XIV IAEG Congress 2023 Field Trip

Field Trip #4: Urban Ground Fissure and Loess landslide

26-27 September 2023 – 2 FULL DAYS WITH ACCOMMODATION
Departure on 26/09 at 8:46 - return to Xi'an on 27/09 at 18:00

Organizer:

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Topic: Xi'an Ground Fissure and Loess landslide, the most serious ground fissure disaster and loess landslides in Xi'an, China.

General description:

Xi'an, which was known as Chang'an in ancient times, has a history of more than 3,100 years and set as a capital city 1,100 years ago. It is the old capital of 13 dynasties and the birth place of the first emperor (Qin Shihuang) in China, and is also one of the important birthplaces of Chinese civilization and Chinese nation. As the starting point of the ancient Silk Road, it is the origin of Chinese civilization going to the world. It is located in the upside of the Weihe rift and south of the Chinese Loess Plateau. So, the geological problems, such as loess ground fissures and ground subsidence downtown as well as loess landslides around the city, are the challenges of the urban development. In the field trip, we will visit some cultural heritage and geohazard sites.

DAY1: Xi'an Ground Fissure - City wall

In this trip, you will visit some disaster points, monitoring points of ground fissures, and have opportunity to visit the famous Xi'an ancient city wall, as shown in Fig. 1. There are 14 ground fissures in Xi'an city, as shown in Fig. 2. The strike of these fissures is in the NEE direction, and the dip angle is between 70° to 85°. Activation of ground fissures have caused massive damage to engineering structures in the past years.

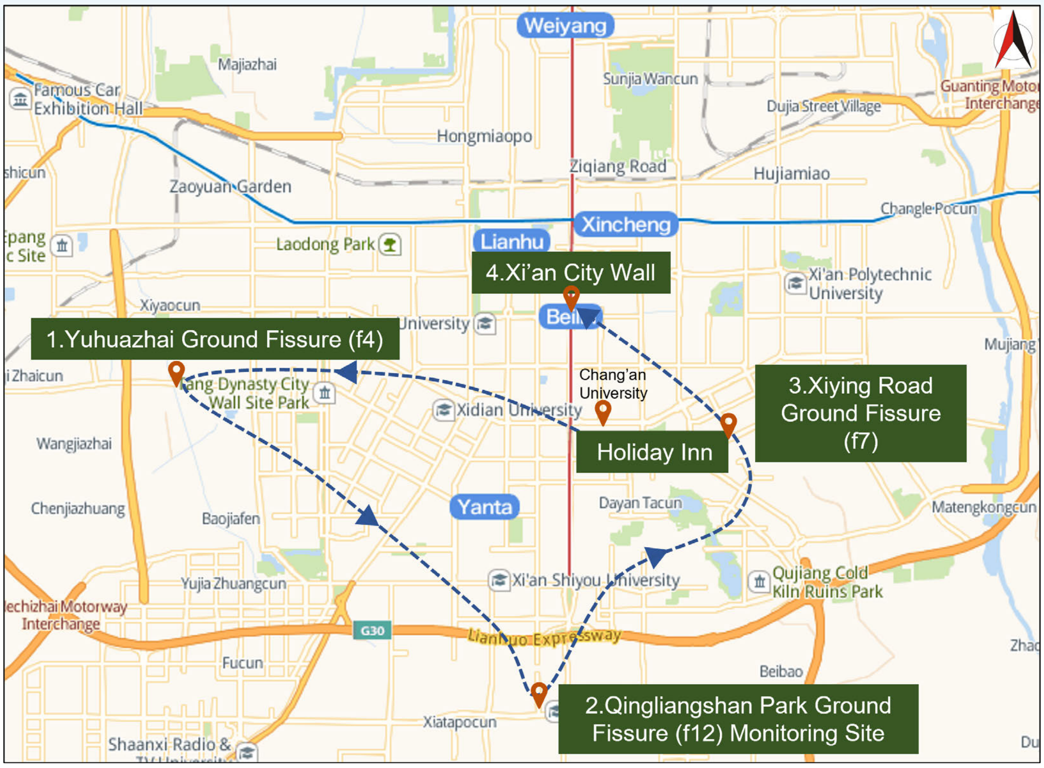


Fig. 1 Sketch map of the field trip itineraries (Day 1: 14:30 - 18:00, September 26, 2023)

1. Yuhuazhai Ground Fissure(f4)

The Yuhuazhai Ground Fissure, which has a length of about 2230m, is located at the edge of the ground subsidence center of the Yuhua Village, and was first founded in 2010. The fissure belongs to the western section of the Xi'an f4 ground fissure. The results of leveling and InSAR monitoring show that the maximum vertical displacement of the ground fissure increased from 300 mm to 650 mm during 2013-2016, and the maximum annual vertical activity rate reached 87.5 mm/a (Fig.3).

