A Historical Earthquake-Induced Landslide Damming Event at the Qiaojia Reach of the Jinsha River, SE Tibetan Plateau: Implication for the Seismic Hazard of the Xiaojiang Fault

Hu, M., Wu, Z., Reicherter, K., Ali, S., Huang, X., & Zuo, J. (2021). A historical earthquake-induced landslide damming event at the Qiaojia reach of the Jinsha River, SE Tibetan Plateau: implication for the seismic hazard of the Xiaojiang Fault. Frontiers in Earth Science, 9, 649543.

Presenter: Nguyen Thanh Tung
Advisor: Jia –Jyun Dong

9th, December 2022

INTRODUCTION

Earthquakes can trigger various type of landslide (earthquake-induced landslides)

Earthquake-induced landslides can be used as indirect evidence to reconstruct the seismic history

The town of Qushan in Beichuan County, China, was destroyed by strong shaking from the 2008 Wenchuan (Mw=7.9)

Jiu-Feng-Er-shan coseismic landslide in 1999, Taiwan (Mw=7.6)

INTRODUCTION

❖ Purpose of this study:

- Investigation of ancient landslides trigger by Earthquake in the area.

- Demonstrate its seismic origin mechanism.

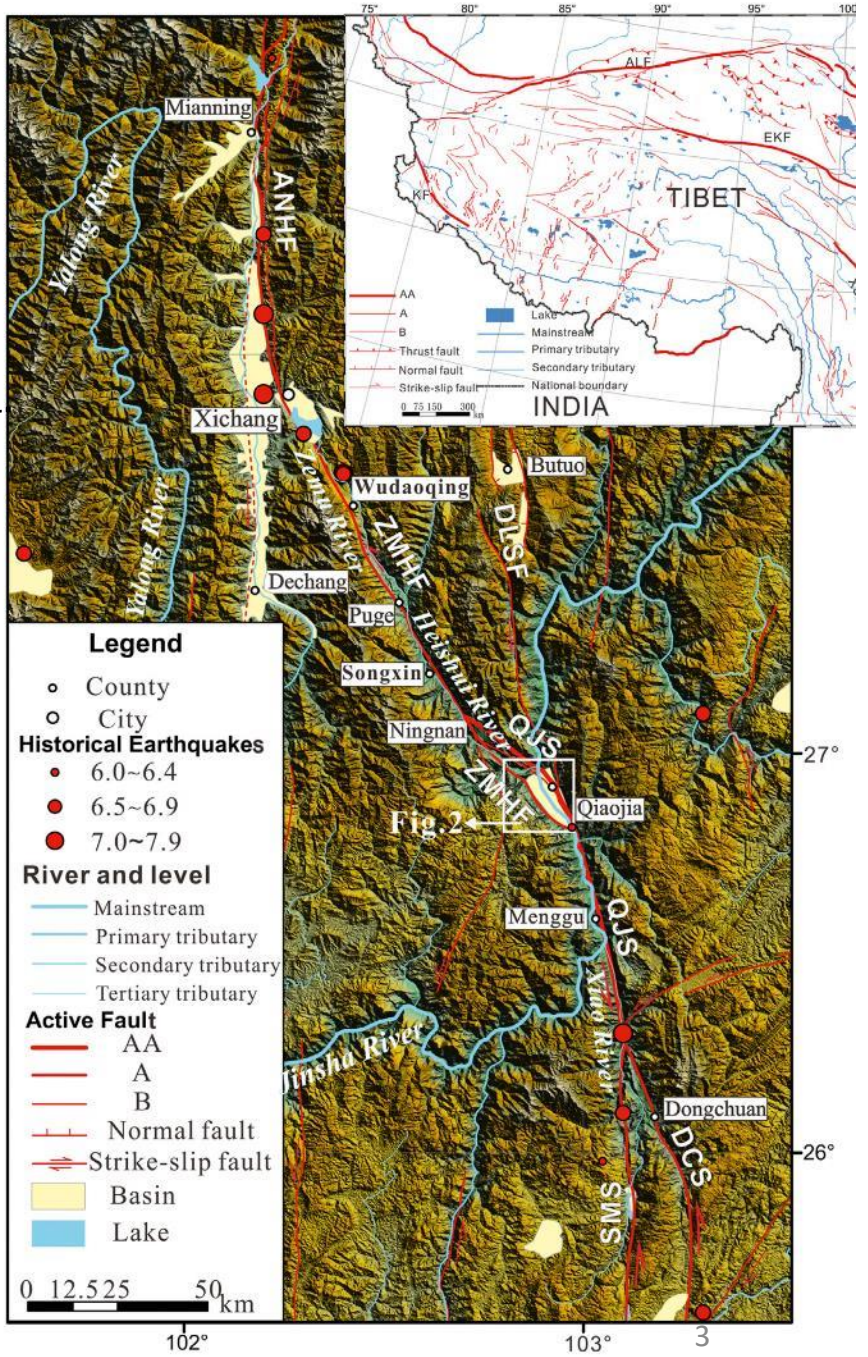
- Discussed the seismic hazard in study area.

❖ What we learned from this paper?

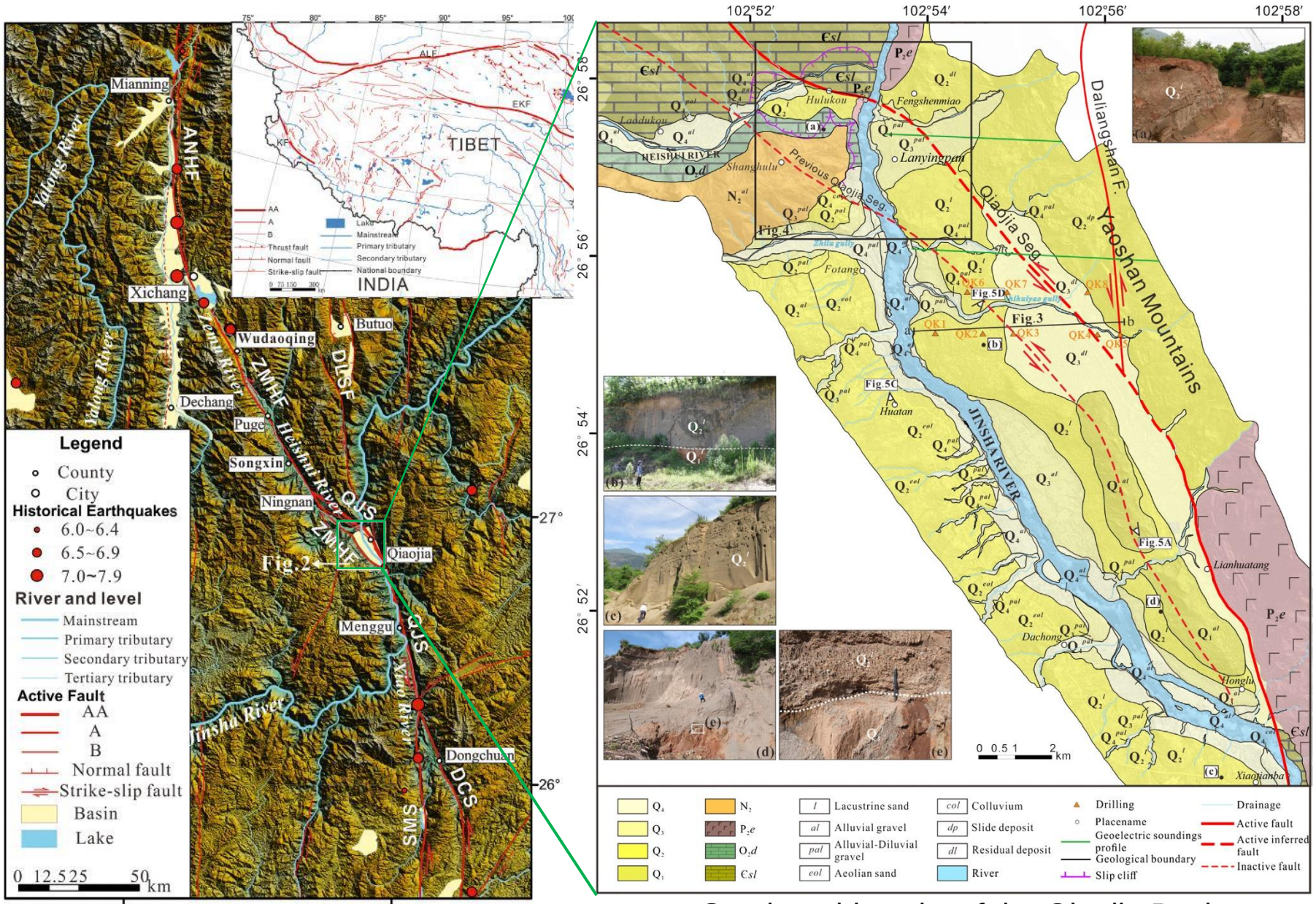
- Adjustment of location of historical earthquake- induced landslide.

- Dating the age of ancient landslides.

- Analyzing the relationship between active fault and landslide distribution.



