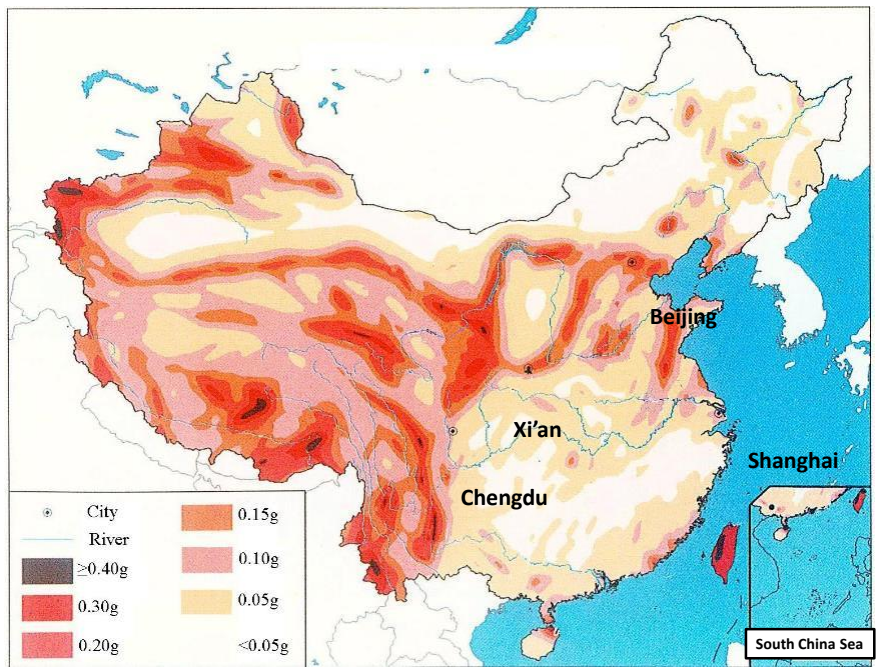

Eurasian
Indian
Pacific
Philippine


SIBERIA
KAZAKHSTAN
Altai
Mts.
Baikal Lake
TFF
TIAN SHAN
Urumqi
TARIM
ATF
HYF
Eurasian
Beijing
Toky
KRF
KLF
XRF
TLF
T I B E T
MFT
50 mm/yr
Indian
INDIA
RRF
Paci
Philippine
Velocity rate
Normal faults
Thrust faults
It's located just at the corner , subjected to colliding from Indian Plate and subducting of Pacific plate, causing extreme high geo-stress there.

Particular geodynamic conditions



The Indian Plate is moving northwards with respect to Eurasia at a rate of approximately 46 mm/yr. This convergence drives the uplift of the Himalaya Mountains, at a rate of approximately 10 mm/yr. (Zhang et al.,2004.)

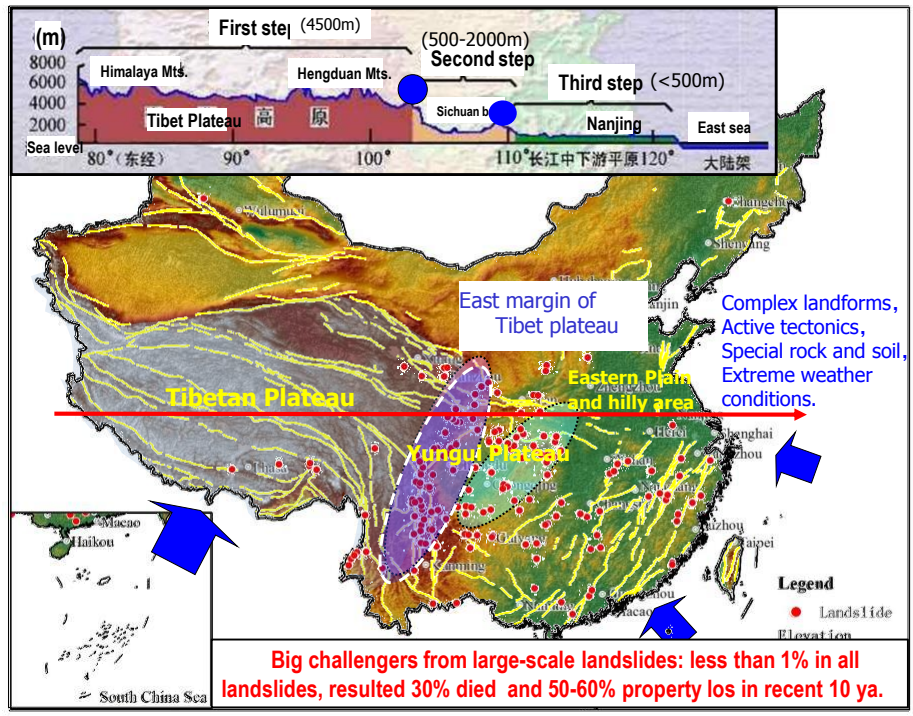


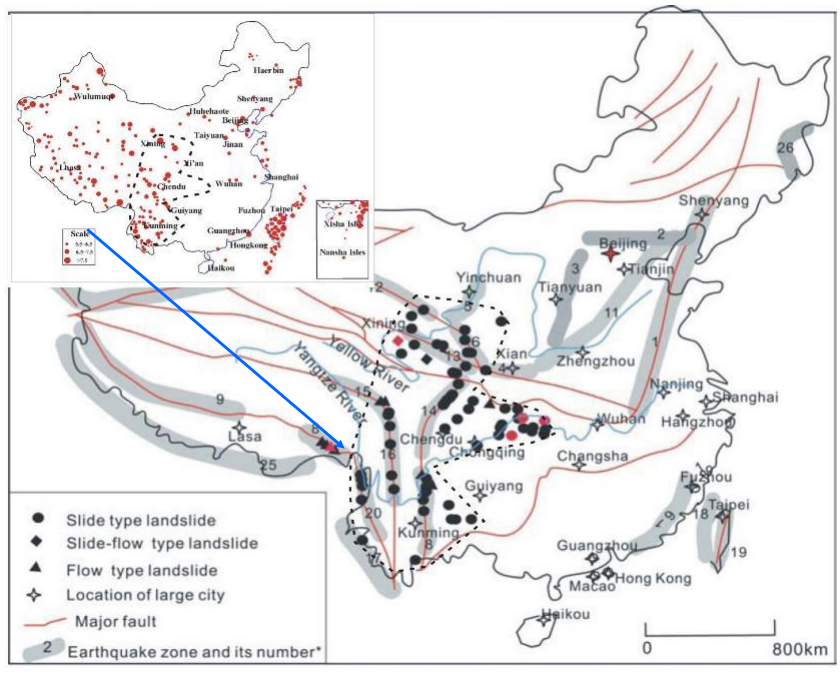
Peak ground acceleration in China (10％ in 50 years) shows the consequence of geo-stress and crust deformation(After China Seismological Bureau.)

Main factors of geo-sphere processes in China

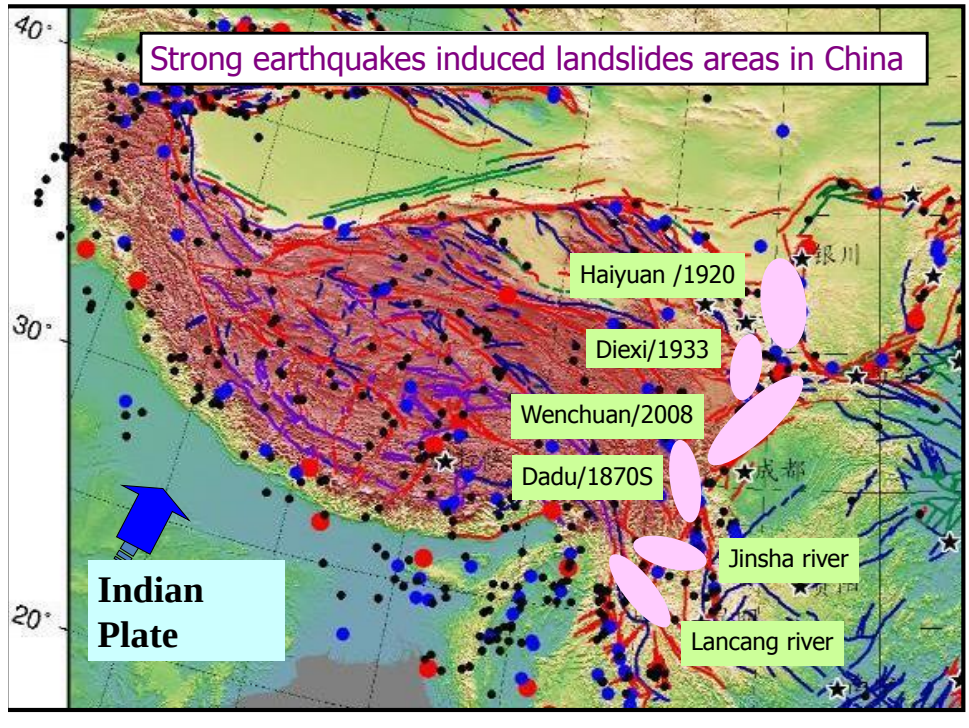
- Stepwise topography and eastward mass movement
- Complex tectonic pattern and activity
- Variety of rock exposures and deposits
- Complex surface-ground water migration

Result in frequent and sever geo-hazards: Landslide etc.





77 Giant Landslides (1900-2000) (Wen and Wang,2004)



Haiyuan earthquake (Ms=8.5)

- On December 16, 1920, the Haiyuan earthquake (Ms=8.5) occurred in the Liupanshan tectonic zone in Ningxia Province, China.
- Haiyuan earthquake directly caused lots of landslides, especially in Xiji County. More than 20,000 people were killed in the earthquake.