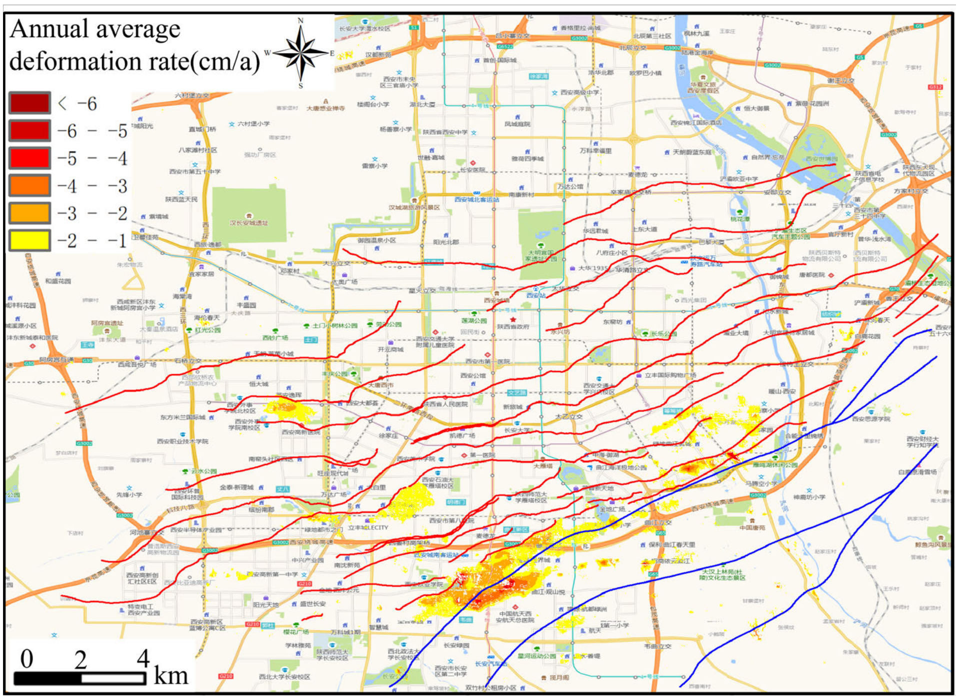


Fig. 2 Distribution of ground fissures and land subsidence in Xi'an, China

After November 2018, the groundwater level raised by nearly 30 m over a five-month period, almost simultaneously with the ground rebound (Fig.4). From the f4 ground fissure level monitoring profile, the relative deformation of its two plates showed a decreasing trend with the increase of groundwater level after 2018. It has caused serious deformation and damage to roads and buildings, and impacted the operation of Xi'an Metro Line 3 (Fig. 5).

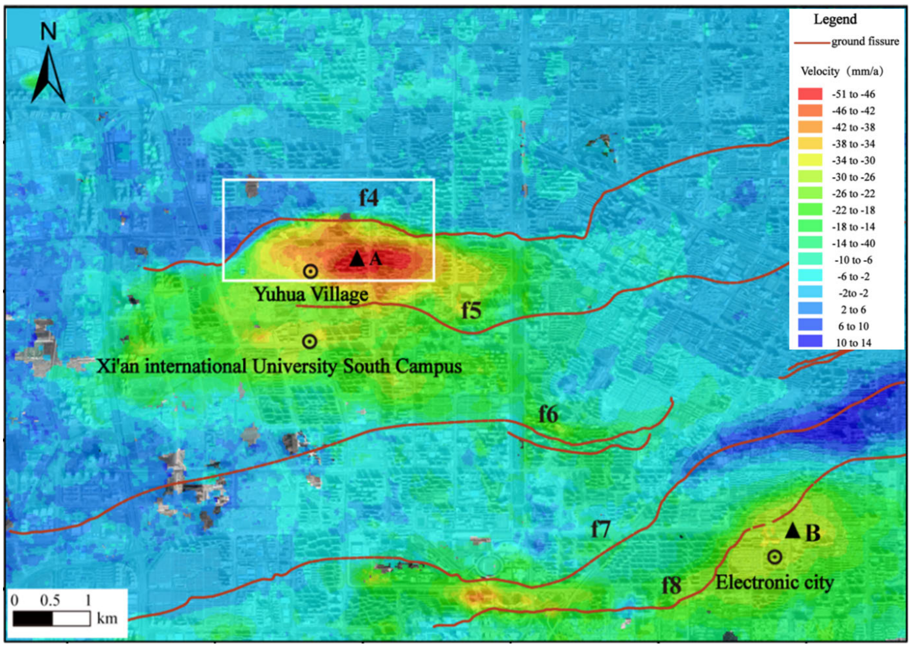


Fig. 3 Xi'an f4 ground fissure and nearby land subsidence rate (2015-2020)