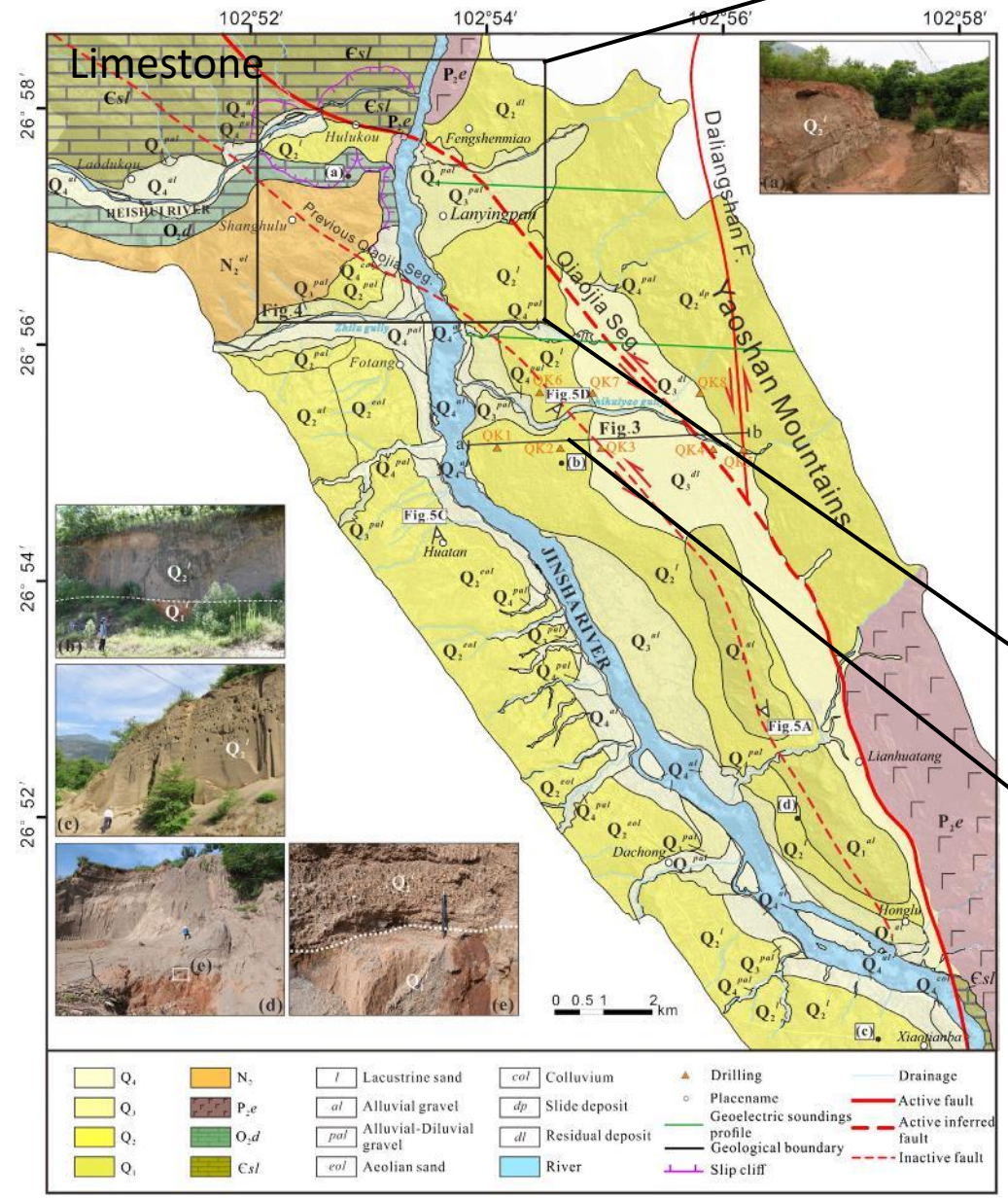
REGIONAL SETTINGS

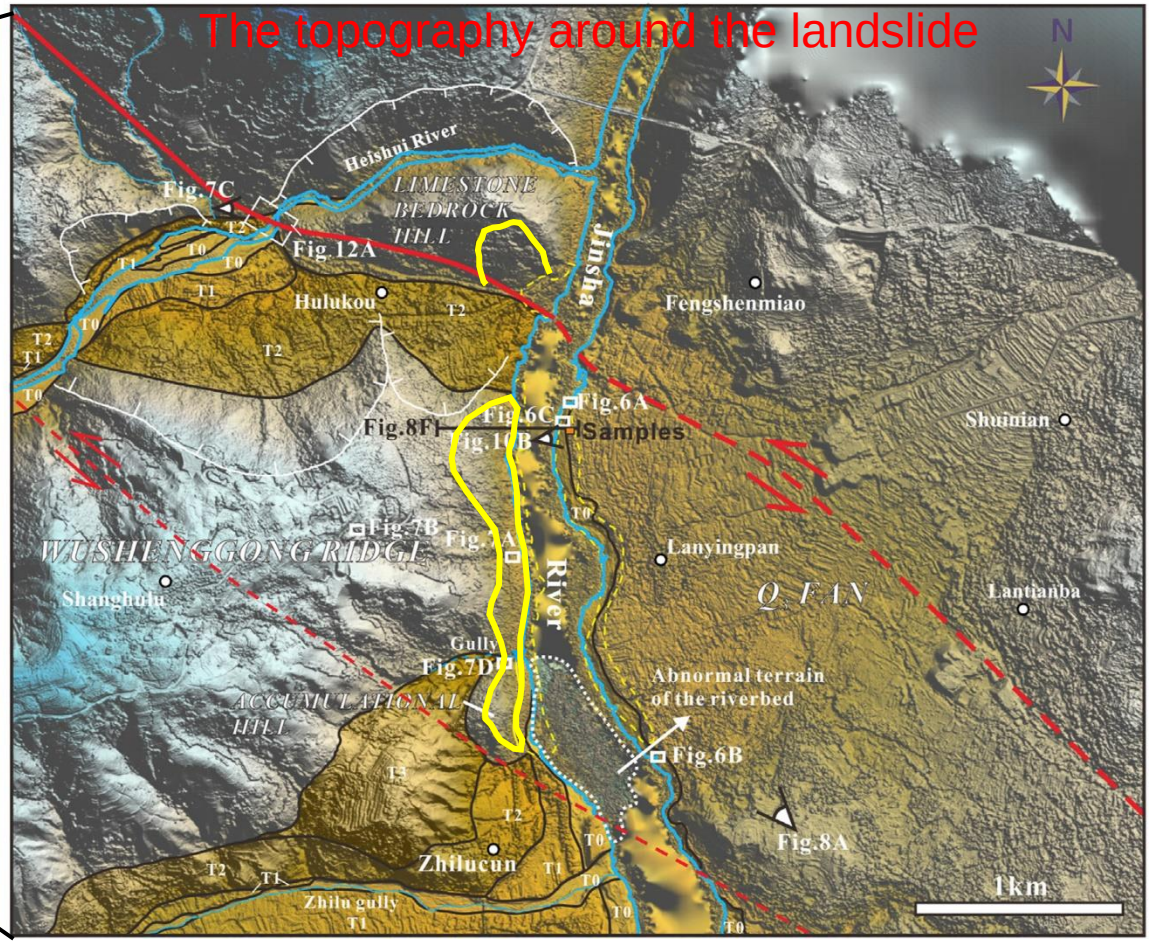


Stratigraphic units of the Qiaojia Basin

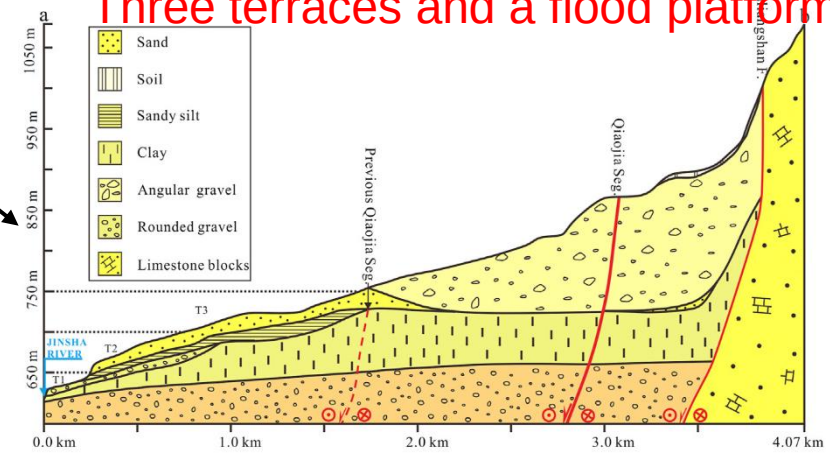
- 3 major active faults: Xiaojiang Fault, Zemuhe Fault, Daliangshan Fault
- Qiaojia Segment changes trend from nearly N-S to a NW direction
- Qiaojia Basin is a 15 km long and 4 km wide
- Quaternary fluvial sediments accumulated: fluvial terraces, proluvial-alluvial fans, and lacustrine sediments

