THE XIV CONGRESS OF THE INTERNATIONAL ASSOCIATION FOR ENGINEERING GEOLOGY AND THE ENVIRONMENT

Field Trip 4

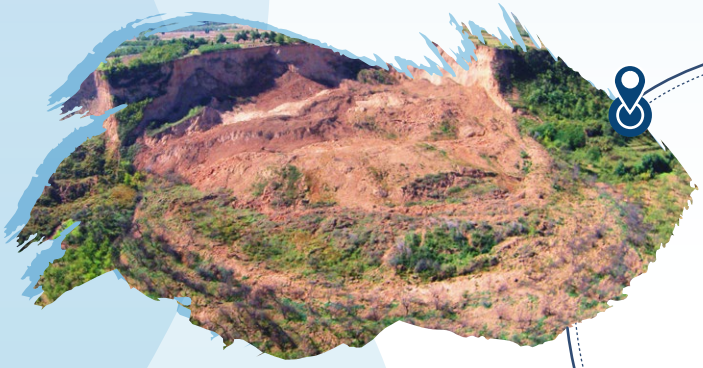
Urban Ground Fissures and Loess Landslides

Xi'an Ground Fissures

A geological hazard that has plagued the ancient city of Xi'an for nearly 100 years. There are 12 ground fissures that traverse the entire city, with a total length of over 150 km. One of the most influential and challenging urban geological hazards in China.

Xi'an City Wall

Spanning over 600 years of history. The oldest and best-preserved city wall in China. Despite being intersected by multiple ground fissures, it still stands tall. Let's see how engineering geology contributes to the protection and reinforcement of ancient architectural heritage.



Jinyang Nan Plateau Loess Landslide Group

The most typical irrigation-induced loess landslide group on the Loess Plateau in China. A natural experimental field for studying loess landslides. The most classic continuous loess stratigraphic profile on the Loess Plateau.

Lishan Landslide and Terracotta Warriors

Lishan landslide prevention and control - a representative project of international cooperation. Post-earthquake restoration of the Terracotta Warriors - protection of ancient terracotta cultural relics in loess. The Terracotta Army is a collection of terracotta sculptures depicting the armies of Qin Shi Huang, the first emperor of China.

Date:
September 26th, 2023, 8:46 - 18:00 (full day, lunch not included, accommodation included);
September 27th, 2023, 8:30 - 18:00 (full day, lunch included, accommodation included)

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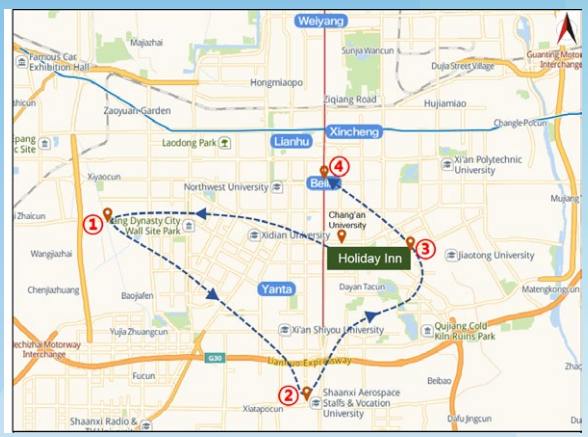


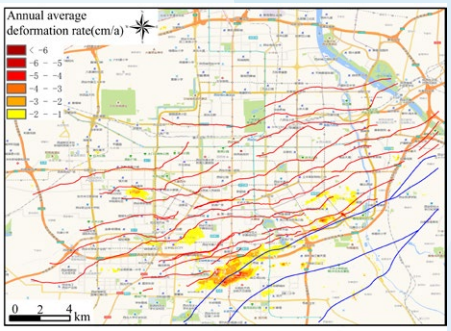
Field Trip Itinerary fo Day 1:
① Yu Huazhai Ground Fissure;
② Liangshan Park Ground Fissure F12 Monitoring Station;
③ Xiying Road Ground Fissure F7 3D Automatic Monitoring Station;
④ Xi'an City Wall Pathological Conditions