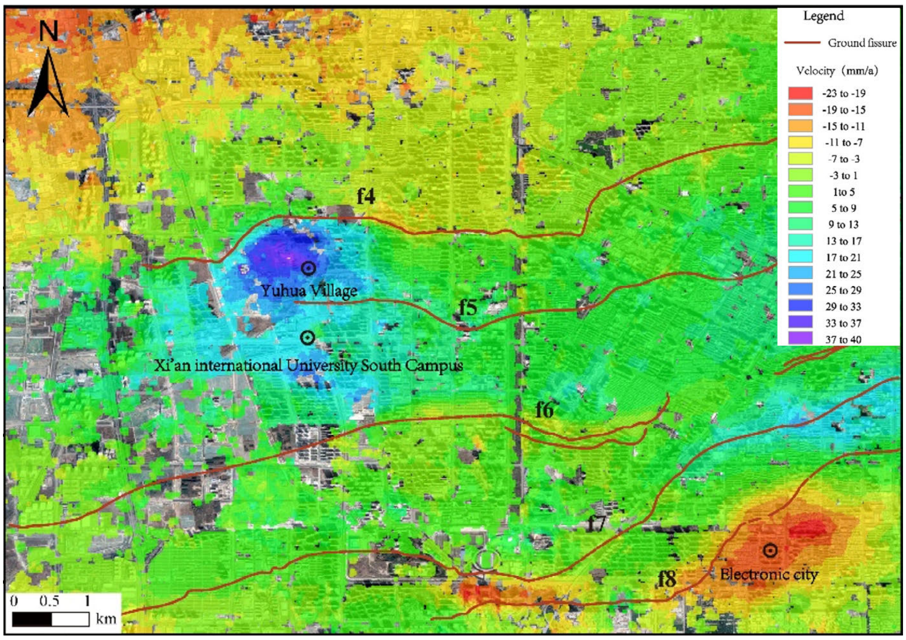
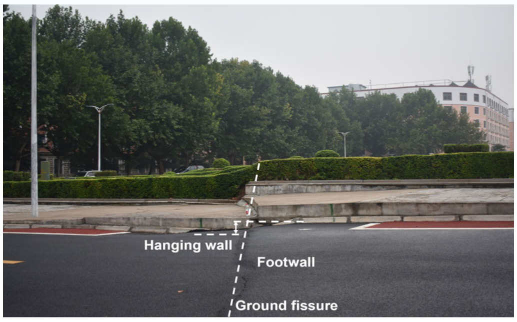


Fig. 4 Annual average settlement rate in Yuhuazhai area (2018-2020)



(a) 300mm in 2013 (b) 700mm in 2018

Fig. 5 Road dislocation and building cracking induced by ground fissures

2. Qingliangshan Park Ground Fissure (f12) Monitoring Site

Qingliangshan Park Ground Fissure Monitoring Site is located in the north side of the Qingliangshan Park in Chang'an District, Xi'an City (Fig. 6 and Fig.7). It was funded and constructed by the Xi'an Natural Resources and Planning Bureau. The design and construction Institute is Chang'an University, and the monitoring of leveling profiles and layered standards is conducted by the Shaanxi Provincial Geological Environment Monitoring Station. By monitoring the land subsidence of the ground fissure zone and its hanging wall and footwall, the compression between different depths of soil layers, and the dynamic changes of groundwater level, we analyzed the influence zone of ground fissures, current activity status, causes of land subsidence, and the mechanism of ground fissure activity. Besides, long term data acquisition also supports the scientific decision-making for the alleviation and prevention of the ground fissure induced disasters.

Fig. 6 Layout of layerwise marks (Benchmark fixed on different stratum)

The monitoring station is located on the f12 ground fissure and its hanging wall and footwall are located in the north side of the Qingliangshan Park, with a level monitoring profile crossing ground fissure and two land subsidence layerwise mark groups (Fig.8). The leveling monitoring profile includes 6 benchmarks.