REGIONAL SETTINGS



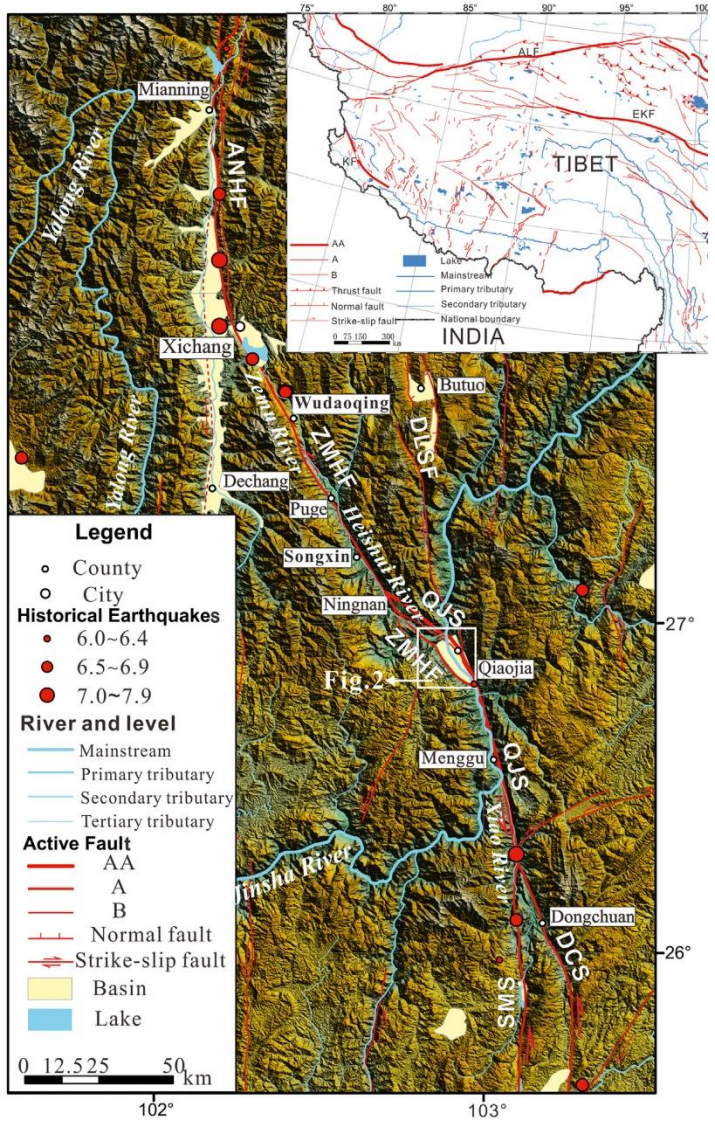


Three terraces and a flood platform

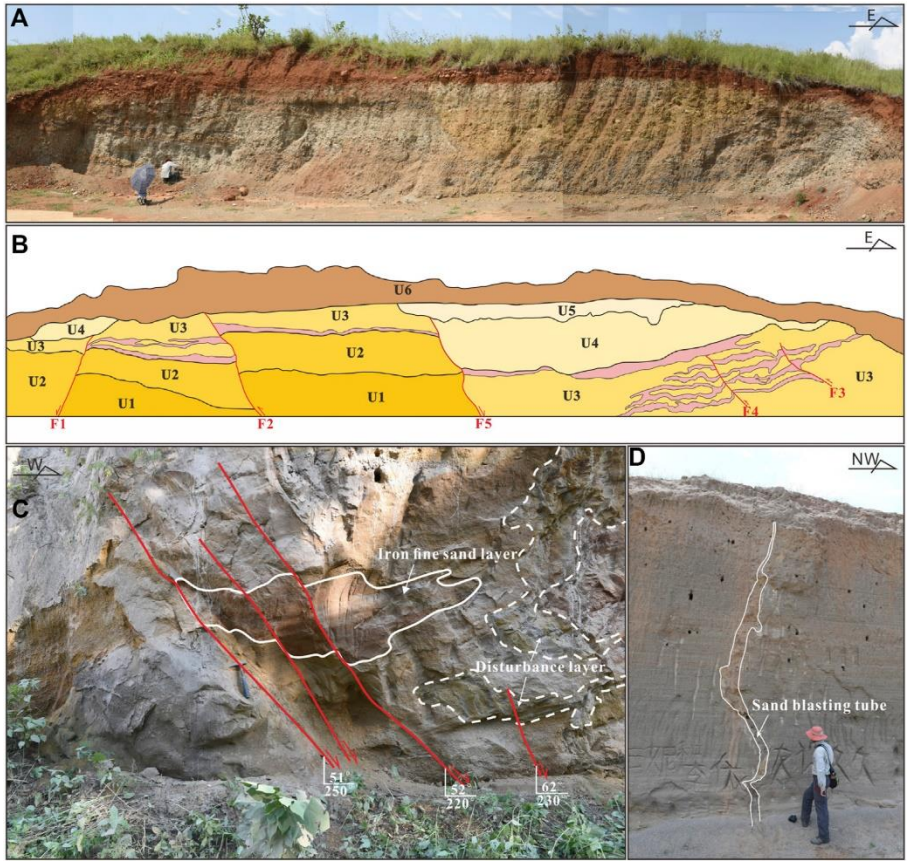


EARTHQUAKES

- Seven historical earthquakes
- Since 1500 AD, only one strong earthquake event (Qiaojia M6 earthquake)
- A series of effects of earthquake induced landslides are well preserved



Earthquake-induced effects in different sedimentary units



Small faults, disturbance layers, and sandblasting tubes

DATA AND METHODS

Mapping the Landslide

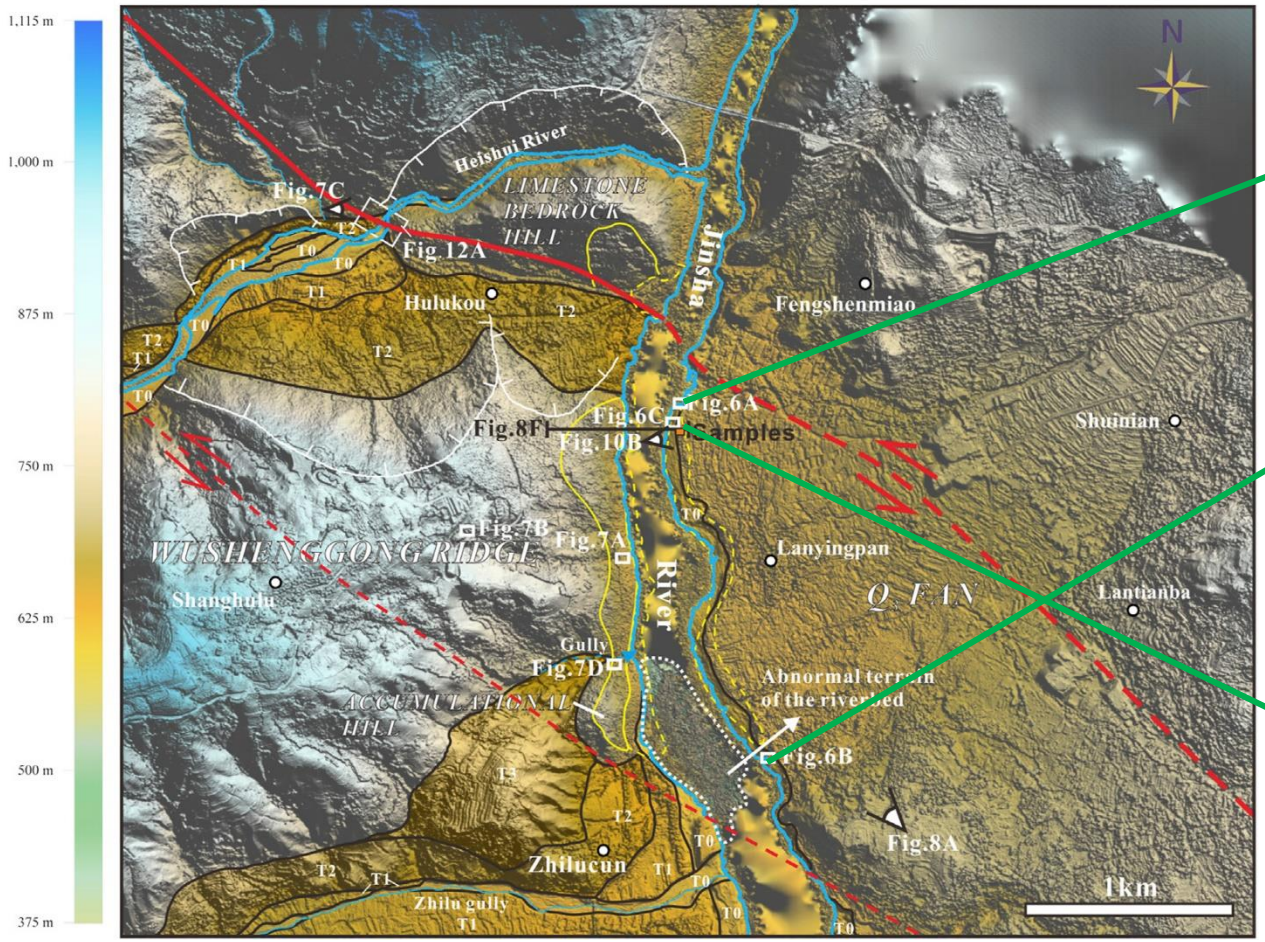
- Field investigation
- Satellite images (Google Earth)
- High-resolution DSM (res-0.6 m) generated with Structure from Motion (SfM)
- Acute3D viewer" software…