Dangjiacha landslide

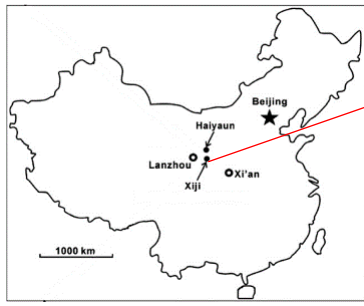
Loess Landslide

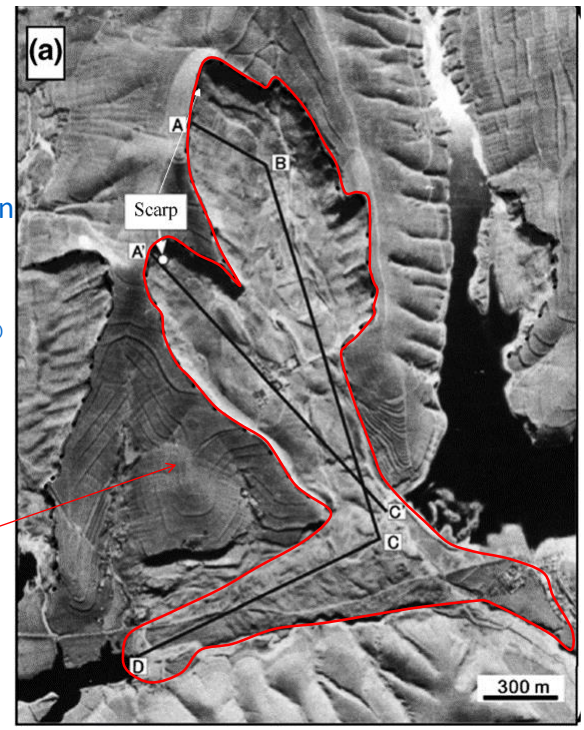
High velocity and long runout

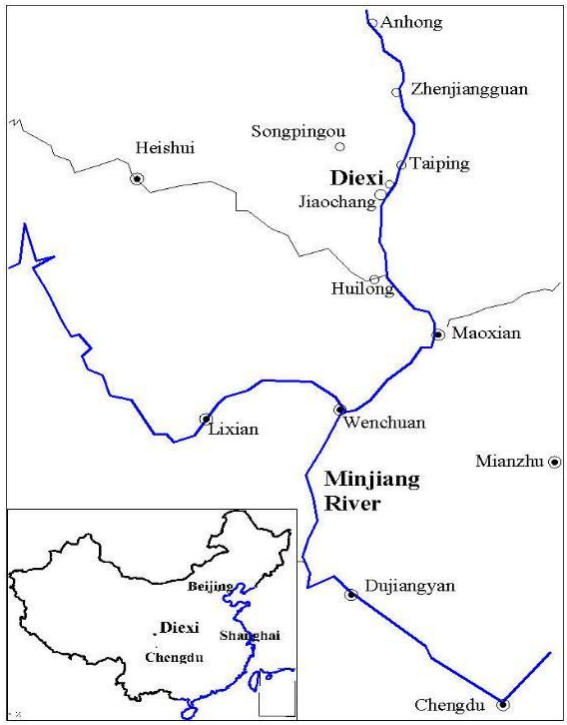
Sliding surface liquefaction

quake dam with a volume of $15 \times 10^6\ m^3$

（Modified after Zhang et al.，2007）



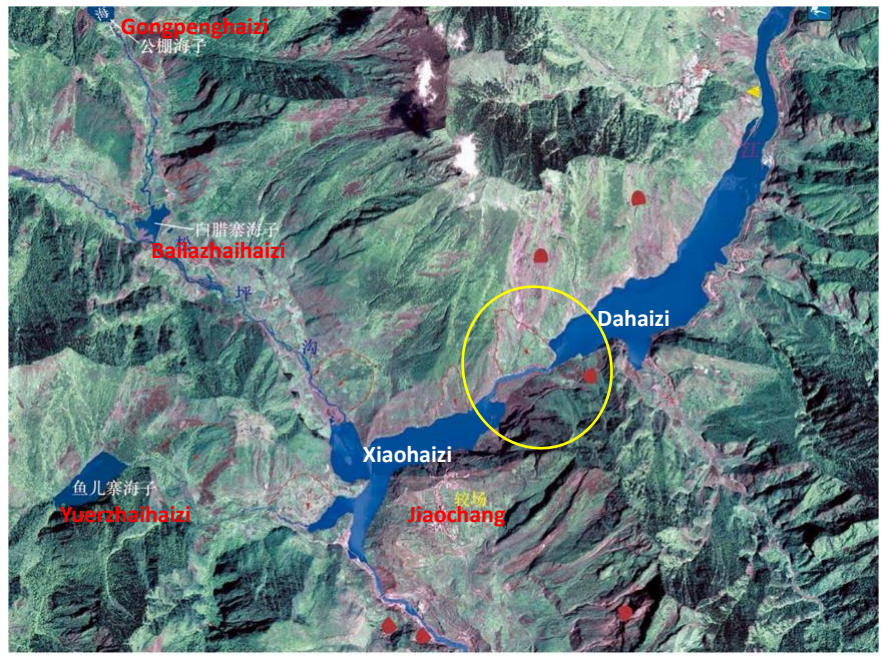




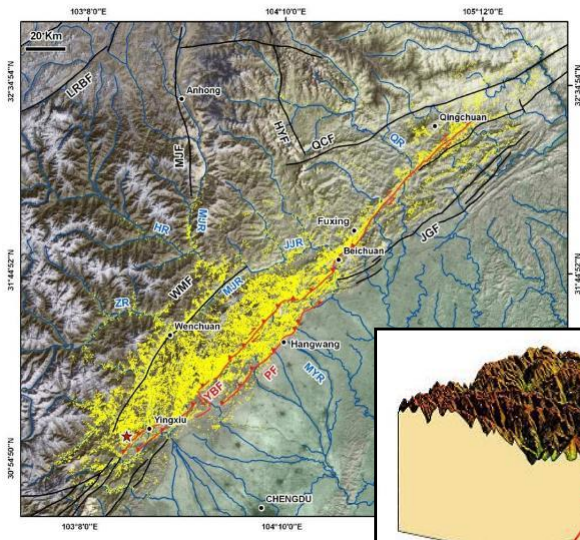
Diexi earthquake (Ms=7.5)

On August 25,1933， a strong earthquake of magnitude 7.5 happened at Diexi， orthwest of Sichuan province.

- Death:
  6800 from slide,
  8000 from flooding
- Under risk
  50,000 people
- Destruction of more than 20 villages, towns
- Washing downstream for 200km along Minjiang river

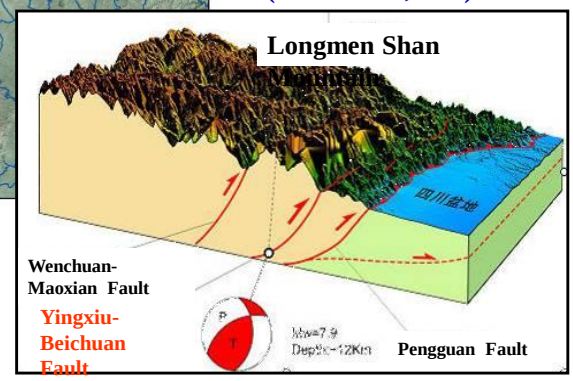


Aerial photographs of landslides dam triggered by the Diexi Earthquake（ Wang et al.，2008 ）



- May 12 2008
- Killed 69,134
- Missing 17,681
- Injured 374,061

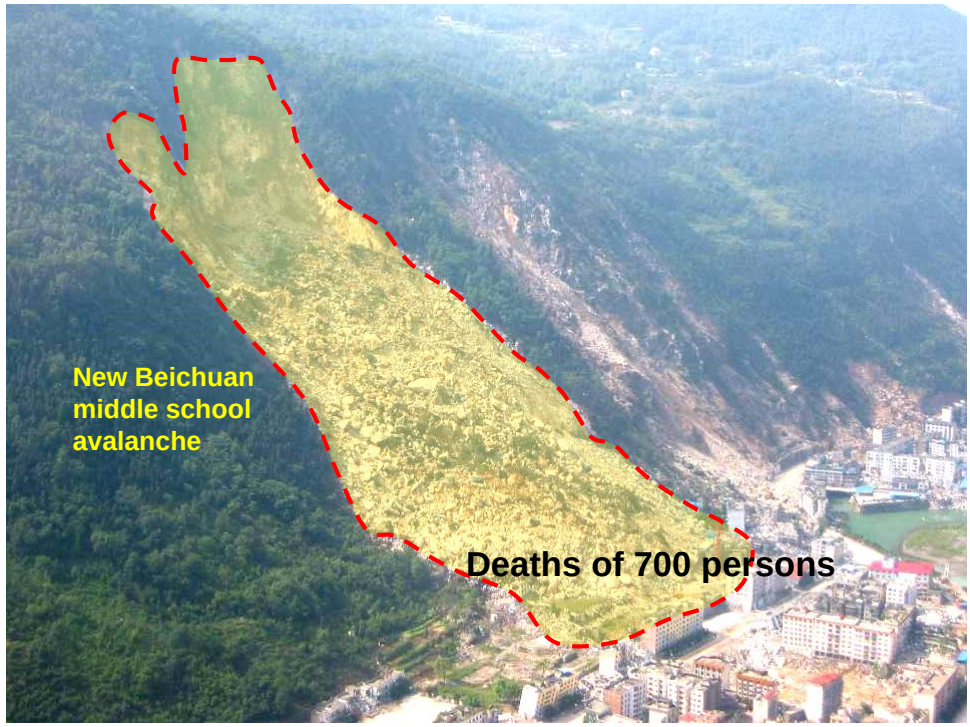
60,100 landslides as points (Gorum et al., 2011)



One of most catastrophic events and one of typical extreme disasters in the history of China

Catastrophic landslides and collapses triggered by 5.12 Earthquake

Hazard spot name	hazard type	Location	Scale(0.01* mil.m3)	Death number	Loss(0.01* mil.Yuan)
Wangjiayan landslide	Landslide	Qushan town, Beichuan county	1000	1600	1600
Yintaogou landslide	Landslide	Chayuanliang, Chenjiaba, Beichuan	188	906	1500
Luanshijiao landslide	Landslide	Jingjia, Qushan, Beichuan	1000	700	1200
Chenjiaba landslide	Landslide	Chenjiaba, Beichuan	1200	400	500
Donghekou landslide	Landslide	Donghekou, Hongguan, Qingchuan	1000	260	5000
Hongyan landslide	Landslide	Hongyan, Chenjiaba, Beichuan	480	141	120
Niming village landslide	Landslide	Niming, Zipingpu, Dujiangyan	20	120	500
Xiejiadian landslide	Landslide	Qishe, Jiufeng, Pengzhou	400	100	4000
Xiaolongtan collapse	Landslide	Yinchan ditch, Pengzhou	5.4	100	8000
Dalongtangoukou collapse	Collapse	Yinchan ditch, Pengzhou	10	100	8000
Taihong village landslide	Landslide	Taihong, Chenjiaba, Beichuan	500	100	110
Dai'an collapse group	Collapse	Qingchengshan, Dujiangyan	120	62	800
Zhenjia landslide group	Landslide	Xinping, Nanba, Pingwu county	1250	60	5000
Hanjiashan landslide group	Landslide	Dujiaba, Guixi, Beichuan	30	50	130
Dayanke collapse	Collapse	Jianxin, Quhe, Qingchuan	70	41	200
Ma'anshi landslide group	Landslide	Ma'anshi, Shuiguang, Pingwu	400	34	8000
Liangaiping landslide	Landslide	Tuanshan, Pengzhou city	40	30	800



Damaged Homeland !