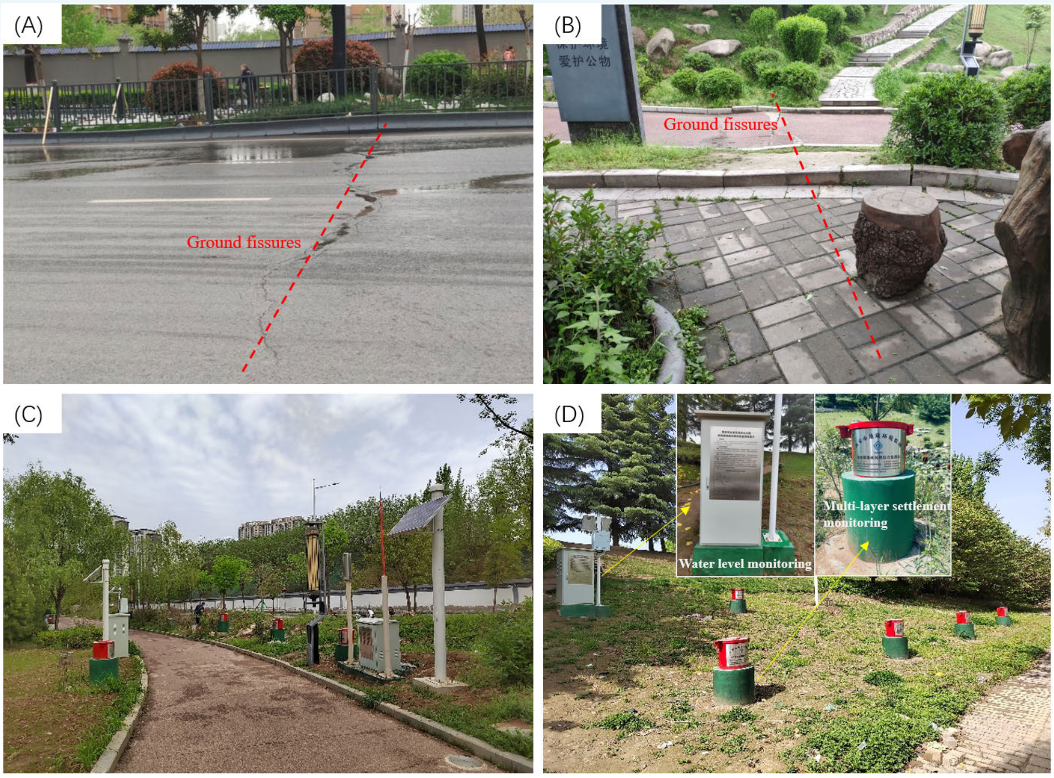


Fig. 7 Ground fissure and layerwise mark (the location of A, B, C and D is shown in Fig. 6)

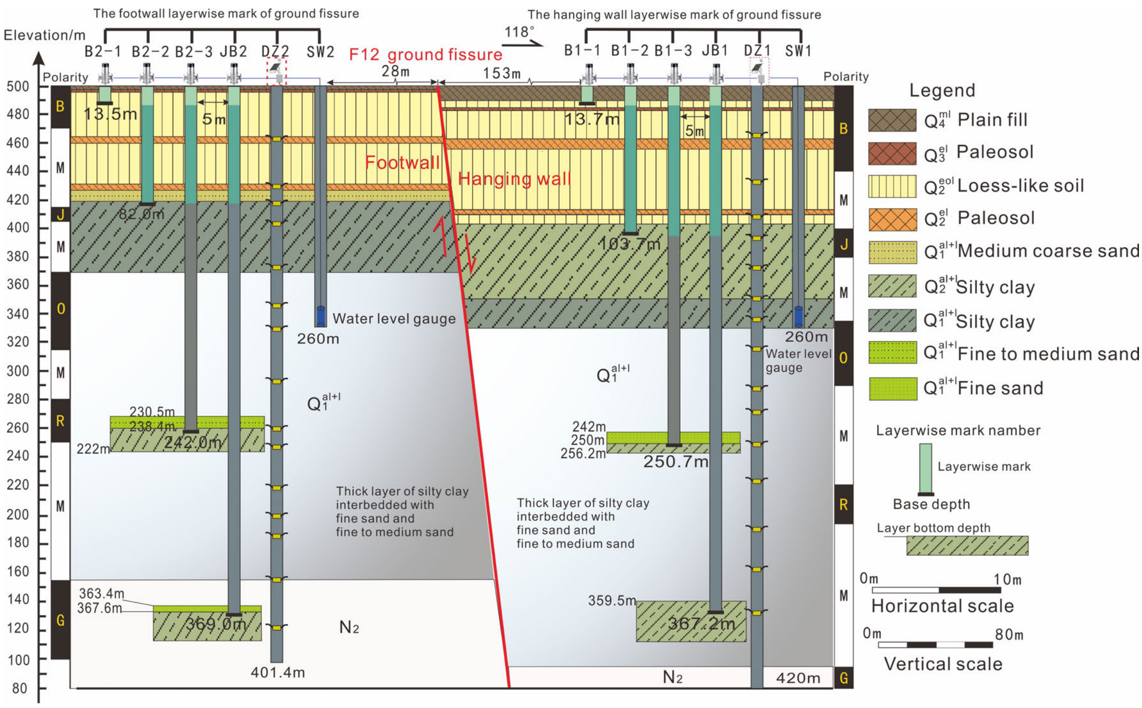


Fig. 8 Layerwise marks for monitoring the Qingliangshan Park Ground Fissure

3. Xiying Road Ground Fissure (f7) Monitoring Site

Xi'an ground fissure three-dimensional automated monitoring station is located in Xi 'an Engineering and Technical School on Xiying Road, Xi'an. The design and construction unit is Shaanxi Provincial General Geological and Environmental Monitoring Station, and GNSS monitoring was undertaken by Chang'an University.