Dating

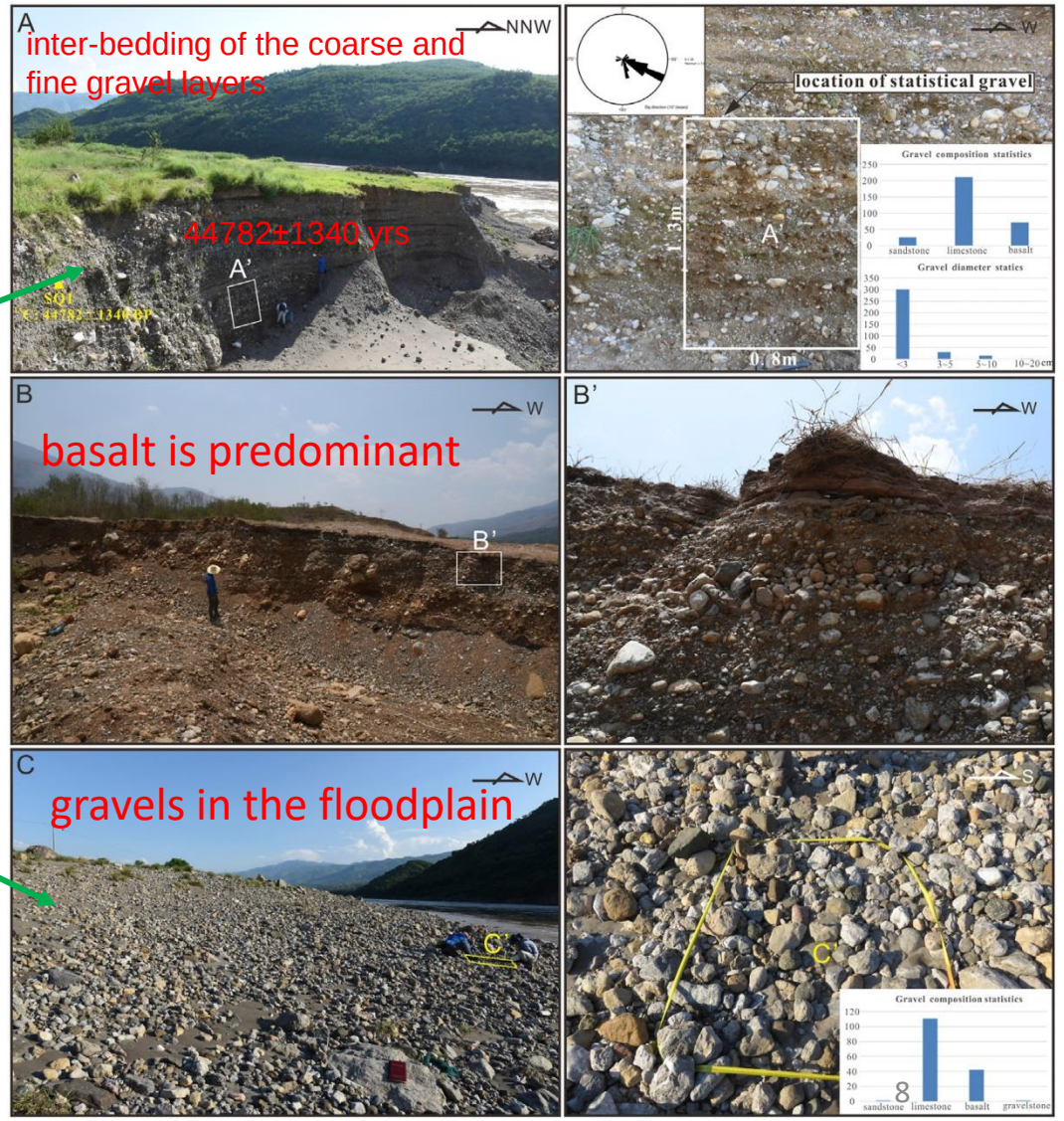
- OSL samples
- ^{14}C samples

RESULTS OF THE INVESTIGATION

Existence of a Landslide

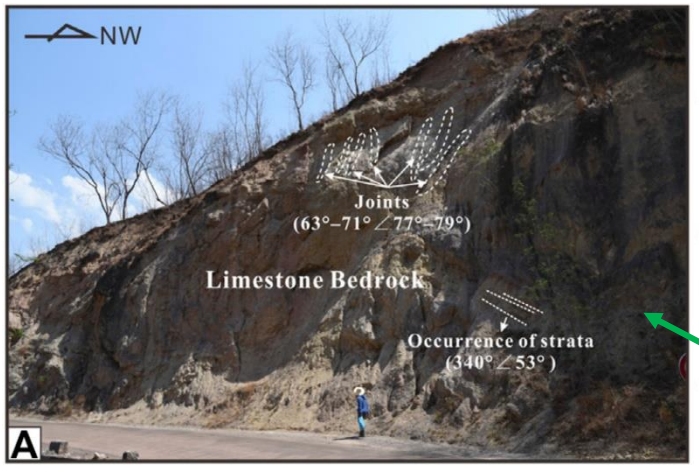


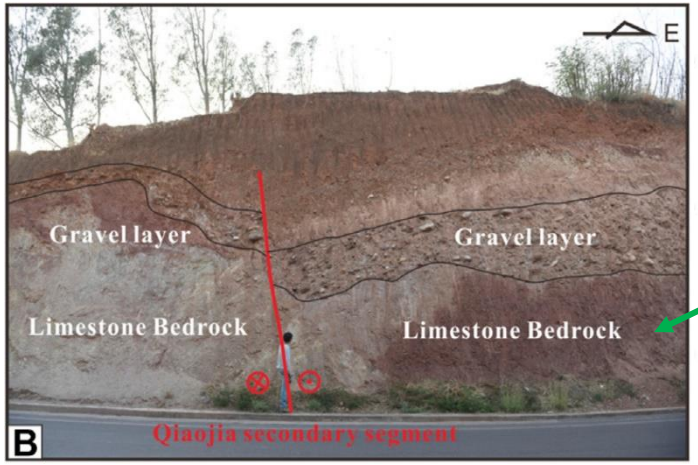
Gravel statistical locations

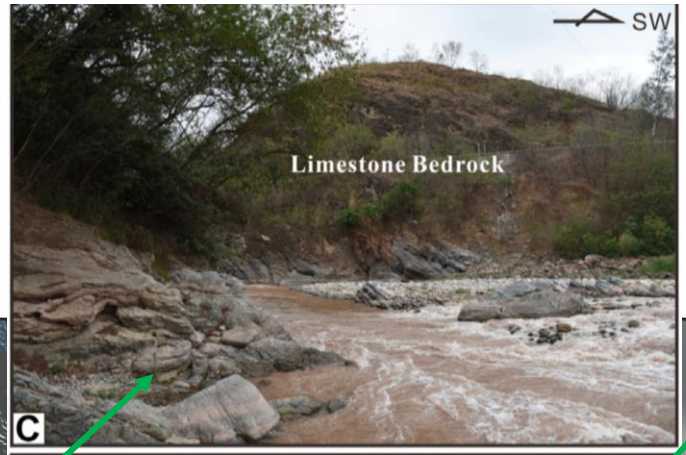


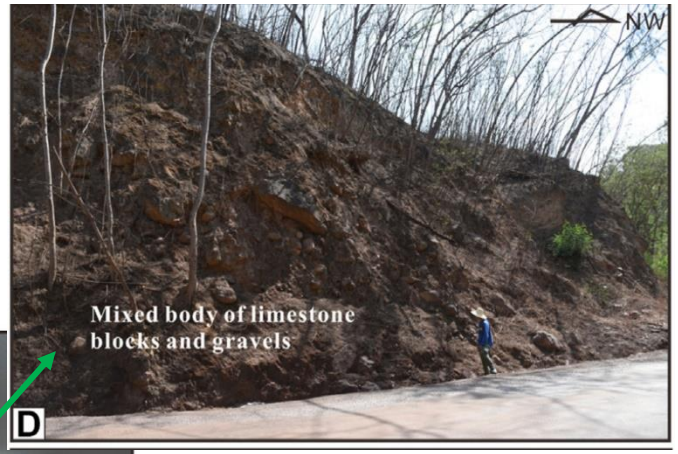
RESULTS OF THE INVESTIGATION

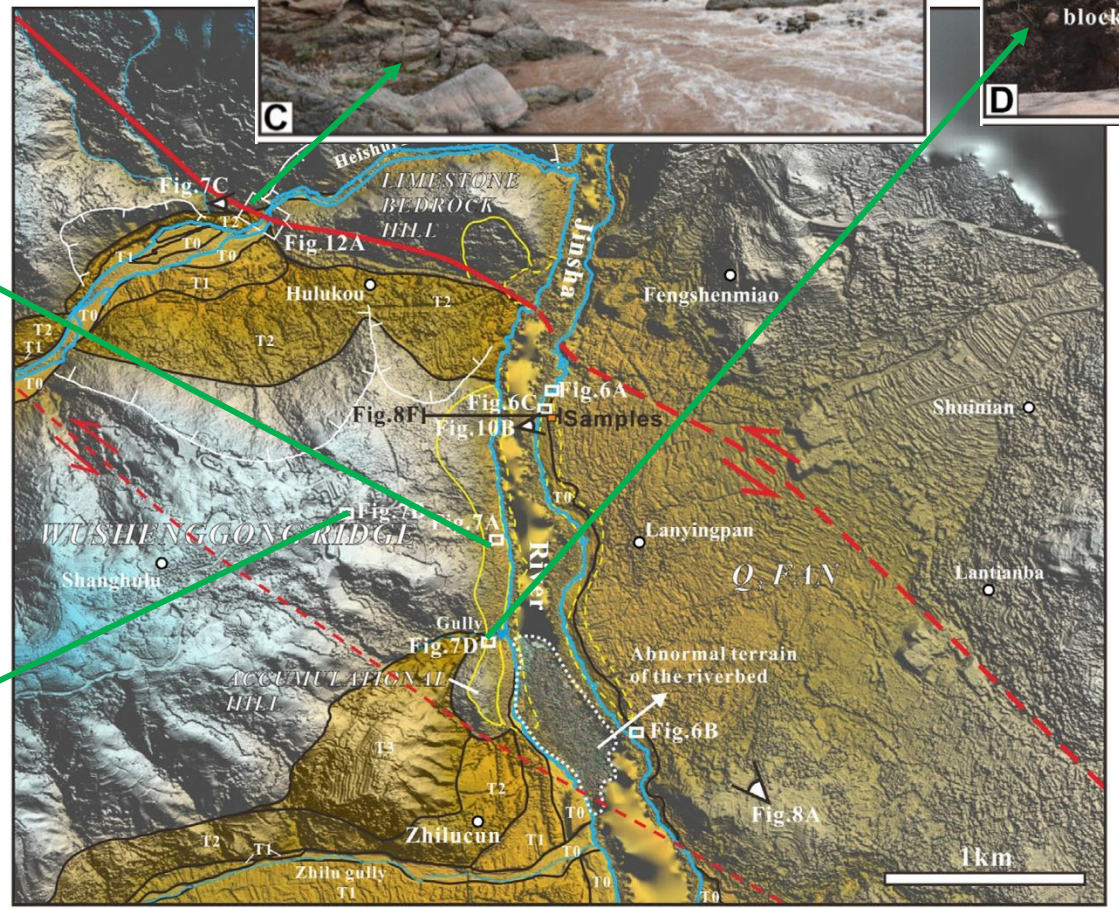
Existence of a Landslide





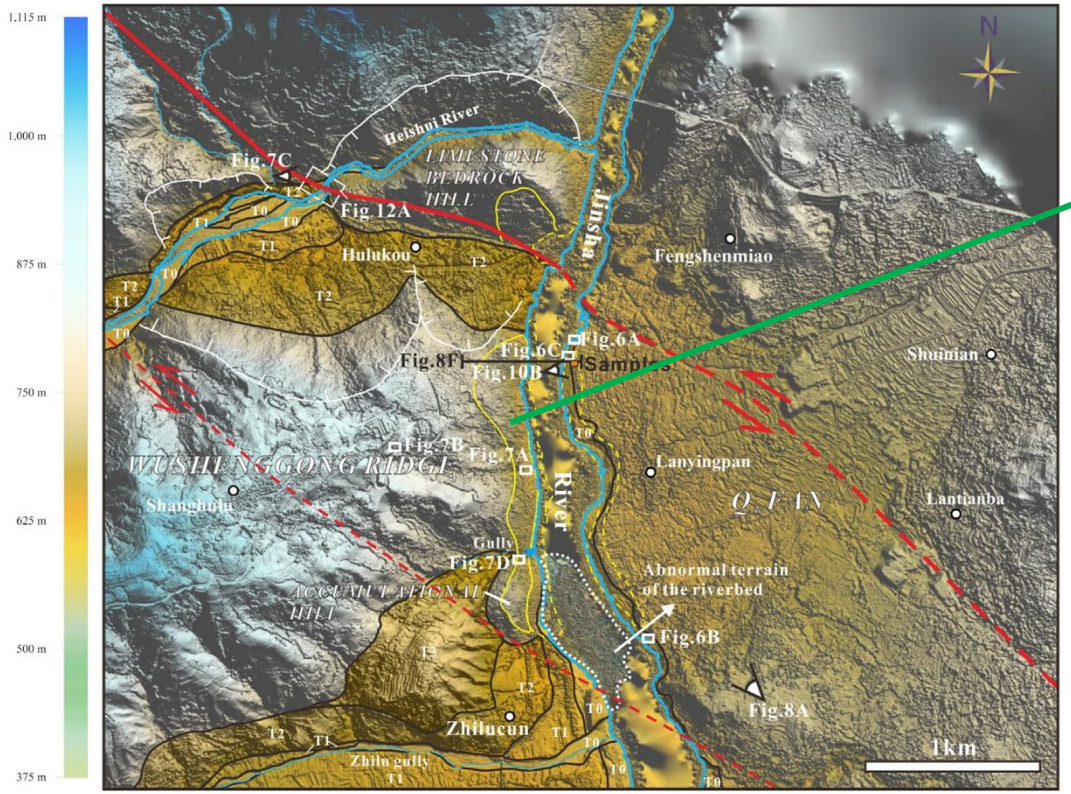






375 m

LANDSLIDE CHARACTERISTICS



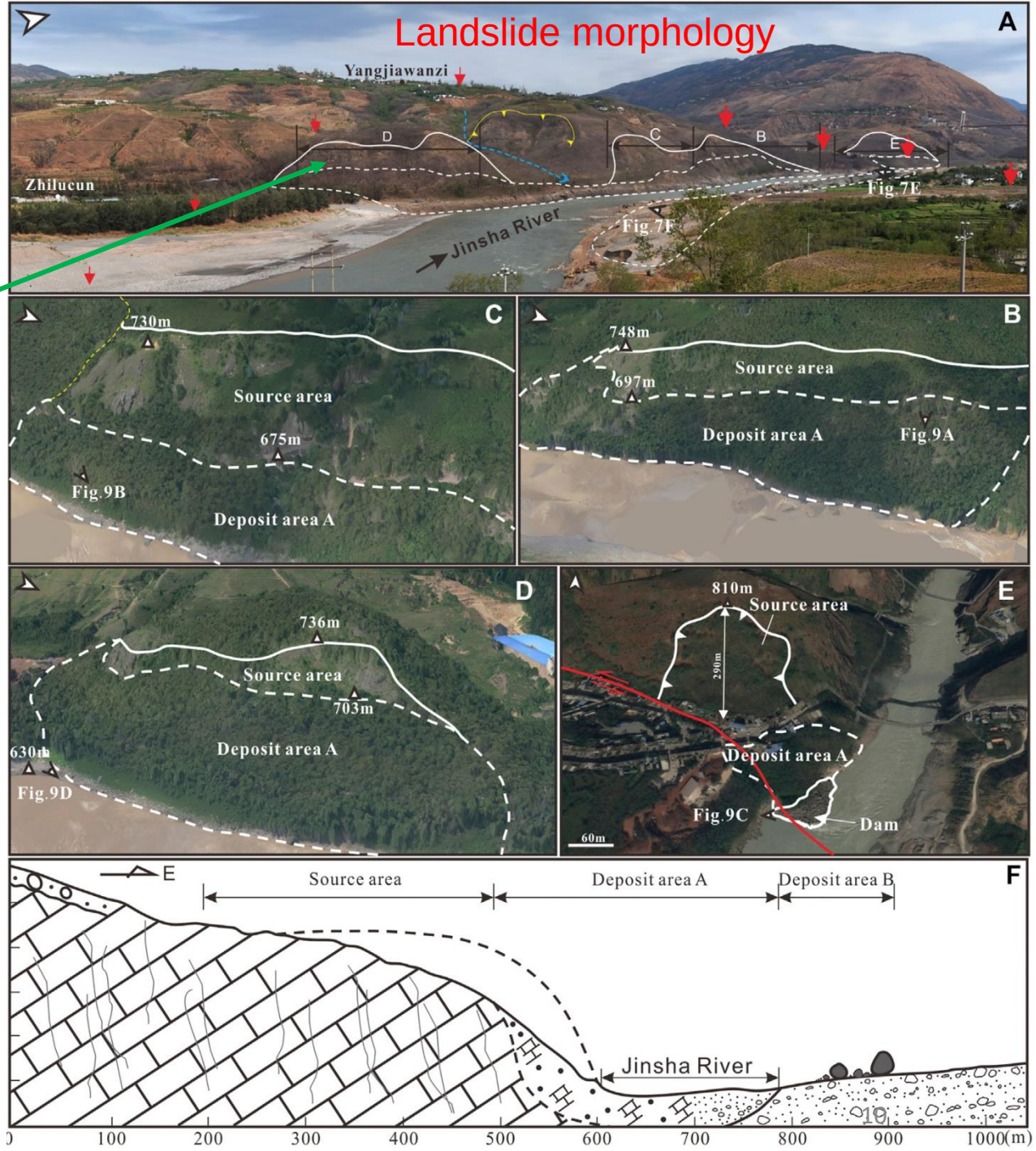
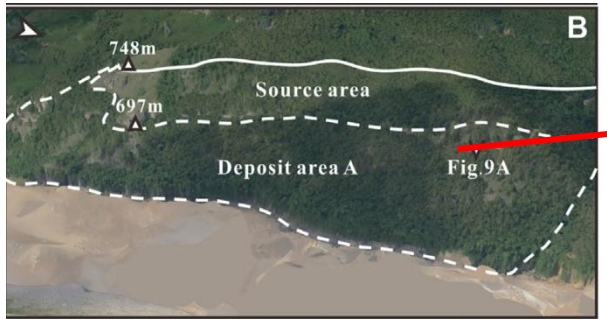
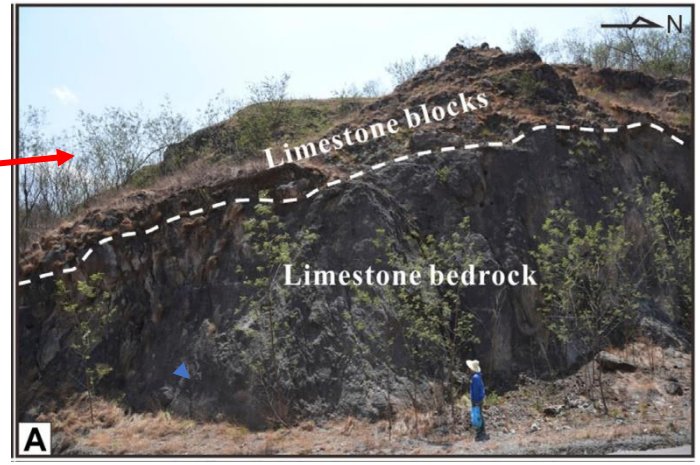


TABLE 3 | Characteristics of the failed slope collapse at different sections.