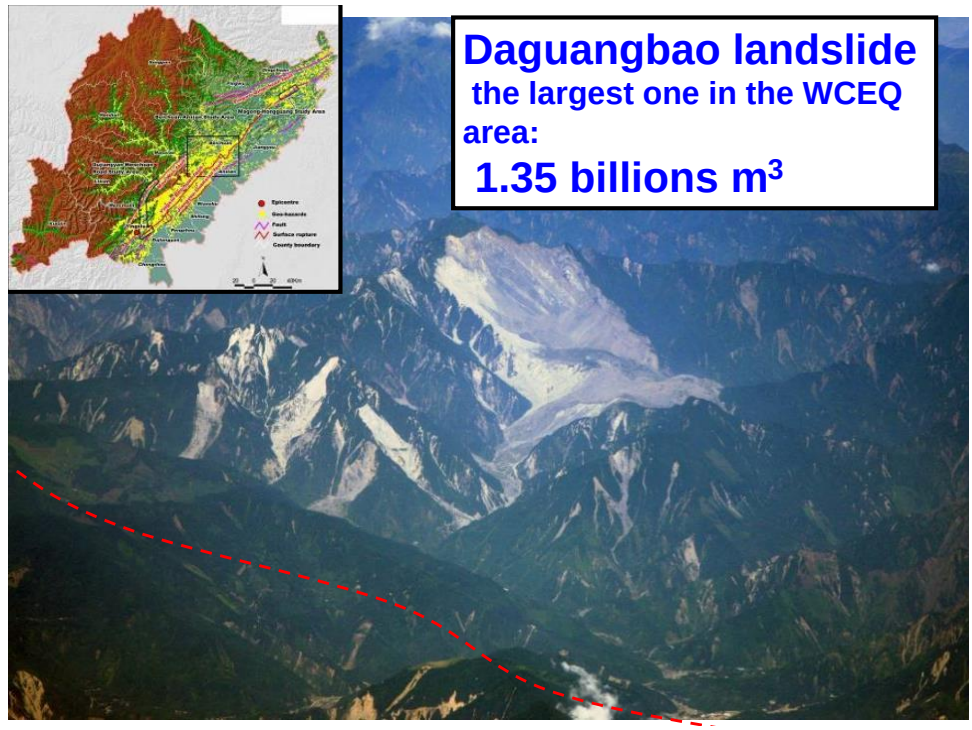
Large proportion of the total fatalities was caused by landlsides, which is almost equal to the total death of the past 30-year caused by geological hazards.

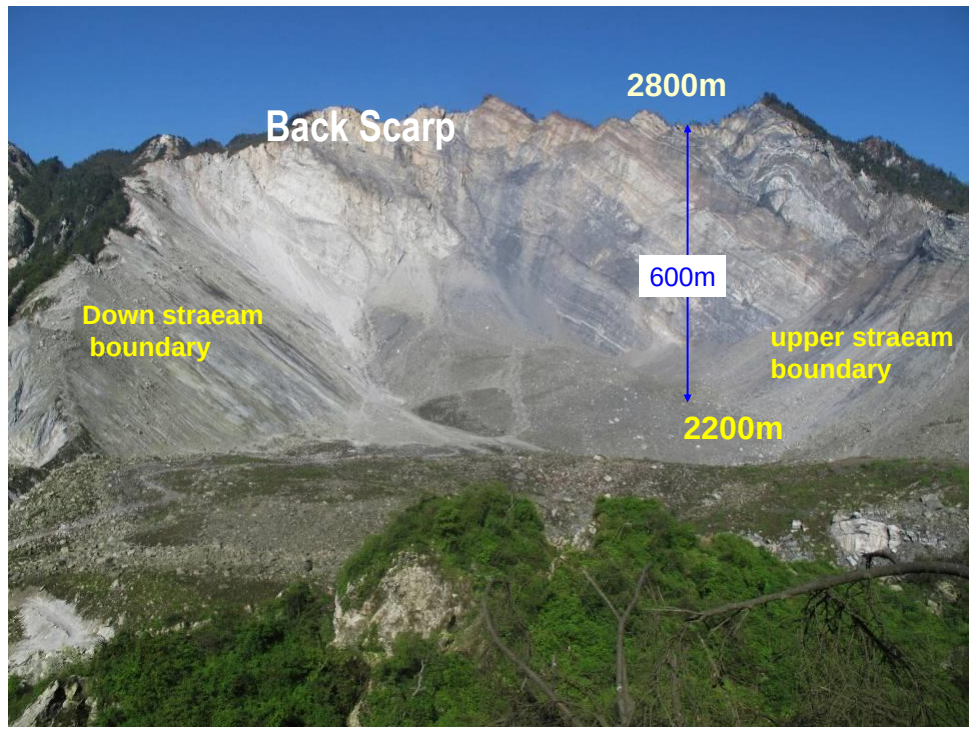
- Understanding Seismicity induced landslide and slope failure during earthquake and after are important for hazard reduction and reconstruction of the suffering area.

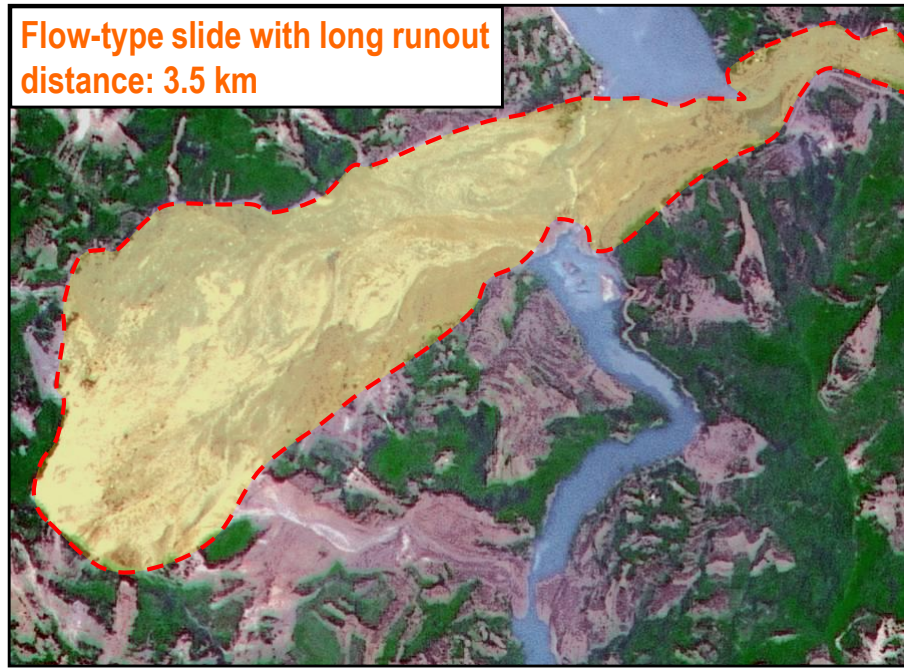
Content

Characteristics of seismic landslides

- Most are Complex landslides-composite types, some show a throwing behavior
- Large magnitude
- High position of failure
- High potential and dynamic energy released
- Long run-out
- Hazard Chain effect