The horizontal torsion, horizontal tension tensor of the ground fissure and vertical relative settlement between the hanging wall and footwall of ground fissure are observed respectively by the three-dimensional automatic monitoring. Through GNSS monitoring and level point monitoring, the land subsidence and relative activity of the hanging wall and footwall of ground fissure are obtained respectively. The dynamic changes of compression and groundwater level between soil layers at different depths can be obtained by layered mark monitoring and groundwater monitoring. The monitoring results are used for determining the influence range and activity characteristics of ground fissures. It serves as a fundamental basis in analysis of the activity status and formation of land subsidence in this area, and facilitate a better understanding on the activity mechanism of ground fissures.

The three-dimensional deformation monitoring system (Fig. 9) was installed in the instrument room to monitor the three-dimensional activity changes of the f7 ground fissure. A group of cross-ground fissure leveling monitoring points, a ground subsidence stratification group, and a GNSS monitoring station group are set outdoors.

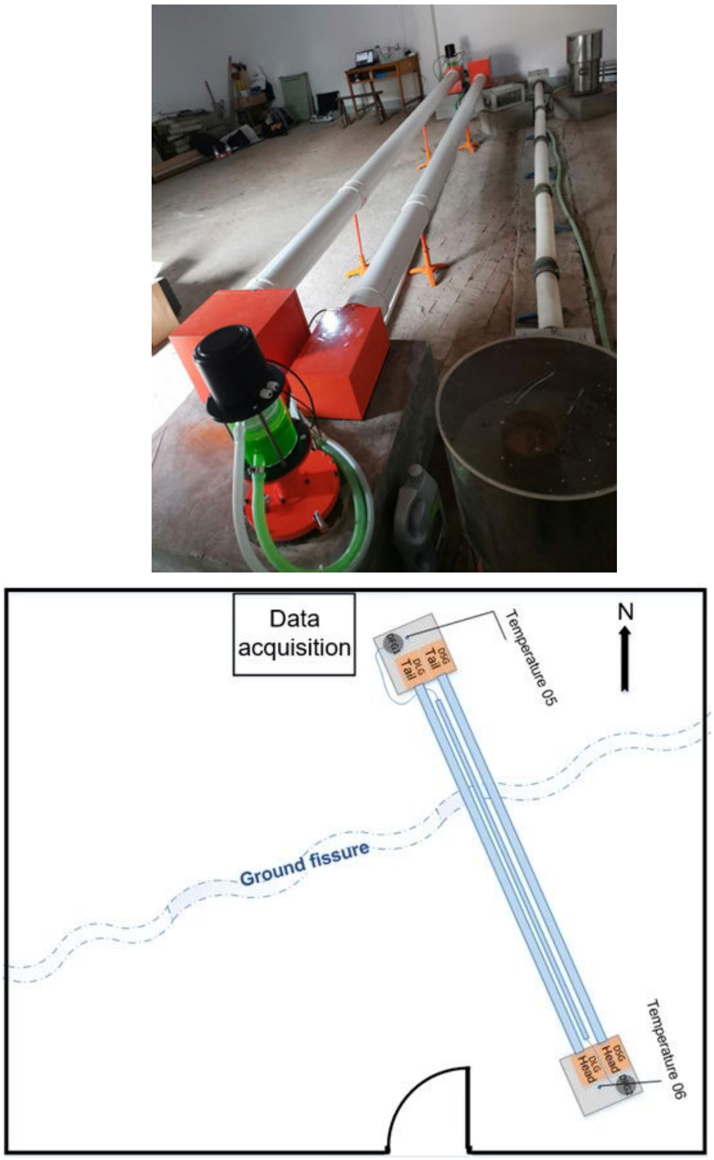


Fig.9 Three-dimensional deformation monitoring system across ground fissure zone

4. Xi’an City Wall

Xi'an City Wall is among the oldest and best preserved city walls in China and one of the largest ancient military defense systems in the world (Fig. 10). The existing walls were built in the Ming

Dynasty in 1370, and have more than 600 years of history.

When talking about the City Wall, it consists of a moat, drawbridge, building gate, watchtower, towers, fortresses, parapet, forts and other a series of military facilities. The City Wall is 12 meters tall, 12-14 meters wide at the top and 15-18 meters wide at the bottom, surrounded by a deep moat. The total length of the City Wall is 13.7 kilometers (8.5 miles) and it covers an area of 12 square kilometers (4.6 square miles) inside the wall. There are four main gates along the City Wall: the eastern gate is named Changle; the western one is Anding; the southern one is Yongning and the northern one is Anyuan.

The City Wall has experienced three major renovations. Longqing two years (1568), Shaanxi provincial governor Zhang Zhi presided over the restoration of Tucheng first into brick city; Qing Emperor Qianlong 46 years (1781), Shaanxi governor, Bi source host on the walls and towers were renovated; since 1983, in Shaanxi Province and Xi'an Municipal People's Government of the City Wall the large-scale renovation, construction has been the demolition of the east gate, north gate of the watchtower, on the South Gate building, suspension bridge, and built around the park,. Since then, this ancient building has become a famous tourist place for visitors in Xi'an.