Field Trip Itinerary for Day 2:
① Jingyang County Loess Landslide;
② Loess-Ancient Soil Profile;
③ Lunch Location;
④ Lishan Landslide and Terracotta Warriors Cultural Heritage Restoration

Details of the Field Trip 4 Day 1

Xi'an Ground Fissures - City Wall Pathological Conditions

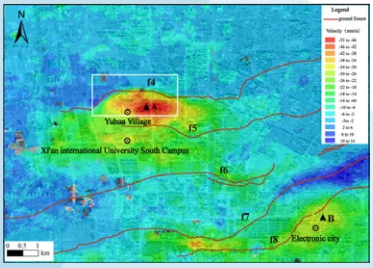
The field trip team will visit typical ground fissures and their monitoring stations in the urban area of Xi'an, as well as the pathological conditions of the Xi'an City Wall and its monitoring stations. There are a total of 12 ground fissures in the urban area of Xi'an (as shown in the diagram below), with a trend of northeast to east and a dip angle ranging from 70° to 85°. Through a day of visits, we will gain an understanding of the significant adverse impacts caused by the activation of urban ground fissures on ground stability and engineering structures.



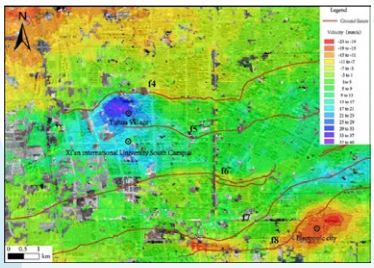
Distribution of Ground Fissures and Ground Subsidence in Xi'an

I. Yu Huazhai Ground Fissure

The Yu Huazhai ground fissure is located on the edge of the ground subsidence center in Yu Huazhai Village, Xi'an. It was first formed in 2010 and has a total length of approximately 2.3 km. This fissure belongs to the western section of the Xi'an F4 ground fissure. According to leveling and InSAR monitoring results, from 2013 to 2016, the maximum vertical displacement of the F4 ground fissure increased from 300 mm to 650 mm. The maximum annual vertical activity rate reached 87.5 mm/year (as shown in the diagram below), causing severe deformation and damage to roads and buildings, and affecting the normal operation of Xi'an Metro Line 3 (as shown in the diagram below).



Annual average subsidence rates in the Yu Huazhai area from 2018 to 2020



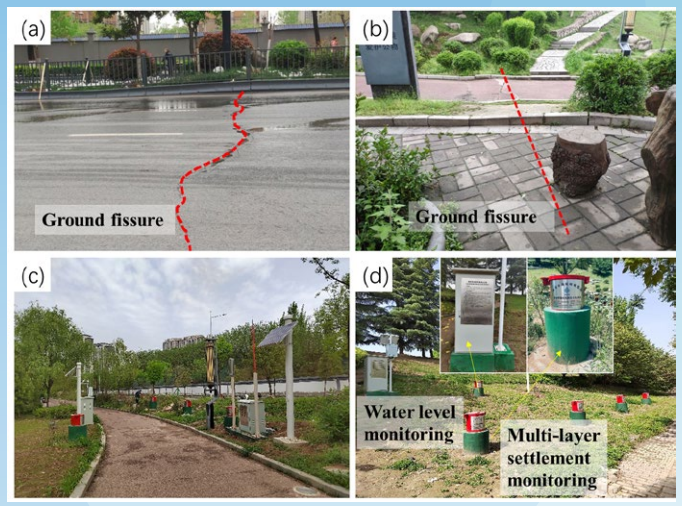
Xi'an F4 Ground Fissure and Nearby Ground Subsidence Rates (2015-2020)

After November 2018, the groundwater level rose by nearly 30 meters in a span of 5 months, almost synchronously with the ground rebound (as shown in the diagram below). From the water level monitoring profile of the F4 ground fissure, it can be observed that the relative deformation on both sides of the fissure decreased as the groundwater level rose after