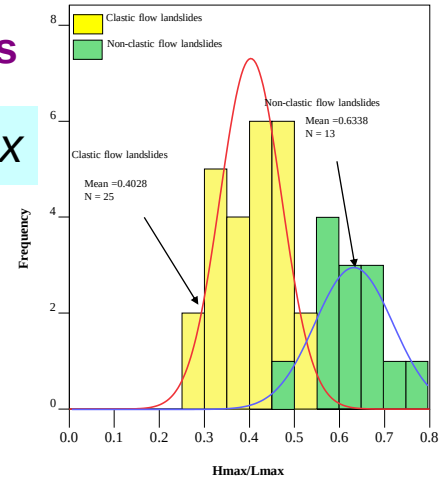

Daguangbao landslide
the largest one in the WCEQ area:
1.35 billions m3

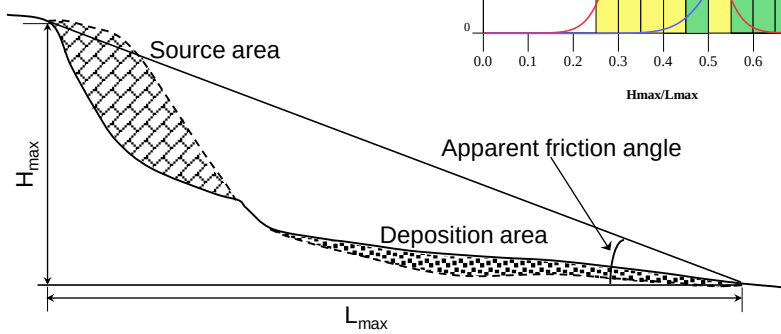

2800m
Back Scarp
600m
Down straeam boundary
upper straeam boundary
2200m



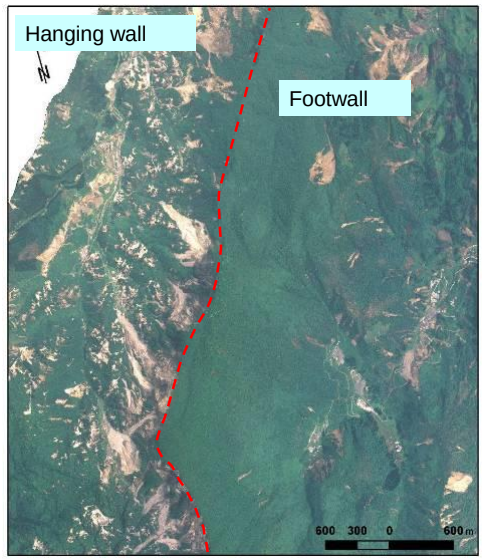
Mobility of landslides

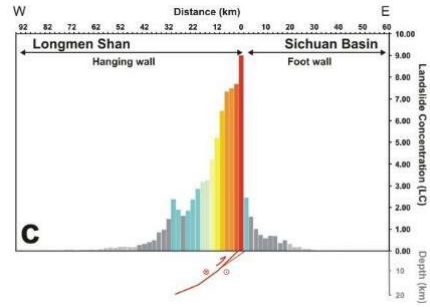
Lmax=2.5~3.0 Hmax



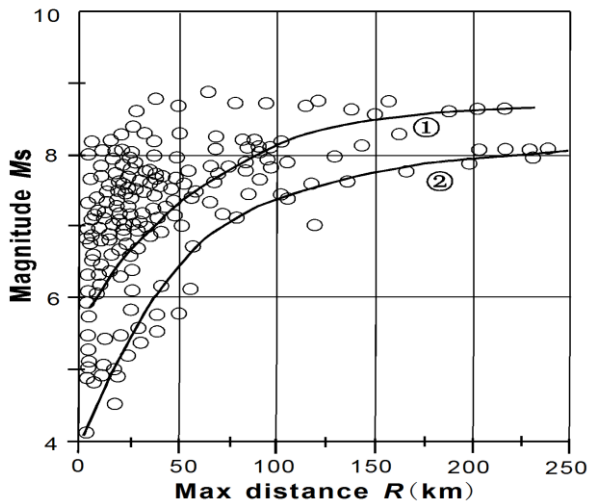


"Hanging wall" effect





Landslide area vs Epicentre Intensity

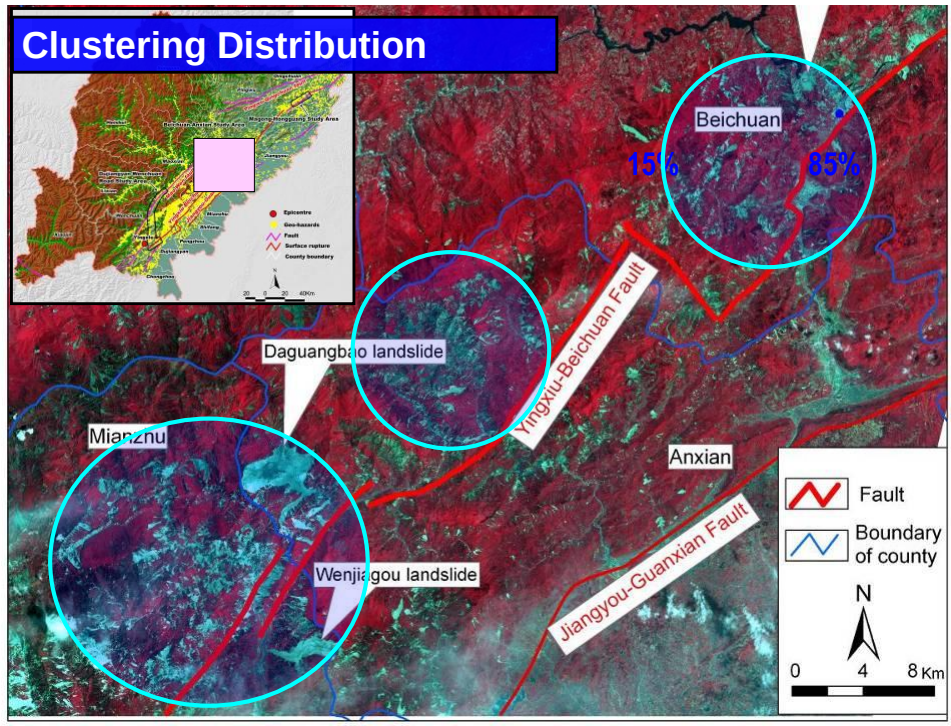


Magnitude vs distance of landslide from epicenter

Seismically induced landslides are likely to be following a relationship denoted by

$$R = 1.775M_S/(1 - 0.118M_S)$$

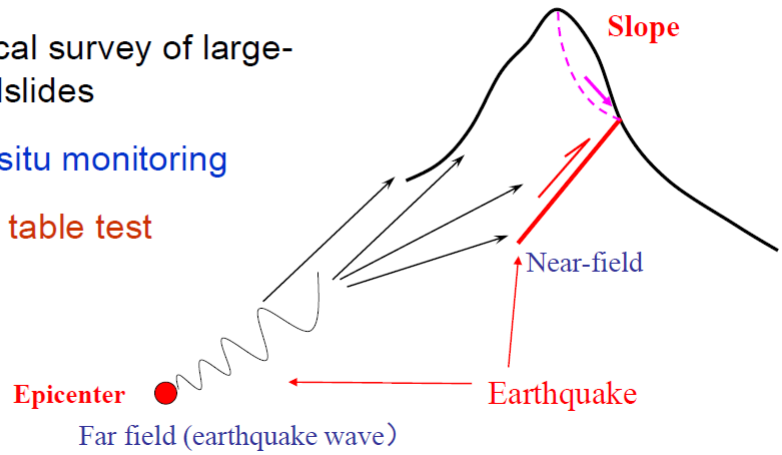
Xing and Wang (1999)



Failure Mechanism of slopes under strong earthquakes

Various methods have been applied to study the failure mechanism of coseismic landslides:

- Geological survey of large-scale landslides
- Field in-situ monitoring
- Shaking table test



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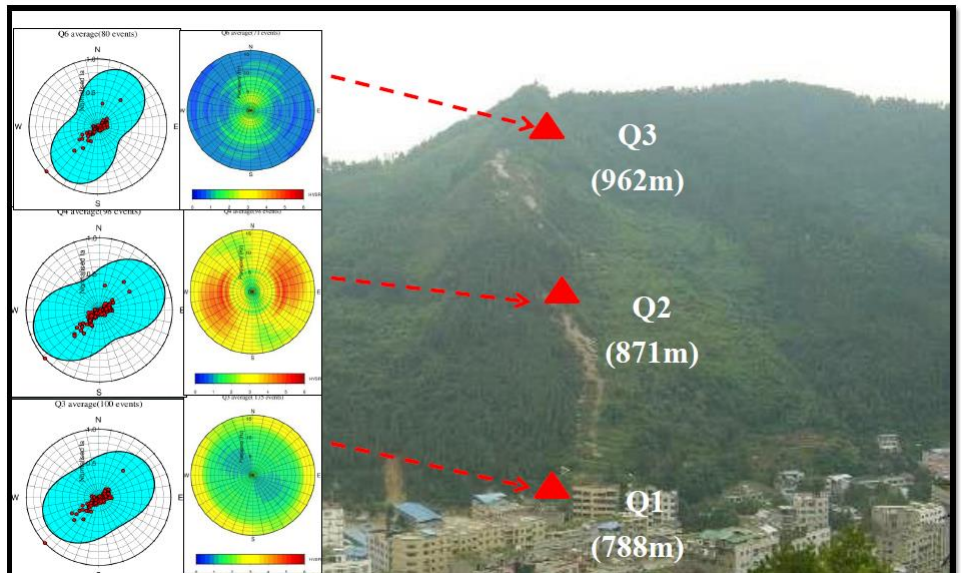
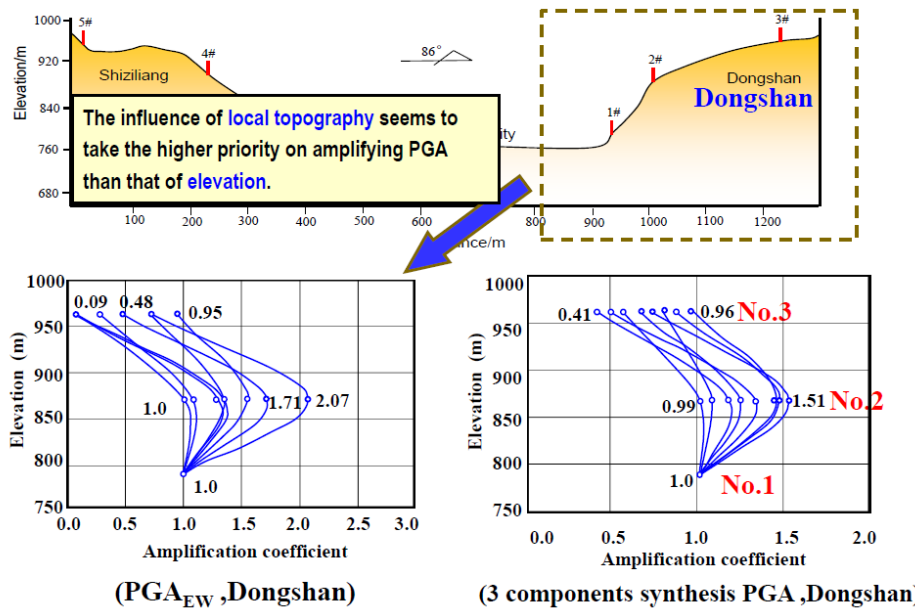
Field Monitoring