The City Wall was built by loess in separated layer. The bottom layer was rammed with the mixture of earth, limes and juice of sticky rice, thus is very solid. Besides, black bricks were used to build the inner, outer walls as well as the top layer. On the top of the City Wall, there is a flume every 40 to 60 meters (44 to 66 yards) for the drainage purpose, and it serves a great contribution for the preservation of the City Wall within a long time.

https://www.xacitywall.com/

(a) The southeast corner of the City Wall.

(b) The beautiful night view of City Wall.

Fig.10 Xi'an City Wall

DAY2 : Xi’an Jingyang Loess Landslide and Loess Profile - Lintong Terracotta Warriors

Loess is a type of wind-borne sediment distributed widely in Chinese Loess Plateau - the very first birthplace of Chinese civilization. This type of soil is usually formed with a loose honeycomb-type meta-stable structure and susceptible to collapse upon wetting. Therefore, loess landslides develop extensively in the loess area.

In this field trip, you will visit several typical loess landslides occurred at the south bank of the Jing River, on the north margin of the Xianyang loess highland triggered by farmland irrigation, and you will also observe the typical geological profile of loess- paleosol sequence. After the field trip, you will have the opportunity to visit the famous Terracotta Warriors and Horses of the Chinese First Emperor, which is the relic of the Qin Dynasty - the first feudal dynasty in China (B.C. 221-B.C. 207) (Fig. 11).

Fig. 11 Sketch map of the field trip itineraries: 1. Loess landslides and loess-paleosol profile sites on the north margin of the Xianyang loess highland; 2. Lunch hotel; 3. Terracotta Warriors & Horses of the Chinese First Emperor

1. Jingyang Loess Landslide

The loess highland at the south bank of the Jing River, Shaanxi Province, China, with an area of 70 km^2, is a part of the Chinese Loess Plateau, where landslides frequently occur. Since 1976, when farmland irrigation began in this region, more than 50 landslides have occurred, and about half of them are rapid flow-like loess landslides (Fig.12). Among these landslides, the Jiangliu landslide occurred in 1984 buried a small village, resulting in 20 causalities. In this field trip, you will visit four typical loess landslides (Dabaozi landslide, Jiangliu landslide, Dongfeng landslide and Shutangwang Landslide) located at the northeastern side of the loess highland. These loess landslides have three typical characteristics: (1) developing on the side of the loess highland where the loess slopes are high and steep, (2) rapid slumping with high kinematic energy and (3) violent impacting on the saturated gravelly sand at the terrace of the Jinghe River, which caused the liquefaction and entrainment of the saturated gravelly sand (Fig.13).