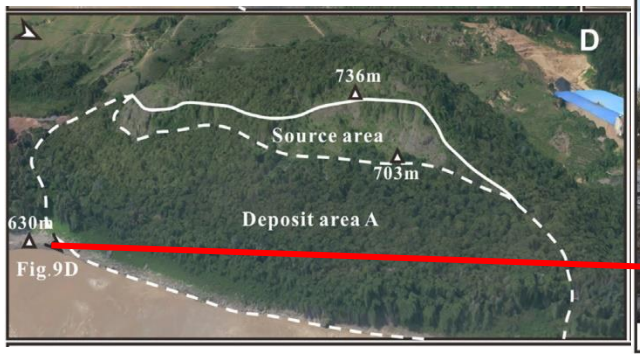
Section	Materials	Crown Elevation (m)	Drop (m)	Cut Volume (m^3)	Fill Volume (m^3)
B	Limestone bedrock	748	118	2,557,072.98	941,062.93
C	Limestone bedrock	730	100	1,326,247.92	118,034.27
D	Mixed body of limestone bedrock and gravels	736	106	717,513.26	627,118.52
E	Limestone bedrock	810	180	2,837,946.70	854,919.42

LANDSLIDE CHARACTERISTICS

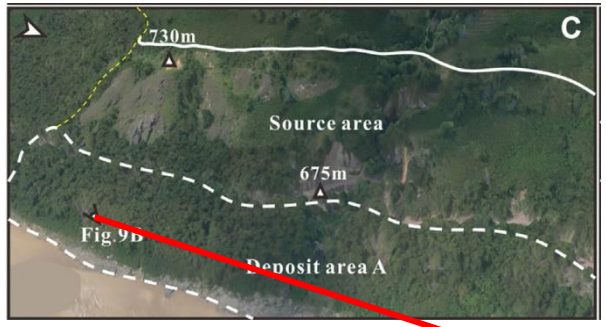


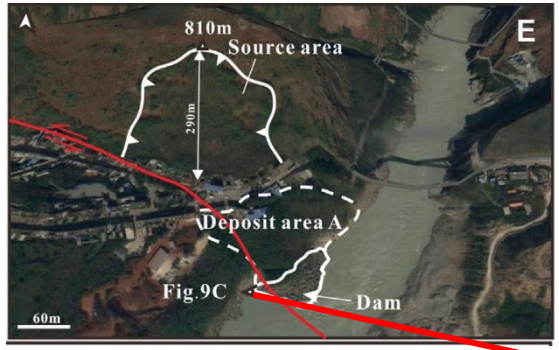


scattered limestone boulders (1–8 m diameter)



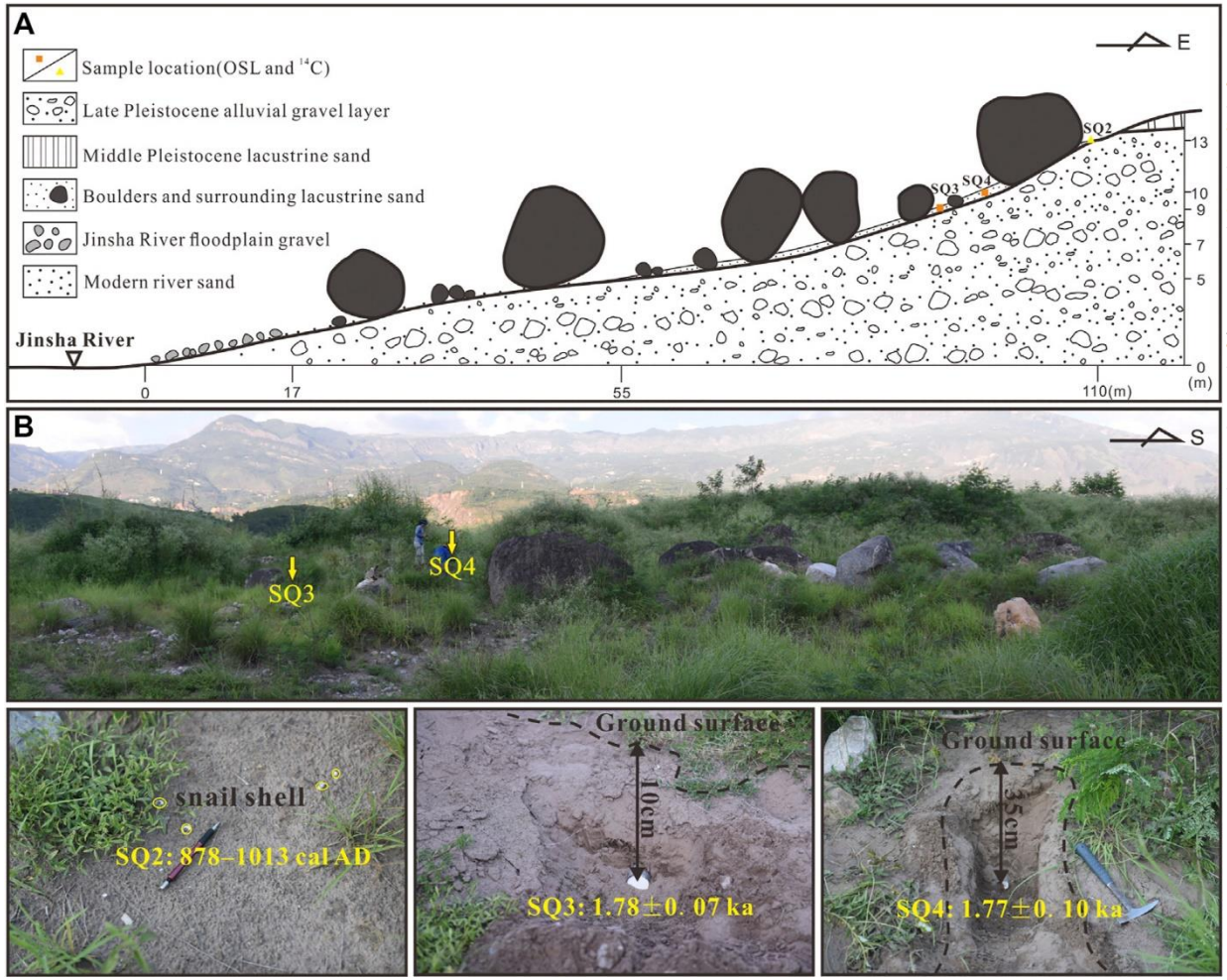
limestone boulders, D= 0.5 to 5 m





accumulation of the limestone boulders(0.5–8 m diameter)

LANDSLIDE AGE



Samples site for dating

TABLE 1 | Results of OSL dating on the lacustrine sand.