Road displacement and building cracks caused by the F4 ground fissure

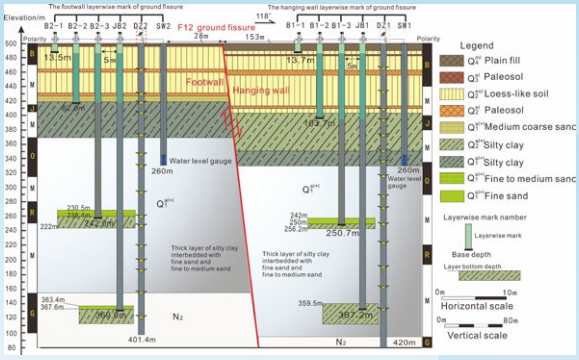
F12 Monitoring Station at Qingliangshan Park Ground Fissure

The F12 monitoring station for the ground fissure at Qingliangshan Park is located on the north side of Qingliangshan Park in Chang'an District, Xi'an (as shown in the diagram below). It was funded by the Xi'an Municipal Bureau of Natural Resources and Planning, with design and construction carried out by Chang'an University. The horizontal leveling profile and layer target monitoring are implemented by the Shaanxi Xi'an Ground Fissure Ground Subsidence Field Scientific Observation Station of the Ministry of Natural Resources. By monitoring the ground subsidence of the ground fissure zone and its upper and lower blocks, the compression between different depth soil layers, and the dynamic changes in groundwater level, scientific data can be provided for the current activity status, affected areas determination, causative mechanism analysis, and disaster prevention and control of ground fissure ground subsidence.



The F12 ground fissure and layer markers (positions A, B, C, D as shown in the diagram above)

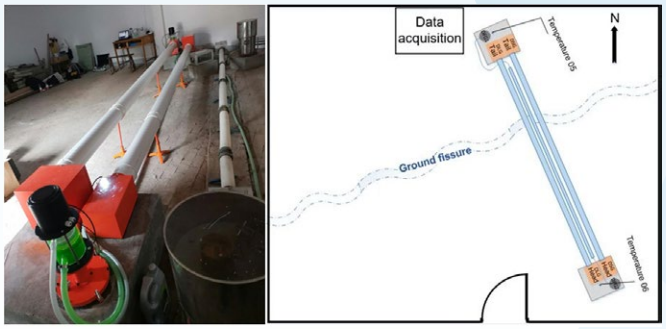
The ground subsidence monitoring station for the ground fissure is located on the north side of Qingliangshan Park. The leveling monitoring profile spans the construction of the F12 ground fissure and includes 6 benchmark points and 2 sets of ground subsidence layer markers. Each set of layer markers is located on both sides of the ground fissure and consists of 4 single-point layer markers, 1 water level monitoring hole, and a single-hole multi-layer monitoring hole.



Layer Markers for Ground Fissure Monitoring at Qingliangshan Park

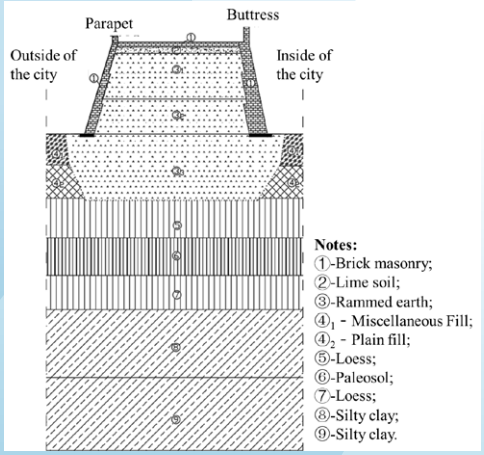
F7 *Three-Dimensional Automated Monitoring Station for Xiying Road Ground Fissure*

The Xi'an ground fissure three-dimensional automated monitoring station is located at Xi'an Engineering Technology School on Xiying Road. The design and construction unit is the Shaanxi Geological Environmental Monitoring General Station, and the GNSS monitoring is undertaken by Chang'an University. Through three-dimensional automated monitoring, the horizontal torsion, horizontal strain, and vertical relative subsidence between the upper and lower blocks of the ground fissure are observed separately. In addition, a set of horizontal monitoring points for ground fissure, a set of ground subsidence layer monitoring stations, and a set of GNSS monitoring stations are set up outdoors at the automated monitoring station.