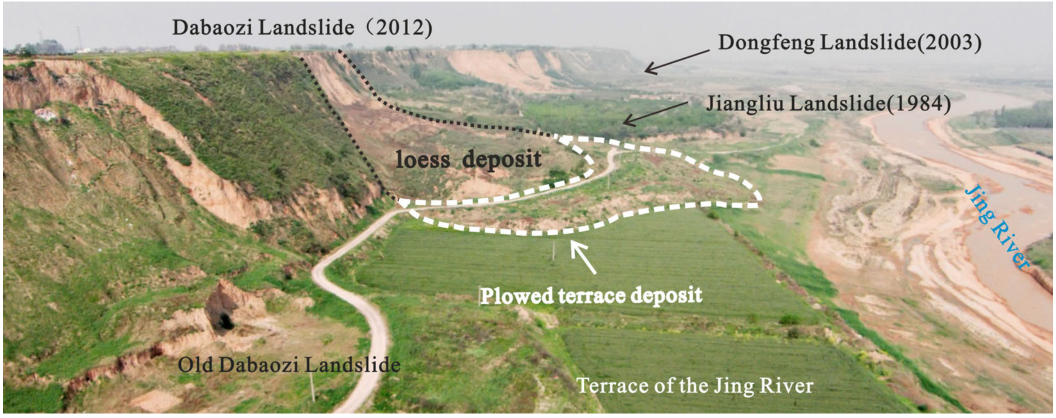


Fig. 12 Aerial view of the landslides group at the south bank of the Jing River

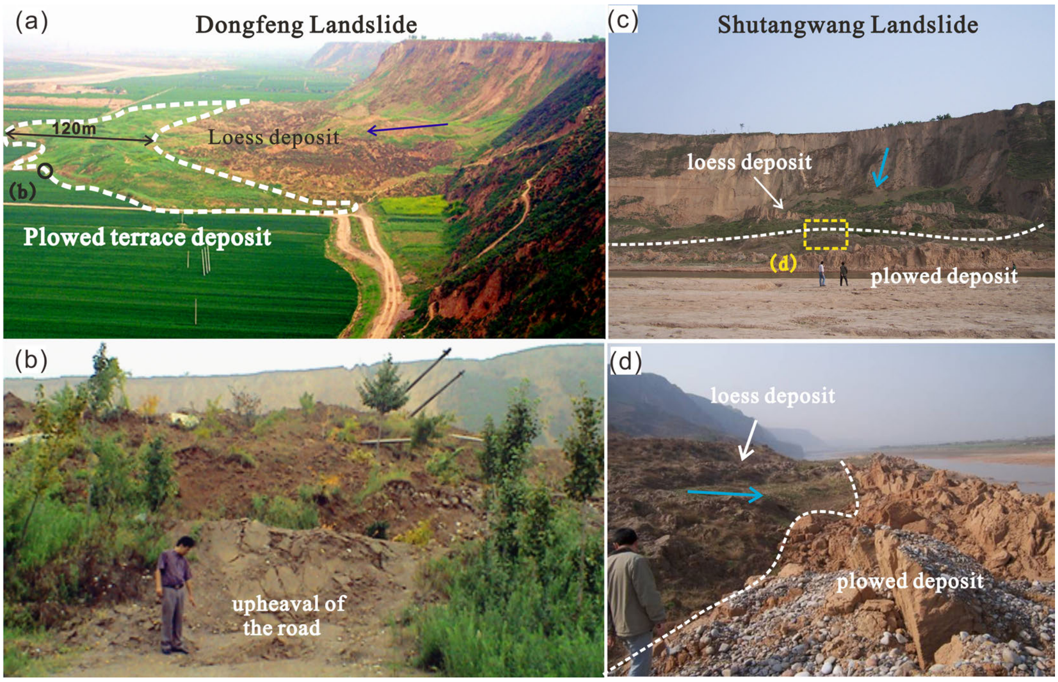
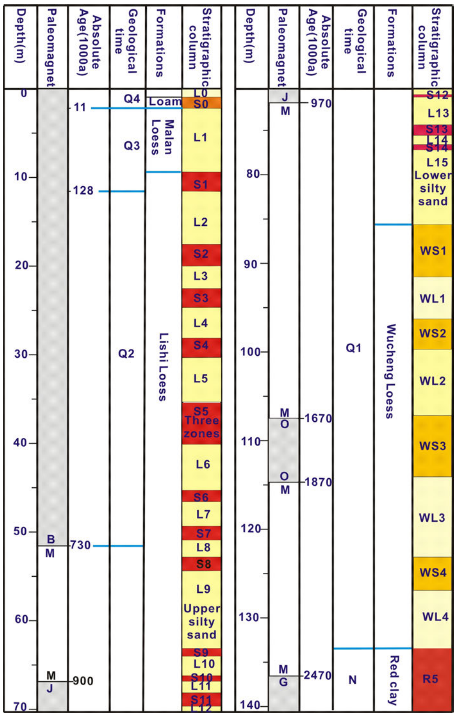


Fig. 13 Phenomenon of entrainment in loess landslides

2. Loess-Paleosol Profile (11:00 a.m. - 12:00 p.m.)

The loess–paleosol sequence constitutes a detailed record of cool-dry and warm-wet cycles that occurred over the past 2.5 Ma in the Chinese Loess Plateau. On the loess slopes at the south bank of the Jing River, there are several good outcrops of loess strata revealing a continuous loess–paleosol sequence from the Modern deposited loess L0, loam S0 (0-11 kyr) to L9 loess. Fig. 14 is the standard loess profile in Luochuan founded by prof. Liu Dongsheng. In this field trip, participants will visit the profile close to the landslide site (Fig. 15) which is well correlated with the standard profile.



Index beds

S0 S1 S5 L9 L15

Main age boundaries

Q4 0-11 ka L0-S0 Holocene

Q3 11-128 ka L1-S1

Q2 128-730 ka L2-L8 Pleistocene

Q1 730-2470 ka S9-WL4

Stratigraphic Formations

Modern loess L0

Loam S0

Malan loess formation L1

Lishi loess formation S1-L15

Wucheng loess formation WL1-WL4

Red clay —Late Tertiary

Fig. 14 A typical geological cross-section of loess-paleosol sequence at the south bank of the Jing River