Sample number	Material	Burial depth/m	Moisture content/%	Ambient dose rate/(Gy/ka)	Equivalent dose/Gy	Age/ka
SQ3	Medium-fine sand	0.1	6 ± 3	2.82 ± 0.08	5.02 ± 0.16	1.78 ± 0.07
SQ4	Medium-fine sand	0.35	8 ± 4	3.20 ± 0.10	5.65 ± 0.26	1.77 ± 0.10

TABLE 2 | Results of ^{14}C dating.

Laboratory number	Sample code number	Material	Conventional radiocarbon age	2 sigma calendar calibrated results
Beta-509563	SQ1	Calcium film	43,310 ± 620 years BP	46,122–43,422 cal BC
Beta-509564	SQ2	Snail shell	1,110 ± 30 years BP	878–1,013 cal AD

- The 10–35 cm thick gray gravel-bearing medium-fine dammed lake sand layer
- The dammed lake formed before 878 AD

*When OSL dating method is applied with fluvial-lacustrine facies sand, the result could be used as a reference rather than accurate result. (Zhang et al., 2015)

DISCUSSION

Seismic Origin of the Landslide

- Qiaojia Basin is placed in the less rainy area.
- The landslide in a range of 2 km long

Ruled out caused by rainfall

- The landslide is its more limited depositional extent
- This failed slope collapse is with a characteristic of cluster

+The boulders on the east bank distributed 1.5 km long in an N-S direction

+ The general extent of the deposit did not exceed the range of the source area (2 km long)

- The blocky appearance of the deposits
- The landslide straddles Xiaojiang Fault straddles (Qiaojia Segment)

Earthquake-induced landslide

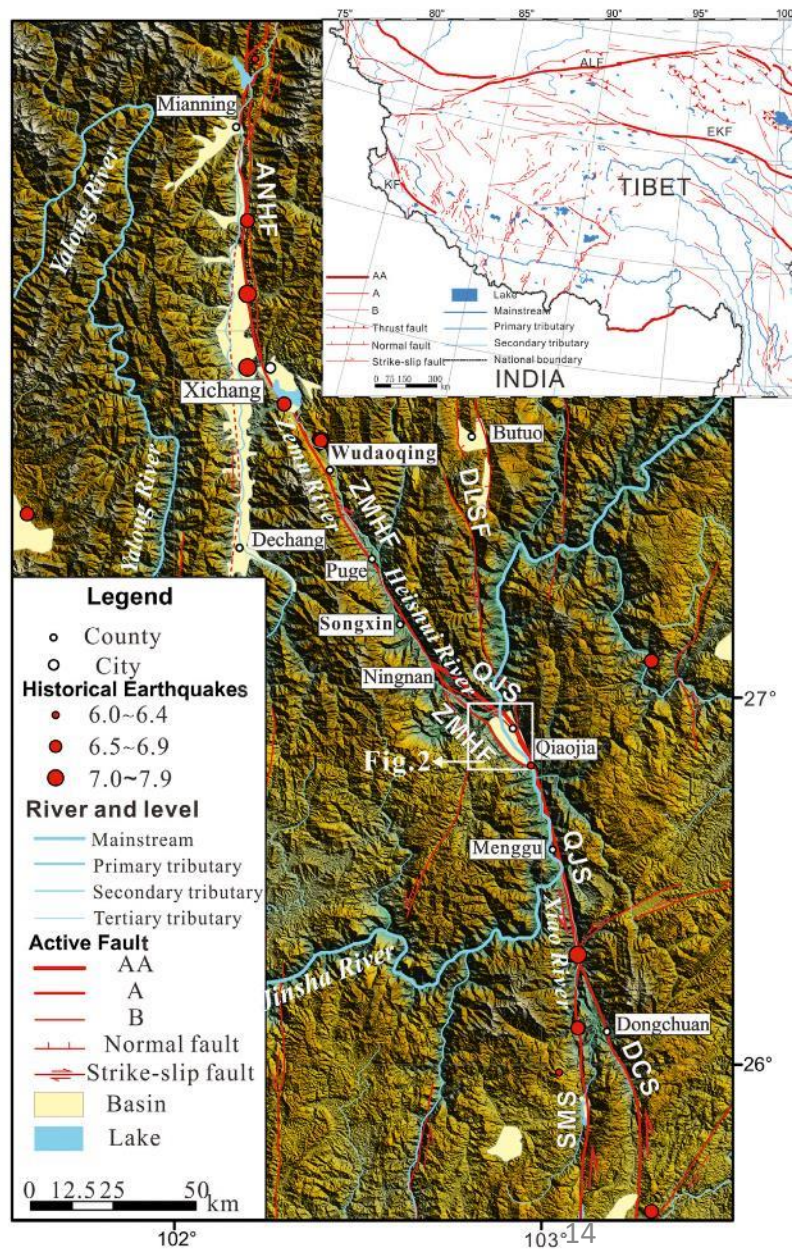
DISCUSSION

Temporal-Coincidence of the Landslide With 624 AD Earthquake

TABLE 4 | Historical earthquakes before 878 AD in Xichang-Dongchuan area.

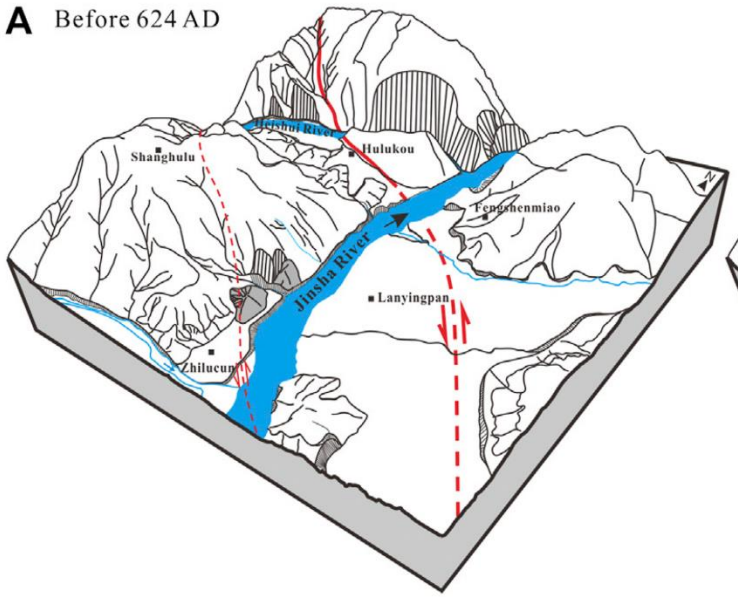
Date	Epicenter		Magnitude (Ms)	MMI	Description
	Latitude, longitude	References location			
624/08/15	27.9°, 102.2°	Xichang area	>6	VIII	Mountains shook, rivers were blocked with the dam
814/04/02	27.9°, 102.2°	Xichang area	7	IX	The aftershock lasted for 80 days, more than 100 people were crushed to death, and compression occurred within 15 km

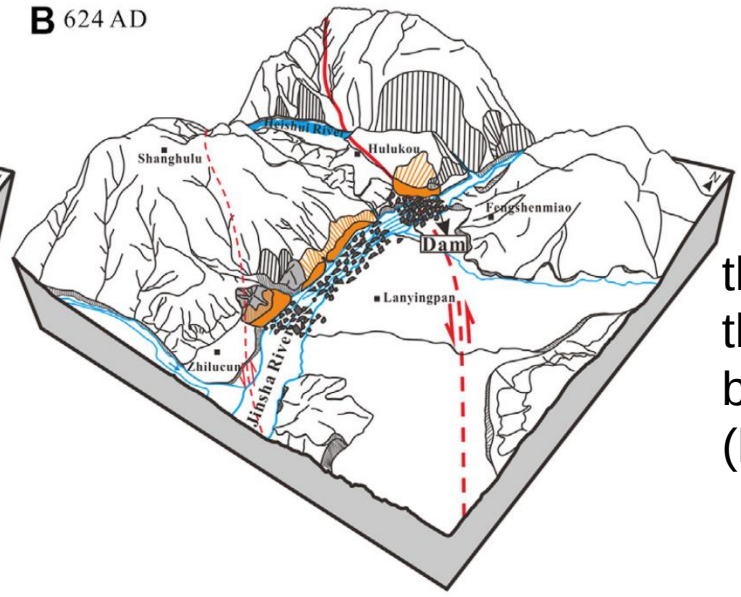
Large landslides are always located within the highest isoseismal (about 10–25 km), tending to be along its major axis(Nikonov, 1988)
=> macro-epicenter of the 624 AD earthquake at somewhere of the Heishui valley



Process of the Landslide

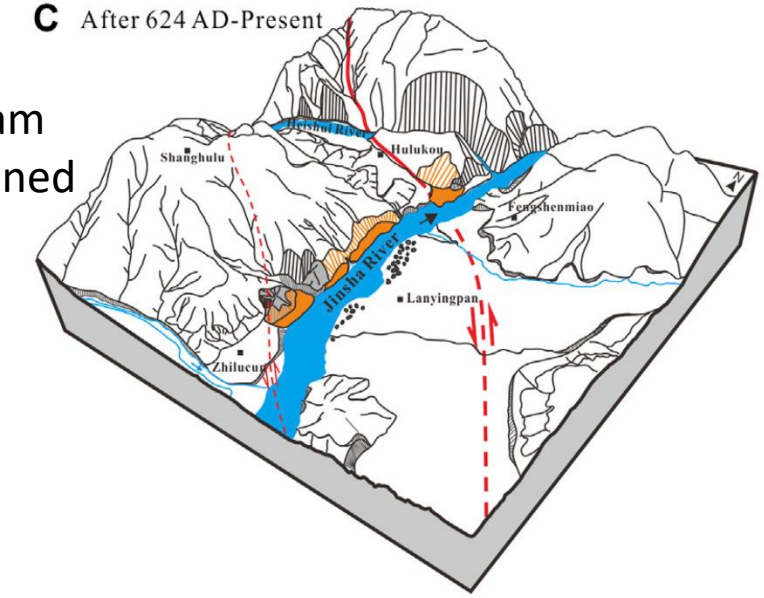
eastern flank of the Wushenggong Ridge is prone to have slope failures