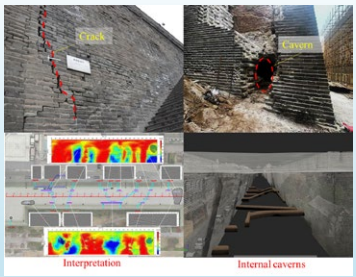
Three-Dimensional Deformation Monitoring System for Fault Zones

Damage of Xi'an City Wall



Profile Schematic of the Wall Structure in the Yongning Gate Area of the Xi'an City Wall

The Xi'an City Wall is constructed using an external brick and internal soil structure. During its construction, a wider trench was first excavated, and then the soil layers were compacted in layers within the trench. Below the compacted soil layers are the original accumulated loess, ancient soil, and clayey silt (as shown in the diagram below).



Xi'an City Wall Damage and Geophysical Exploration

Monitoring and Early Warning System for Xi'an City Wall Damage

Due to its age, climate, groundwater, and the combined impact of engineering activities, the Xi'an City Wall has experienced localized cracking, subsidence, and other damages. In response, the Mechanical Industry Survey and Design Research Institute Co., Ltd. has been involved in the monitoring of the city wall since the 1990s. Through the use of conventional instruments, Internet of Things (IoT) monitoring, geophysical exploration, and other methods, comprehensive monitoring covering a total length of 13.74 kilometers of the Xi'an City Wall has been implemented (as shown in the diagram below). The monitoring includes wall deformation, groundwater, vibrations, voids, and other aspects. Based on specialized research, four-color warning thresholds for deformation monitoring of the Xi'an City Wall have been determined, and a four-color warning monitoring system has been established, laying the foundation for proactive protection of the Xi'an City Wall.