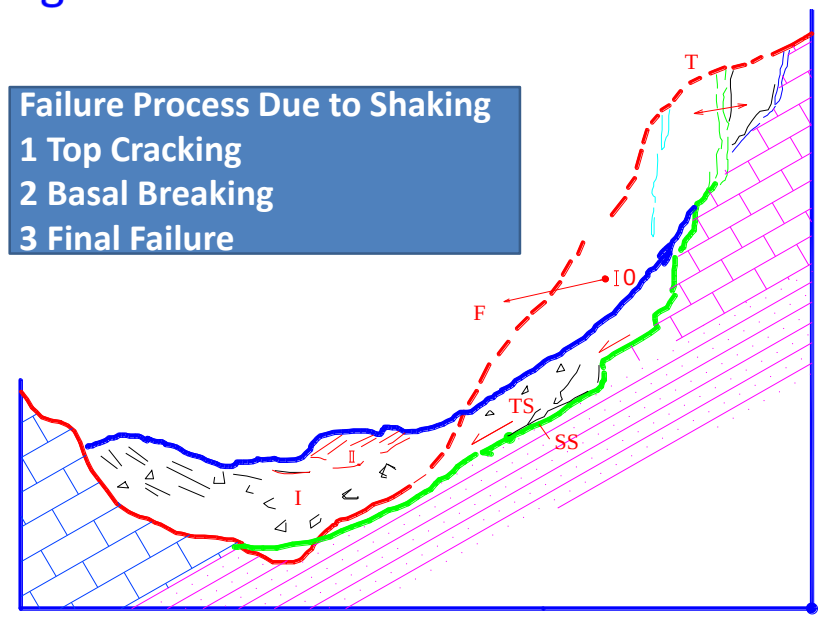
Acceleration amplification factor varies with elevation

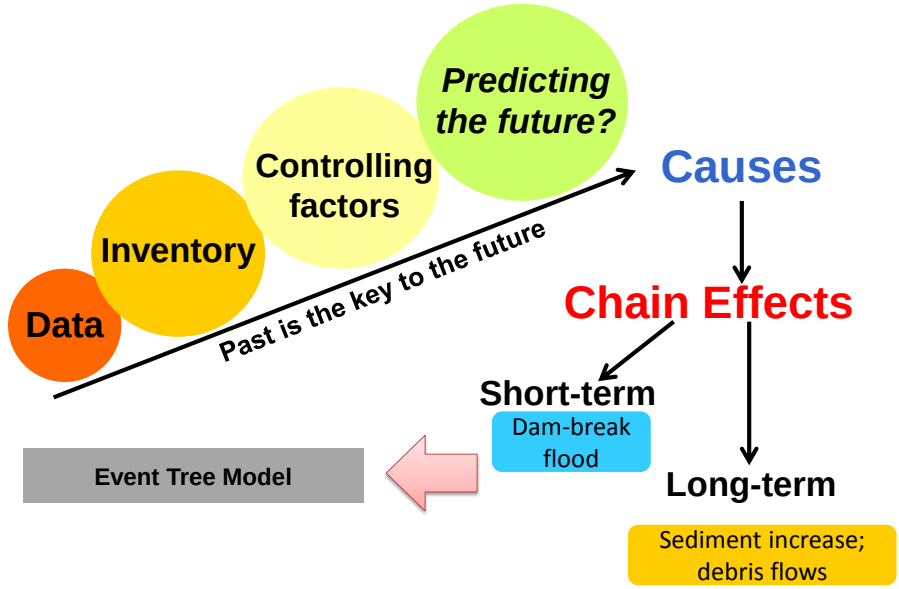


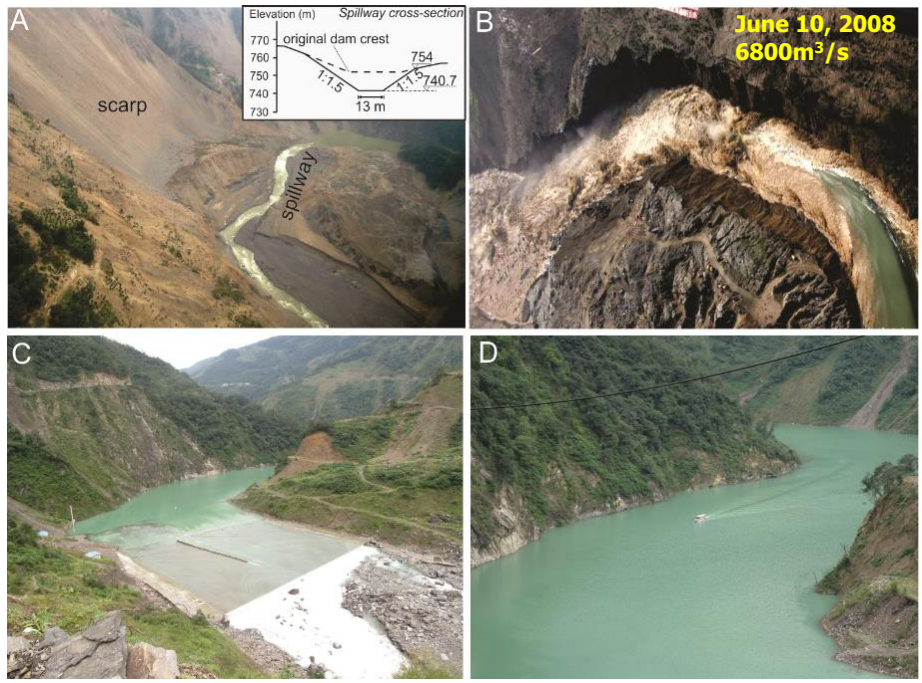
(PGA_{EW} ,Dongshan)

(3 components synthesis PGA ,Dongshan)

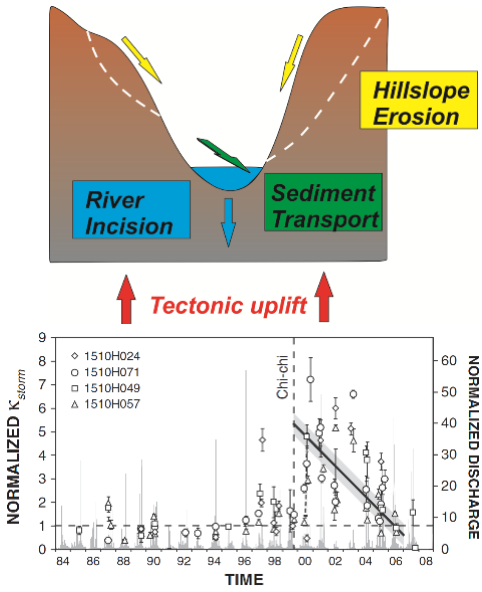
Progressive failure





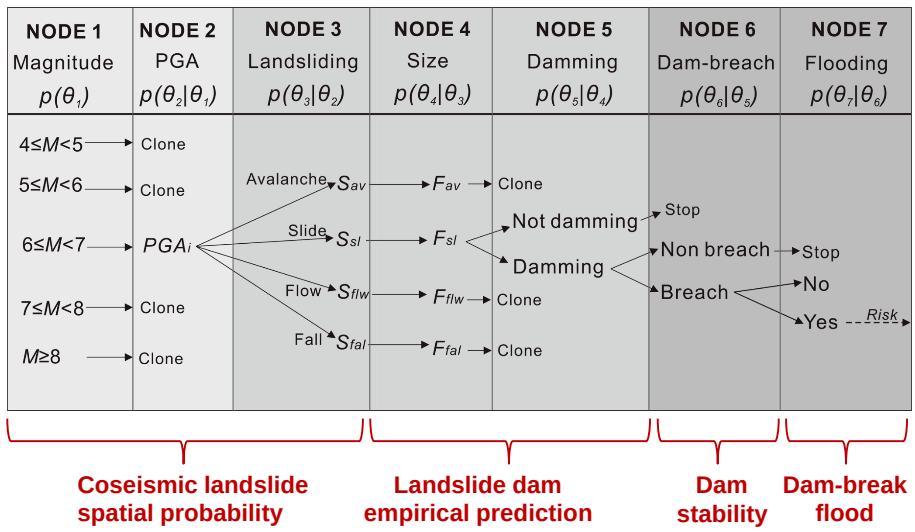

A
Elevation (m)
Spillway cross-section
770
760
750
740
730
original dam crest
754
740.7
1:1.5
1:1.5
13 m
scarp
spillway
B
June 10, 2008
6800m³/s
C
D

Post-earthquake sediment problem

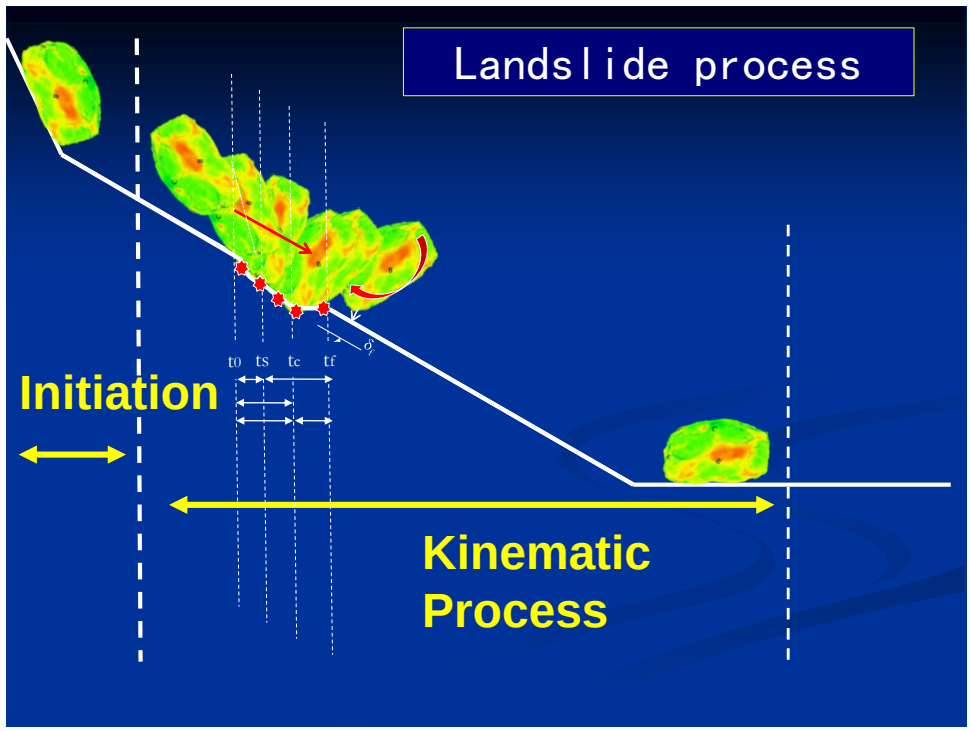


Hovius et al. (2011)

Event tree model



Content



Rockfall Analyst (RA): 3D Process Modeling

Lan, H.; Martin, C. D. & Lim, C. H. 2007. Rockfall Analyst: a GIS extension for three-dimensional and spatially distributed rockfall hazard modeling. ***Computers & Geosciences,*** *33*: 262-279