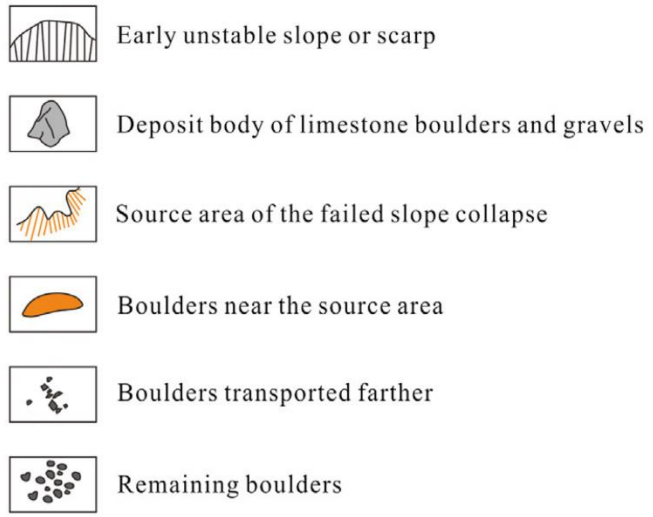




the boulders spread into the Jinsha River and both side during EQ (landslide dammed)

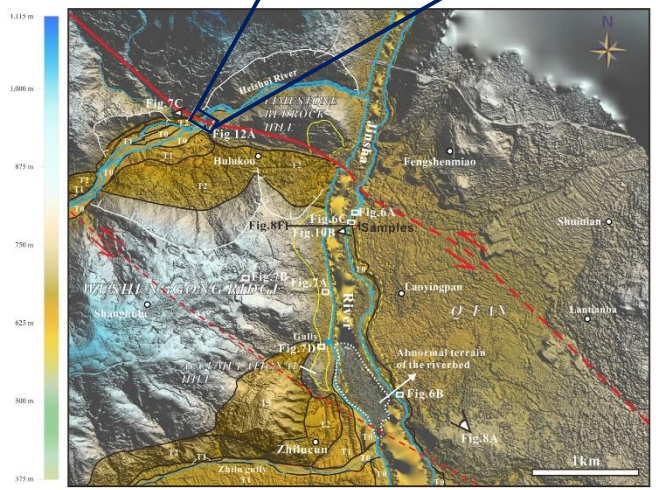
several hours later, the dam broke and the river reopened its flow

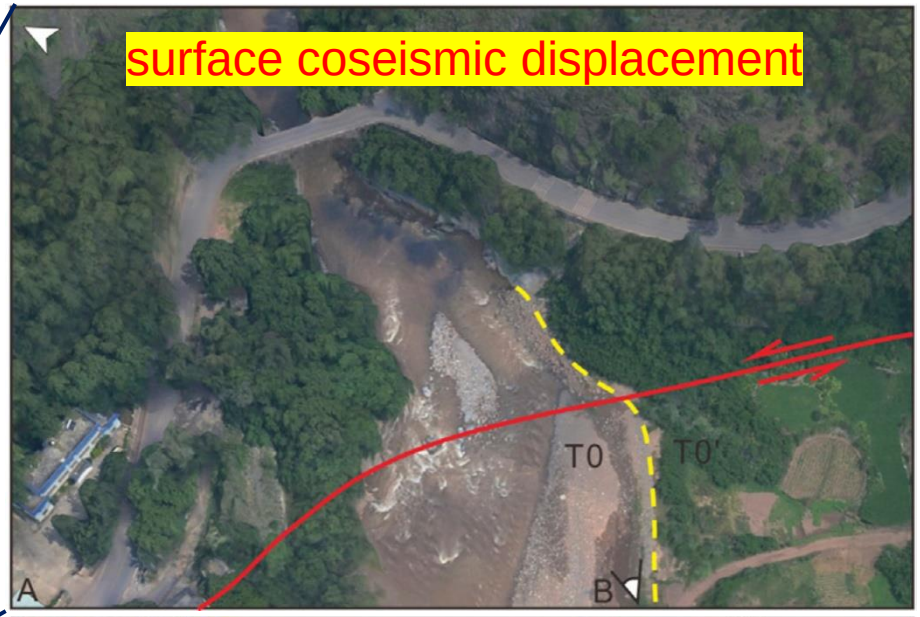


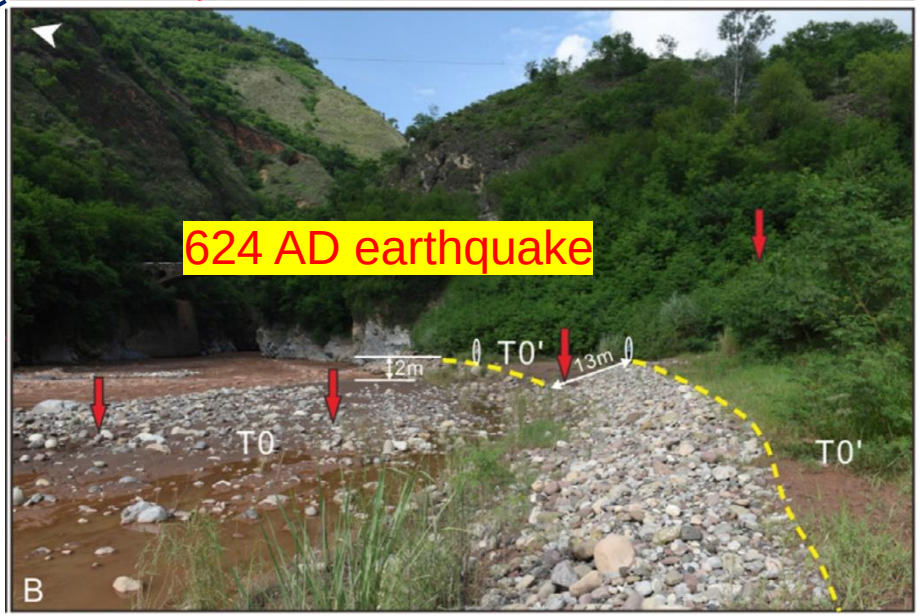


Seismic Hazard Assessment of Qiaojia Segment

- The lower limit of the age of the floodplain is no earlier than 1700 years BP
- Since 111 BC only M ≥ 6 since then, that is, the 624 AD earthquake







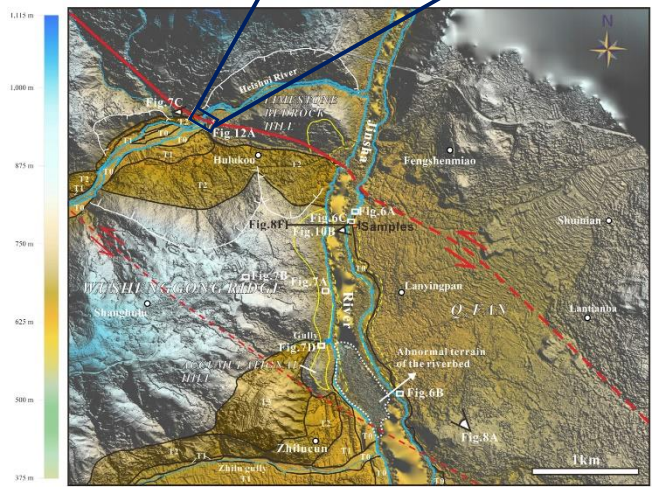
Seismic Hazard Assessment of Qiaojia Segment

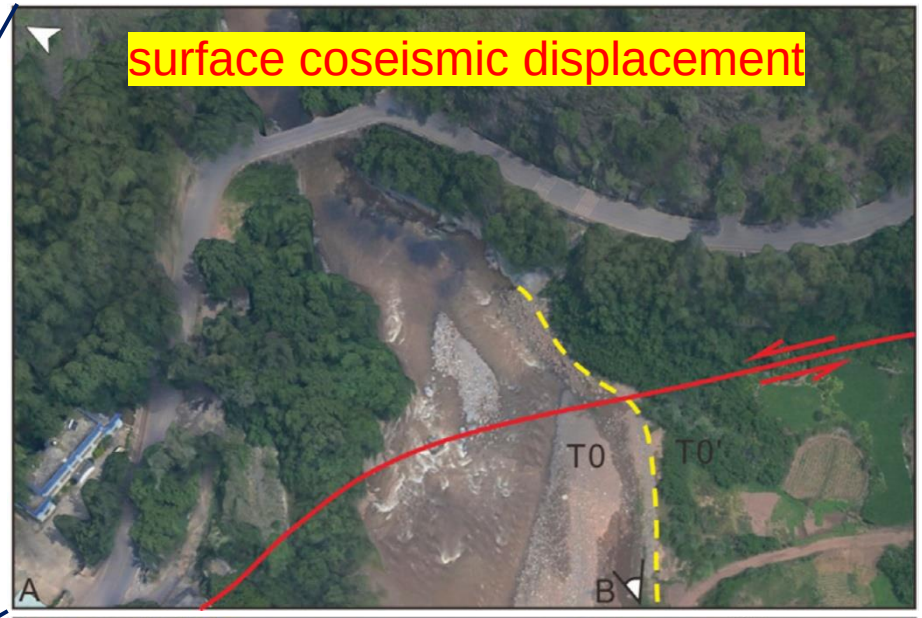
- The lower limit of the age of the floodplain is no earlier than 1700 years BP
- Since 111 BC only M ≥ 6 since then, that is, the 624 AD earthquake

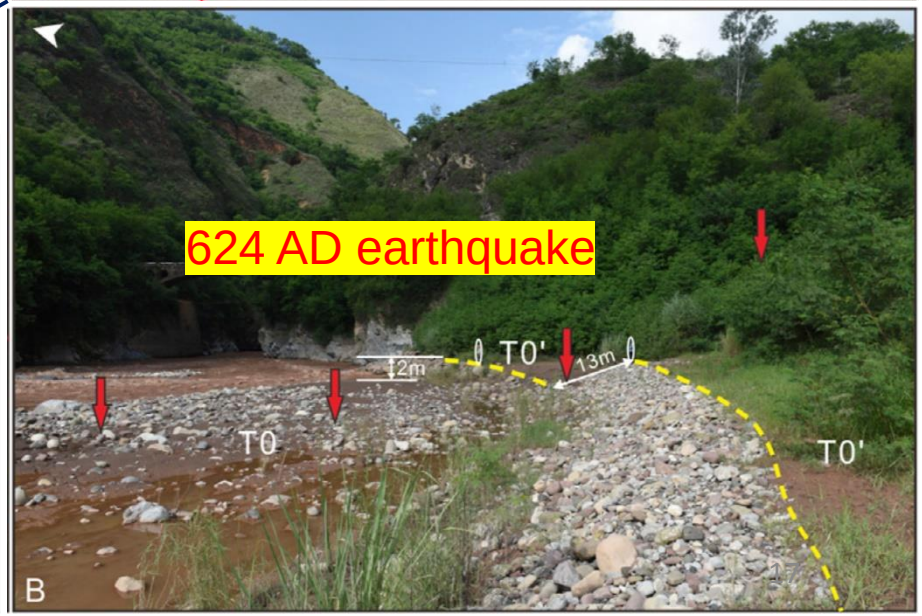
$$M_w = 6.81 + 0.78*\text{plog}(MD) \approx 7.7$$

MD refers to maximum displacement (m)

Wells and Coppersmith (1994)