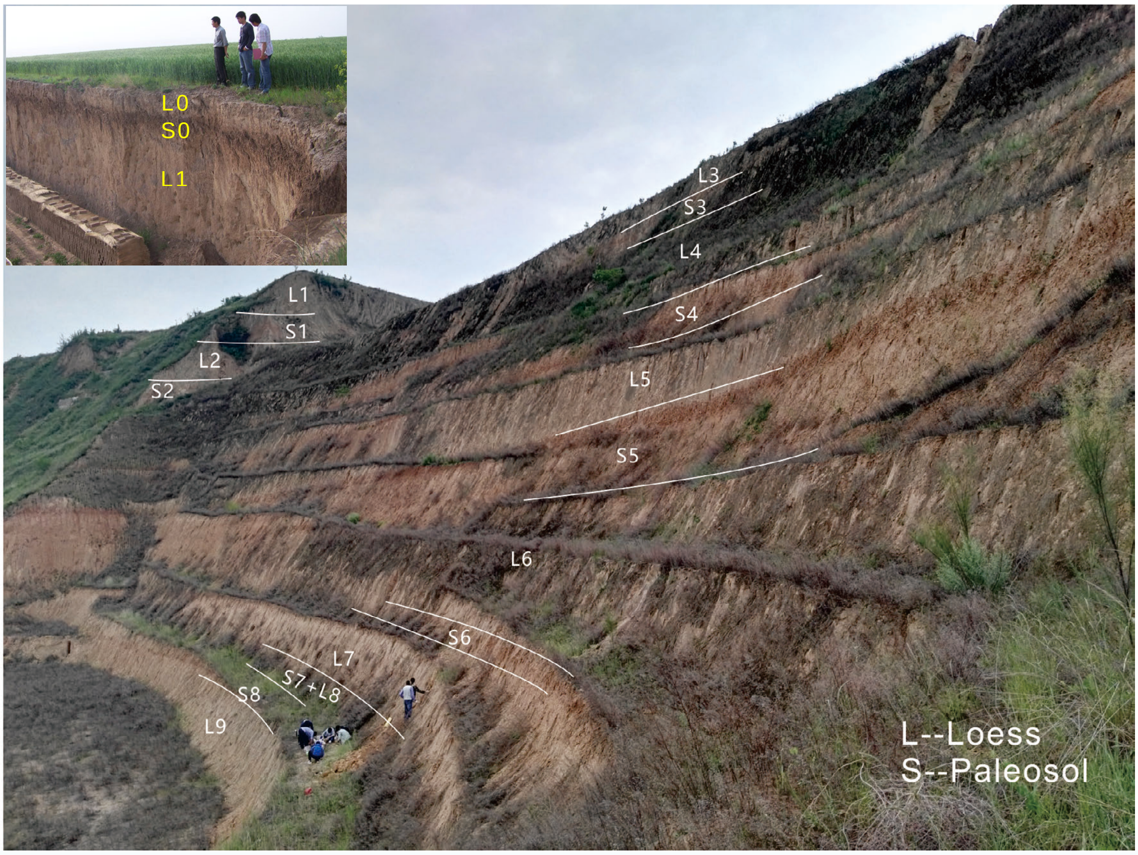


Fig. 15 Loess-paleosol sequences on the north side of Xianyang loess highland

3. Terracotta Warriors of the First Chinese Emperor (Qin Shihuang)

Emperor Qin Shihuang's Mausoleum Site Museum (Fig.16) is the largest on-site museum in China. It displays the Terracotta Warriors & Horses (Fig.17), which are known as the eighth wonder of the world, and the First Emperor's Mausoleum Site Park. This is the Mausoleum of Emperor Qin Shihuang, the First Emperor of Chinese history. It is the best-preserved, largest, and richest buried mausoleum in Chinese history. The construction of the mausoleum lasted 38 years and more than 700,000 laborers were conscripted, and its scale far exceeds the mausoleums of the kings of the pre-Qin era. For more than half a century, over 300 burial pits, burial tombs, and sites of the buildings have been discovered by the archaeologists within the protection scope of Emperor Qin Shihuang's Mausoleum. These burial pits and burial tombs were constructed in strict accordance with the ritual system of "treating the dead as they were alive". The total area of the mausoleum complex is 45.59 square kilometers, which fully embodies the features of Emperor Qin Shihuang's Mausoleum: large in scale, rigorous in layout, and rich in burial objects.

Fig. 16 Aerial view of the Chinese First Emperor (Qin Shihuang) Mausoleum

Fig. 17 Terracotta Warriors & Horses and the Bronze Chariots & Horses of the Chinese First Emperor (Qin Shihuang) Mausoleum

Appendix

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- Peng, J.B., Wang, S. K., Wang, Q. Y., Zhuang, J. Q., Huang, W. L., Zhu, X. H., Lang, Y. Q., Ma, P. H. 2019. Distribution and genetic types of loess landslides in China. Journal of Asian Earth Sciences, 170, 329-350.

Tentative programme:

1st Day Program-September 26, 2023

8:46: departure from Chengdu by railway (G2236, arrive at 12:20)

14:30: Yuhuazhai Ground Fissure

15:30: Qingliangshan Park Ground Fissure Monitoring Site

16:40: Xiying Road Ground Fissure Monitoring Site

17:40: visit the Xi'an City Wall

2nd Day Program-September 27 2023

8:30: Jingyang Loess Landslide

11:00: Loess-Paleosol Profile

12:00: Lunch Break

14:00: visit the Terracotta Warriors of the First Chinese Emperor (Qin Shihuang)

18:00: Arrive at Xi'an