Lan, Hengxing, Martin, C. Derek, Zhou, Chenghu, Lim, Chang Ho. Rockfall hazard analysis using LiDAR and spatial modeling. ***Geomorphology***, 118(1-2), pp 213-223, 2010

Module1:

3D process

-Detachment

-falling/flying

-bouncing

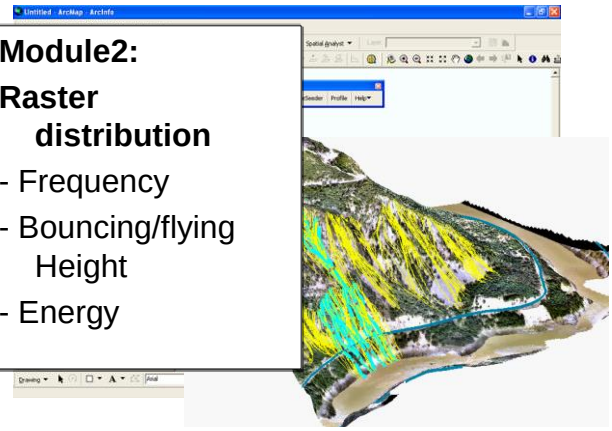
-rolling/sliding

-final deposition

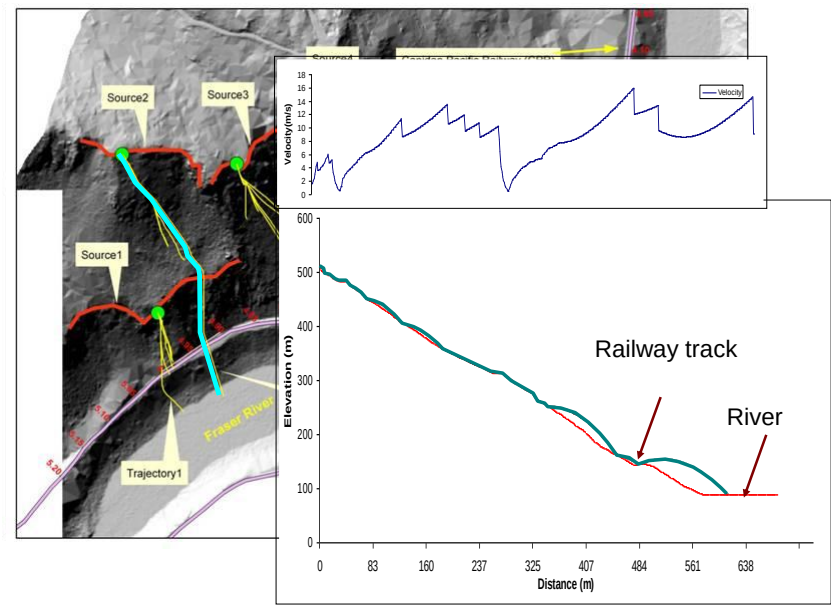
Module2:

Raster distribution

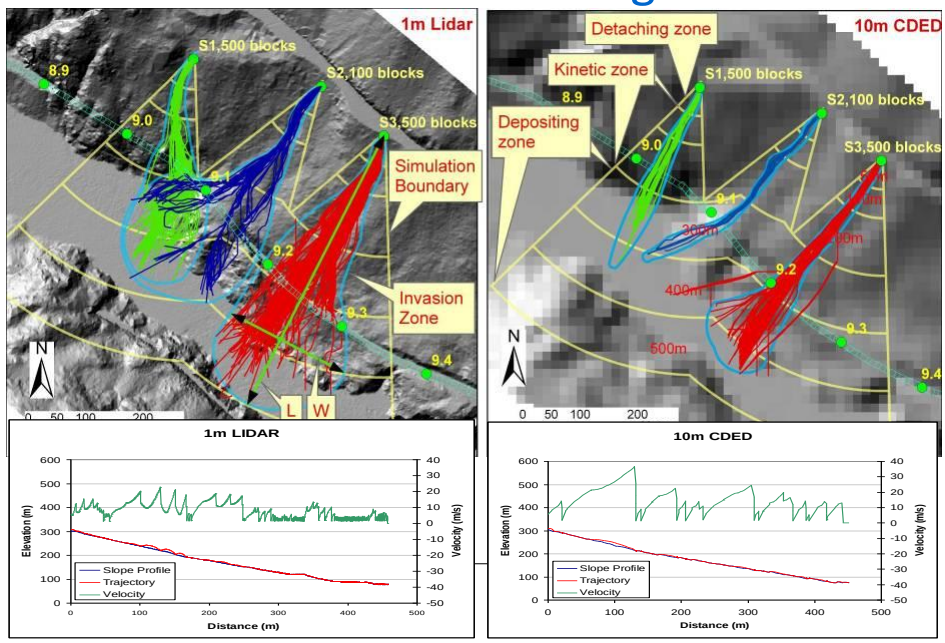
- Frequency
- Bouncing/flying Height
- Energy



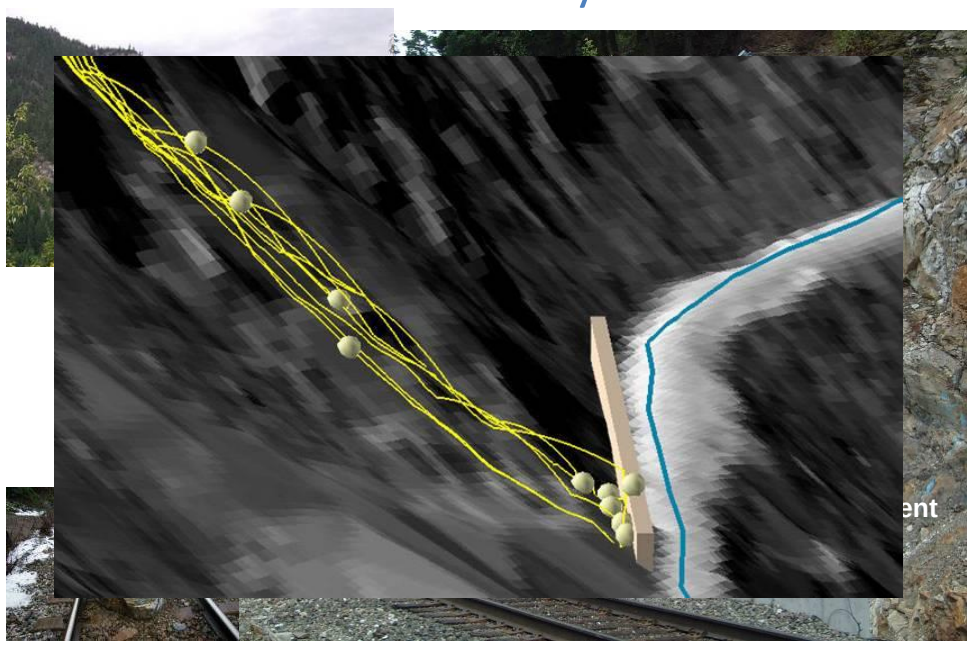
3D Trajectory



Run out modeling



Barrier analysis

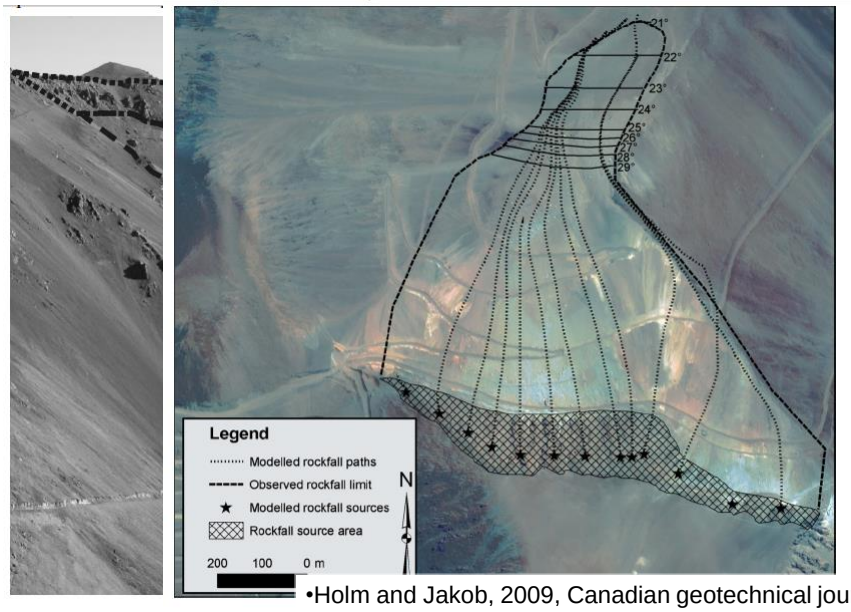


Hazard assessment

Application

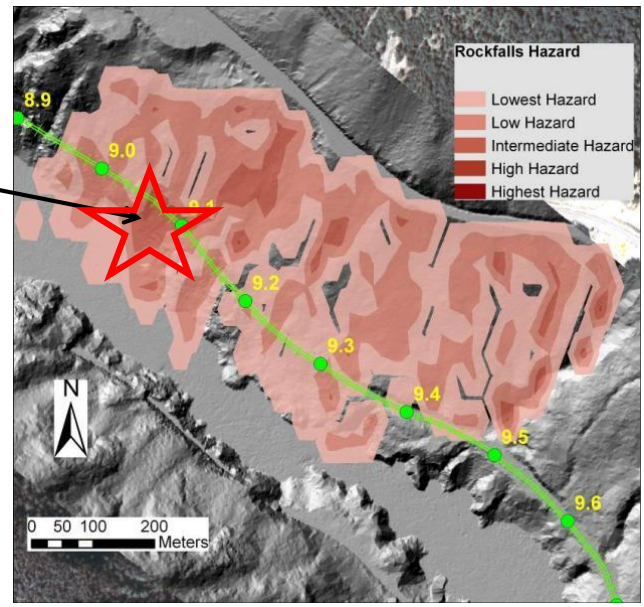
RA has been used in nearly 40 countries around the world

Chile - Long runout (**Pascua Lama, Chile**)