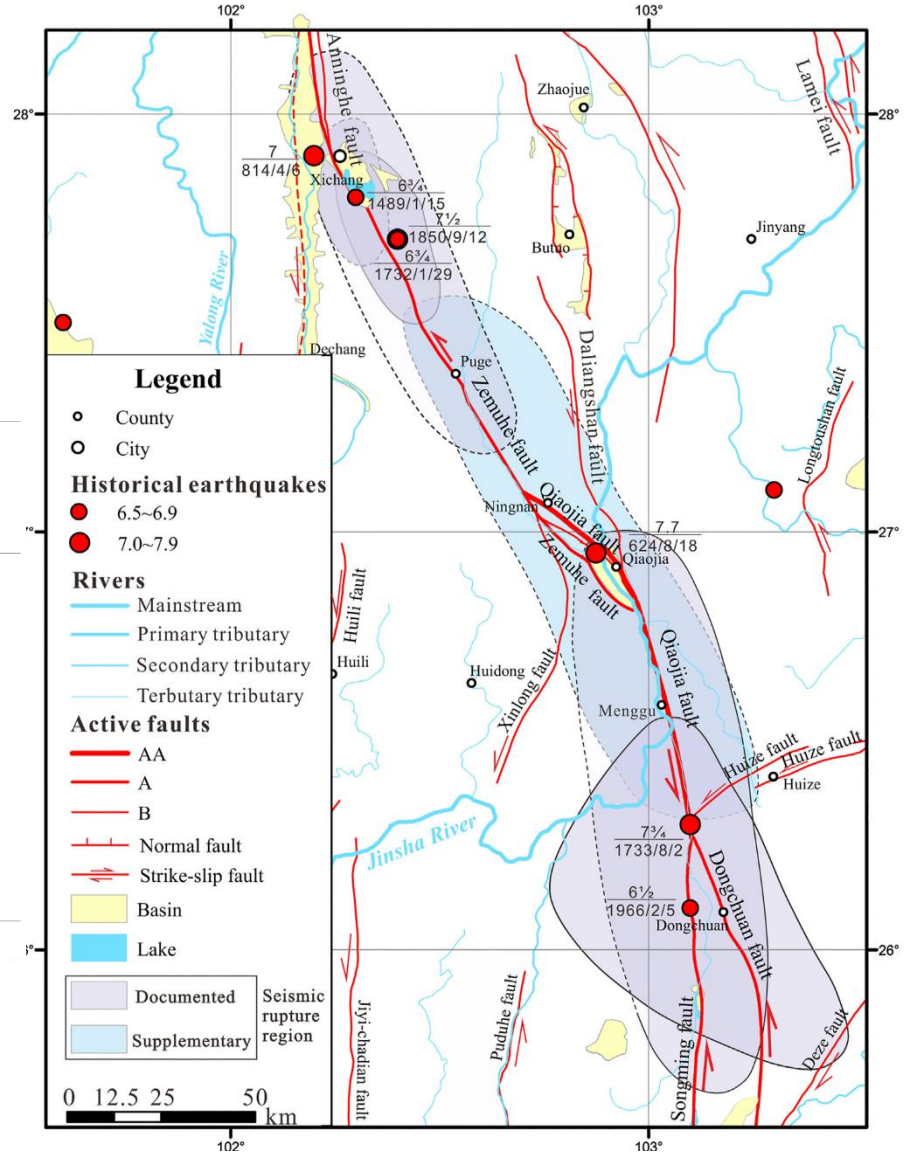
Seismic Hazard Assessment of Qiaojia Segment

- Tibetan Plateau, M6.5 may represent the magnitude threshold of the surface rupture.
- The distribution of seismic gaps on a fault can be seen directly by statistical analysis of the historical earthquakes with magnitudes ≥ 6.5 and delineation of their rupture areas with intensity ≥ IX.

TABLE 5 | Parameters of earthquakes with intensity ≥ IX from Xichang to Dongchuan.

No	Date	Magnitude	Macroscopic epicenter	Epicentral intensity	Epicentral region (Major axis, minor axis) km	Epicentral region Trend	Seismogenic fault	Data sources
1	624/8/18	7.9	Qiaojia	X	(158,33)**	N31°W	Qiaojia Fault	a
2	814/4/6	7	Xichang	IX	—	—	Anninghe Fault	b
3	1489/1/15	$6^3/_4$	Xichang and Yuexi	IX	(39,18)*	N6°W	Zemuhe Fault	c
4	1732/1/29	$6^3/_4$	Xichang	IX	(50,21)*	N23°W	Zemuhe Fault	b
5	1733/8/2	$7^3/_4$	Dongchuan	X	(152,42)*	N11°W	Qiaojia fault and dongchuan Fault	b
6	1850/9/12	$7^1/_2$	Xichang-puge	X	(116,29)*	N25°W	Zemuhe Fault	b
7	1966/2/5	$6^1/_2$	Dongchuan	IX	(97,53)*	N44°W	Songming Fault	b

*Annotation: * from documented data; ** calculated according to the formula (3) in the text; - no data; a. This paper; b. Department of Earthquake Damage Prevention (1995); c. Wen, 2000.*



The regression of surface rupture length and displacement (Wells and Coppersmith, 1994)

$$Log(SRL) = 1.49 + 0.64*plog(MD)$$

Seismic Hazard Assessment of Qiaojia Segment

TABLE 5 | Parameters of earthquakes with intensity ≥ IX from Xichang to Dongchuan.

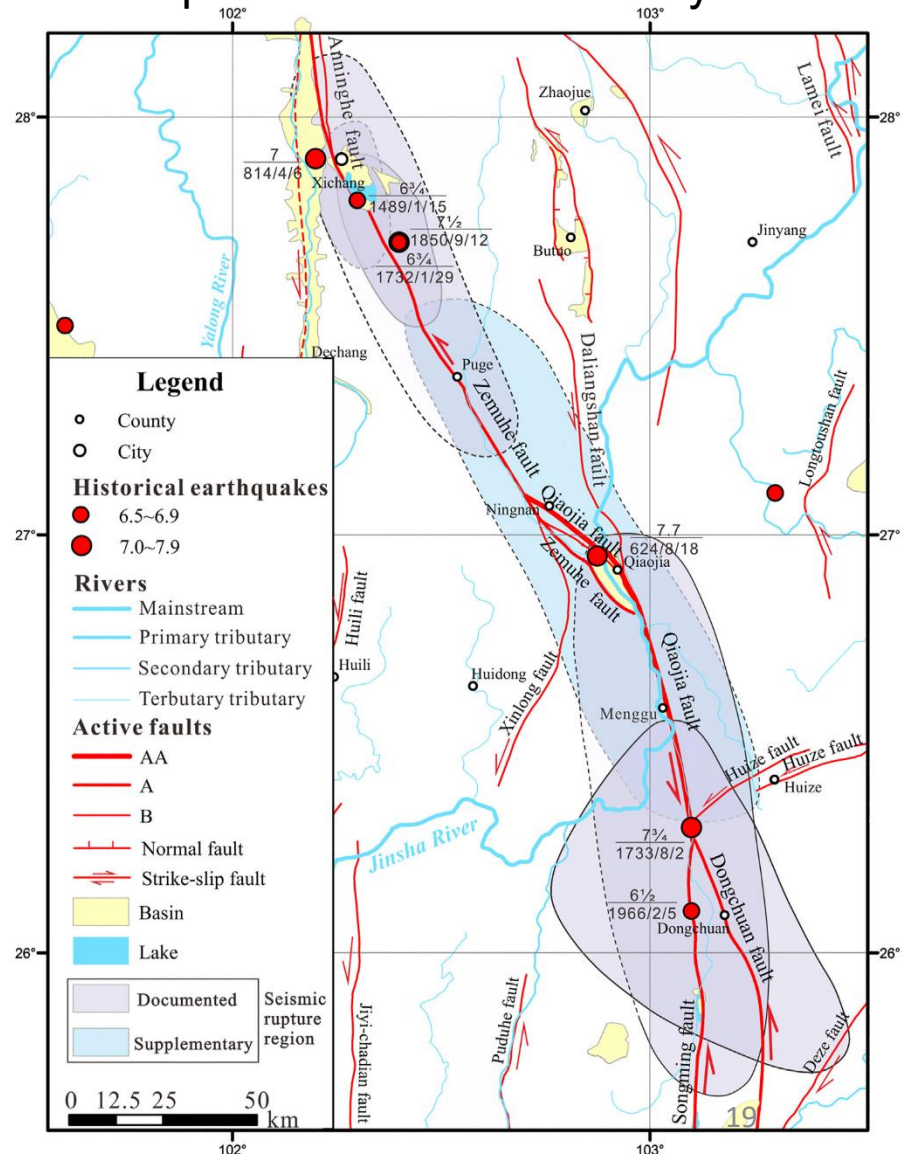
No	Date	Magnitude	Macroscopic epicenter	Epicentral intensity	Epicentral region (Major axis, minor axis) km	Epicentral region Trend	Seismogenic fault	Data sources
1	624/8/18	7.9	Qiaojia	X	(158,33)**	N31°W	Qiaojia Fault	a
2	814/4/6	7	Xichang	IX	—	—	Anninghe Fault	b
3	1489/1/15	$6^3/_4$	Xichang and Yuexi	IX	(39,18)*	N6°W	Zemuhe Fault	c
4	1732/1/29	$6^3/_4$	Xichang	IX	(50,21)*	N23°W	Zemuhe Fault	b
5	1733/8/2	$7^3/_4$	Dongchuan	X	(152,42)*	N11°W	Qiaojia fault and dongchuan Fault	b
6	1850/9/12	$7^1/_2$	Xichang-puge	X	(116,29)*	N25°W	Zemuhe Fault	b
7	1966/2/5	$6^1/_2$	Dongchuan	IX	(97,53)*	N44°W	Songming Fault	b

*Annotation: * from documented data; ** calculated according to the formula (3) in the text; - no data; a. This paper; b. Department of Earthquake Damage Prevention (1995); c. Wen, 2000.*

- No M ≥ 7 earthquakes since 1400 years Qiaojia Segment
- The average recurrence interval of large earthquakes on the segment around Dongchuan (1,447 ± 822 years) - Shen et al. (1998)
- Quaternary strike-slip rate of the Qiaojia Segment is 8.5 ± 1.5 mm/yr

Earthquake in the future

Rupture areas with intensity ≥ IX



CONCLUSION

- The landslide is located in the seismic region nearly 2 km long failed slope collapse of 624 AD earthquake in Qiaojia Segment.
- The macro epicenter of 624 AD earthquake to be Mw7.7
- 624 AD earthquake filled the seismic gap in the Qiaojia.
- The early 1400 along-time elapsed time is close to the average recurrence interval of larger earthquakes on the Qiaojia segment, then the seismic hazard of the area should be considered in the future.

Thank you for your attention!