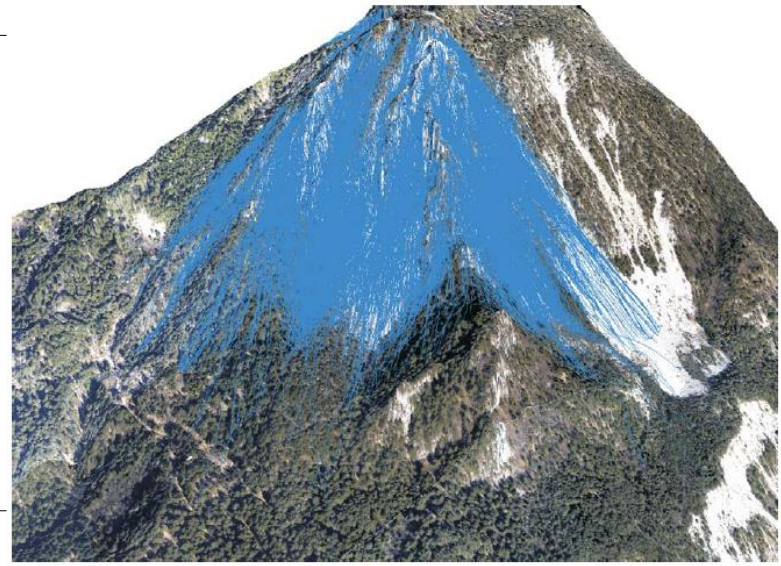
•Holm and Jakob, 2009, Canadian geotechnical journal

Canada-Railway Risk

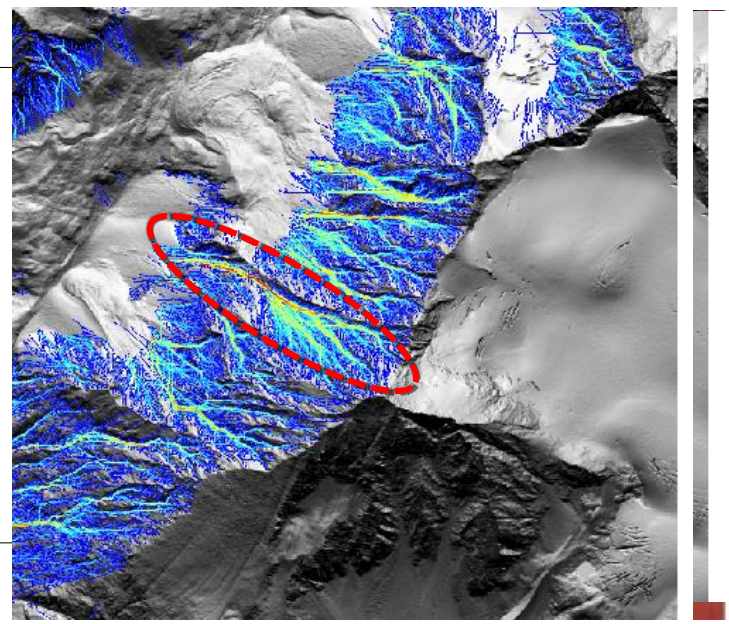


Greatest hazard

Italy –Landslide runout



Austria-Risk Control



Content

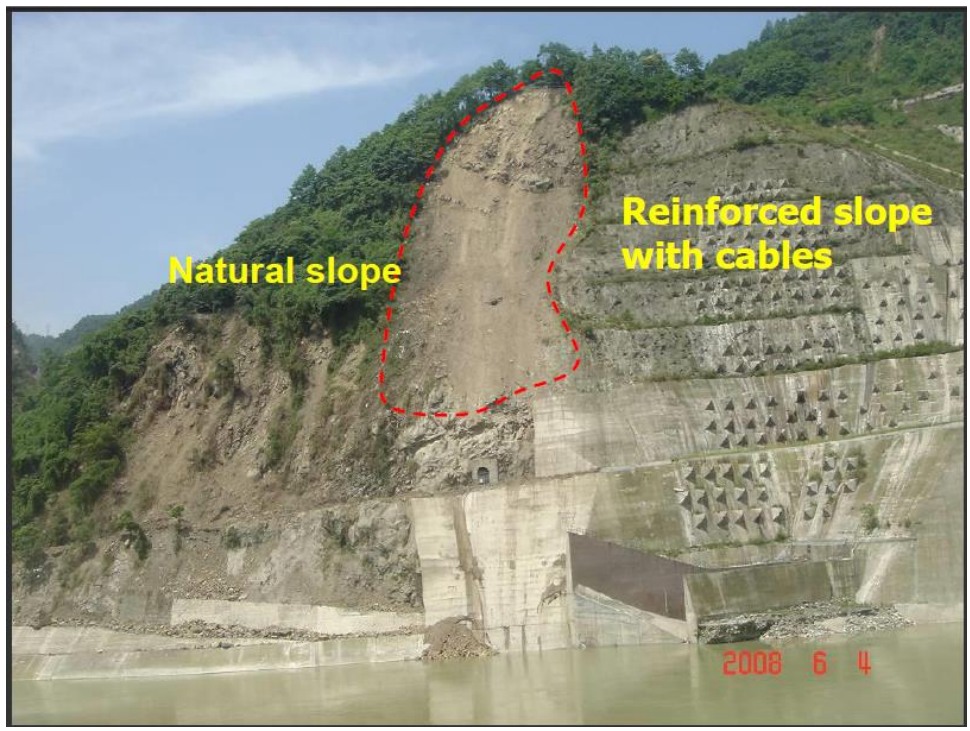
Risk Control Strategies

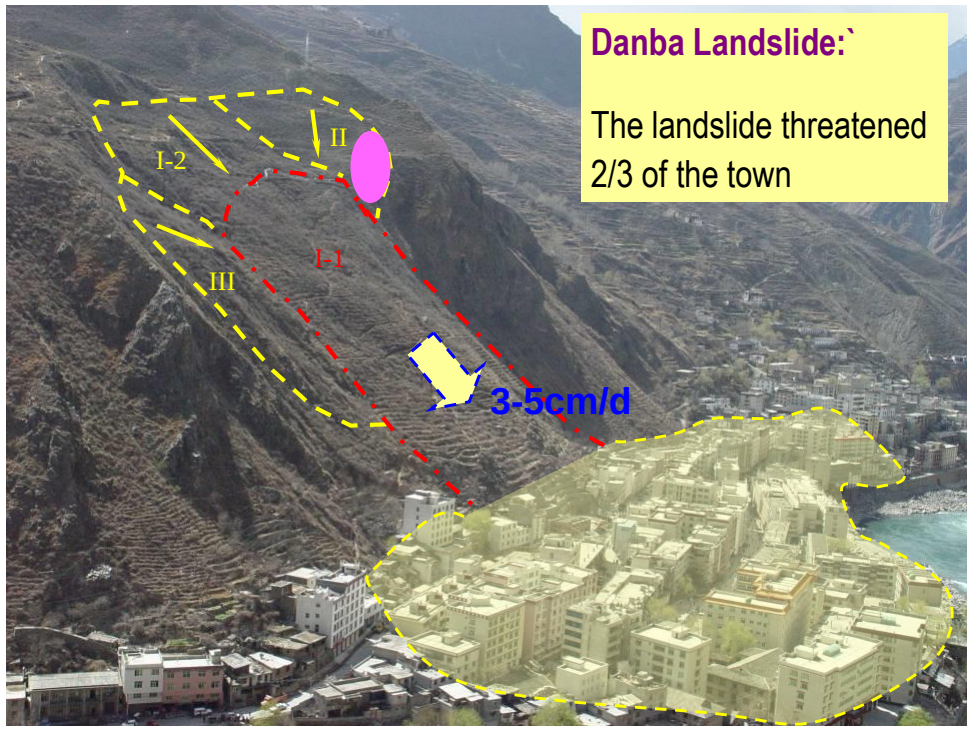
- Risk control strategies are required for risks that have been classified as unacceptable or tolerable with mitigation. In generic terms, these strategies can focus on
- eliminating the situation, substance, condition or activity that generates the risk;
- reducing the probability of occurrence; or
- mitigating (reducing) the consequences.

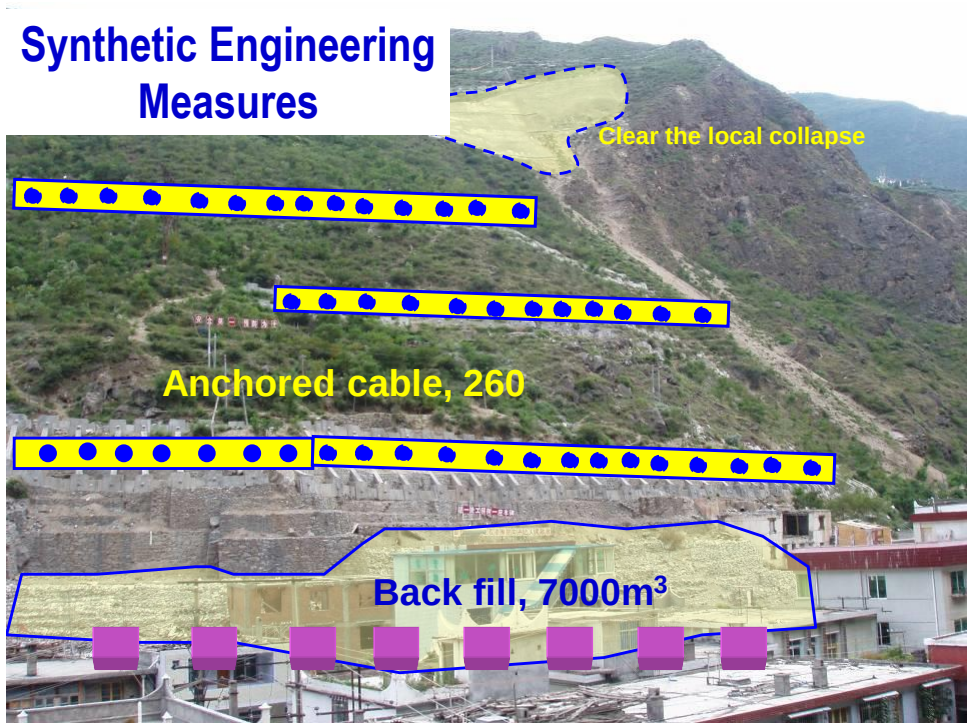
Risk Control Strategies

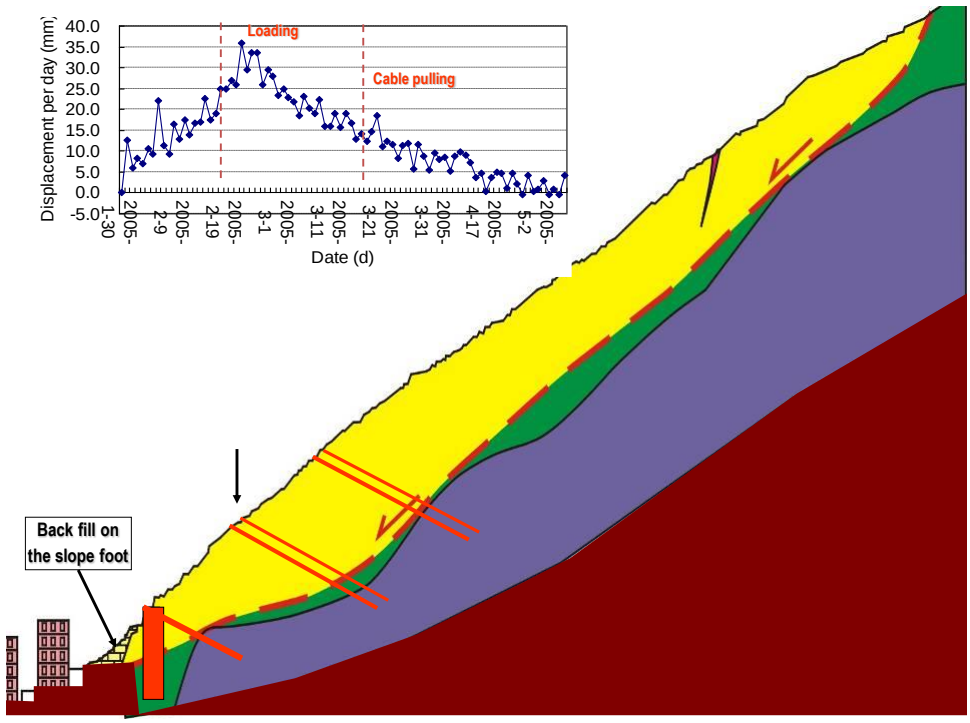
Area	Risk Control Strategy
Post - Earthquake Reconstruction	Mitigation-Engineering Measure Detection/Monitoring Avoidance of High Risk

2




Danba Landslide:`
The landslide threatened 2/3 of the town
I-2
II
I-1
III
3-5cm/d

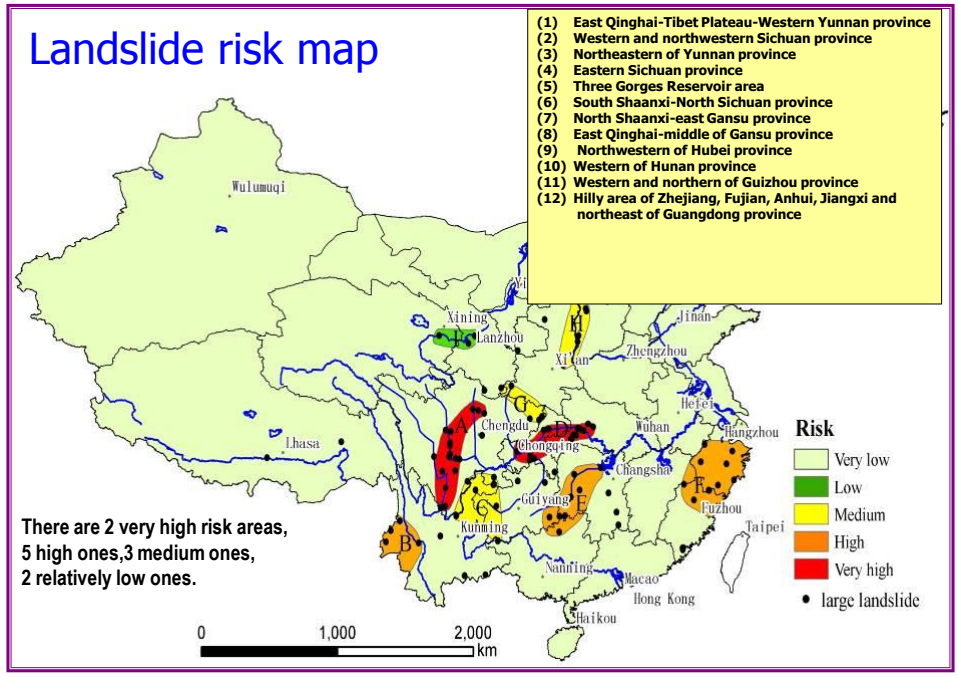

Synthetic Engineering Measures
Clear the local collapse
Anchored cable, 260
Back fill, 7000m³



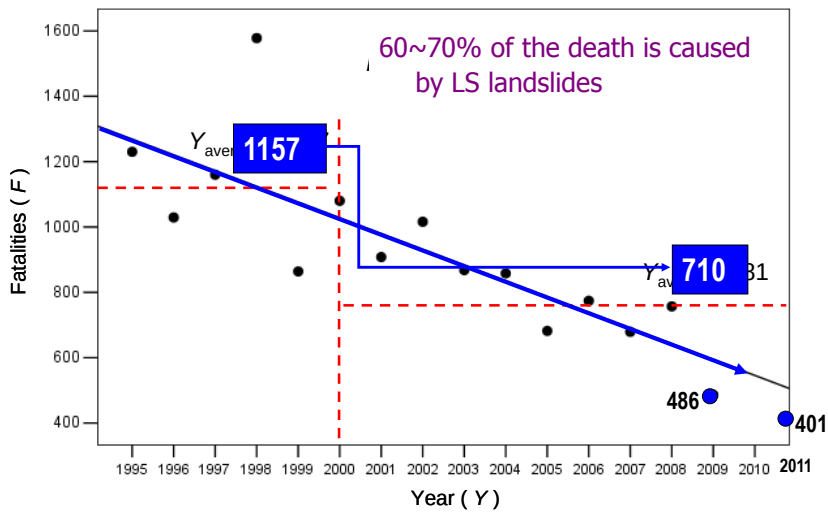
Main geo-engineering principles in poster-disaster reconstruction

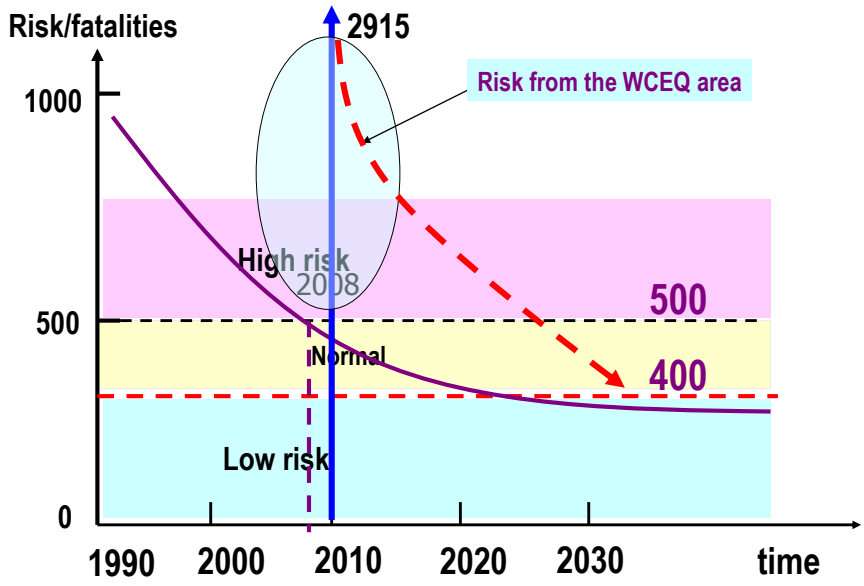
Avoiding the high risk area- Safeland for resettlement and reconstruction

- Avoidance of active fault with high strong earthquake potential
- Avoidance of affected area of geohazards such as landslides and debris flow
- Avoidance of vulnerable constructions sites



Geohazards risk in China and its control



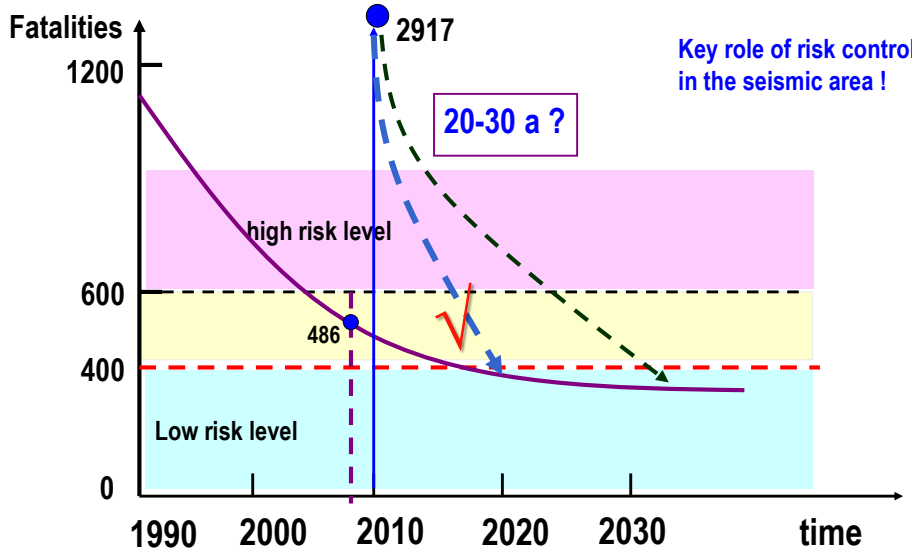


Risk variation curve of geohazards in China

Risk reduction measures

- Relocate some of the towns and residents to safer places.
- Stabilization using feasible reinforcing remedial measures.
- Establish long term safety monitoring system
- Scientific research to provide scientific basis for the risk control
- Education: Disseminate knowledge of disaster prevention and disaster avoiding.

Geohazards risk control in China



Acknowledgments

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Thanks!

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