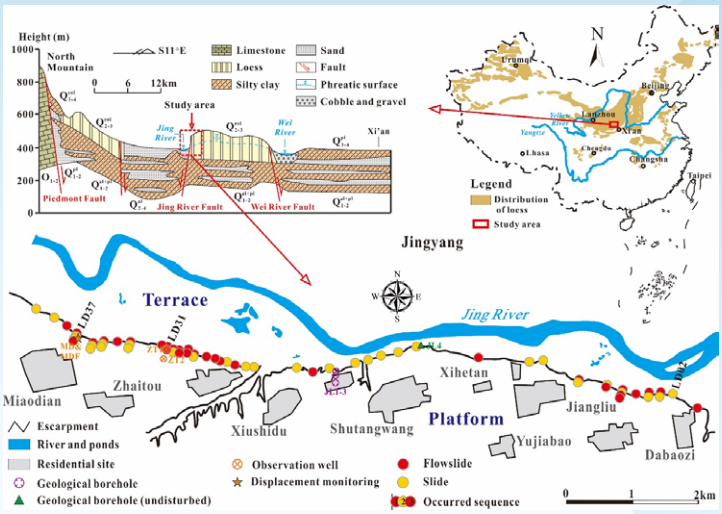
Day 2

Jingyang Loess Landslide and Profile - Lishan Landslide

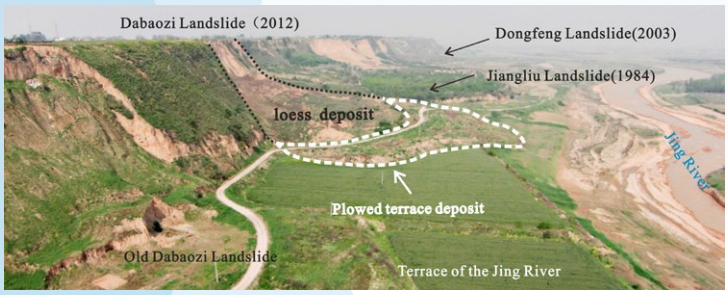
The Loess Plateau in China is the birthplace of Chinese civilization, and loess is a wind-deposited sediment widely distributed in the Loess Plateau. It has a loose honeycomb-like semi-stable structure that is prone to collapse when wet. Therefore, loess landslides are widespread in loess areas. Additionally, the Loess Plateau is also famous for the terracotta warriors and horses made primarily from loess, but the restoration of these artifacts remains a challenging task. On this day of the field trip, you will visit the Jingyang loess landslide caused by agricultural irrigation, the loess-paleosol sequence geological profile, the Lishan loess landslide, and the restoration of the terracotta warriors and horses. Through these visits, we will gain a deeper understanding of the characteristics and mechanisms of loess landslides, as well as the challenges in restoring loess-fired cultural relics.

Jingyang Loess Landslide

The loess terrace on the south bank of the Jing River in Shaanxi Province is one of the most representative areas prone to landslides in the world. Since the beginning of agricultural irrigation in 1976, a total of 62 severe loess landslides have been recorded (as shown in the two figures below). These landslides have caused significant economic losses and casualties. Among these landslides, the Jiangliu landslide in 1984 buried a small village and resulted in 20 deaths. In the extremely dry climate of northwest China, irrigation is necessary to transform natural loess into farmland. However, long-term irrigation disrupts the natural water cycle of the Loess Plateau. With ongoing irrigation activities, the groundwater level in the slopes at the edge of the plateau gradually rises, reducing the stability of the slopes and eventually leading to these landslides.

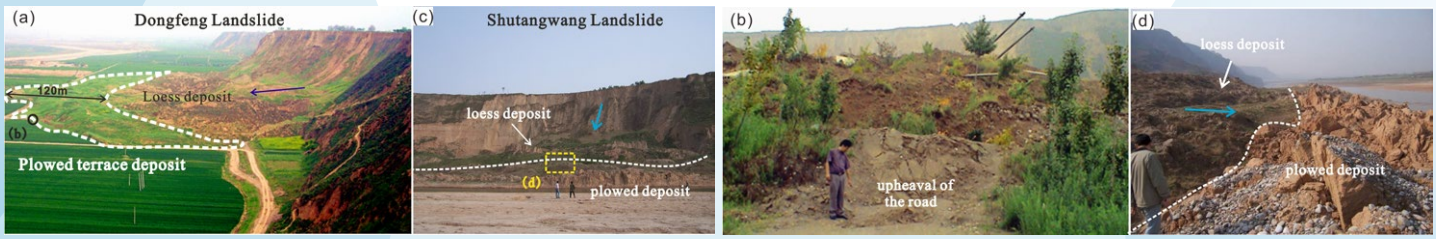


Location of the Loess Landslide on the South Bank of the Jing River



Aerial view of the landslide group on the south bank of the Jing River

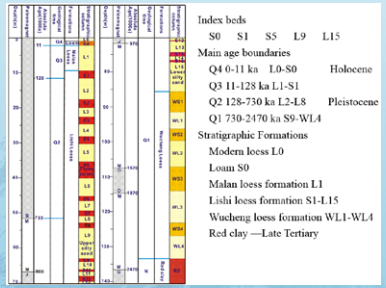
There are four typical loess landslides in this area: Dabaozi landslide, Jiangliu landslide, Dongfeng landslide, and Shutangwang landslide. They exhibit three notable characteristics: (1) they develop on steep loess slopes at the edge of the loess terrace; (2) they have a high kinematic energy and slide rapidly; (3) they violently impact the saturated sandy soil of the Jing River terrace, causing liquefaction and entrainment of the saturated sandy soil (as shown in the figure below).



Entrainment phenomenon in loess landslides.

Loess-Paleosol Profile in Jingyang County

The loess-paleosol sequence is a detailed record of the cold-dry and warm-wet cycles in the Loess Plateau of China over the past 2.5 million years. On the loess slopes on the south bank of the Jing River, there are several well-exposed layers of loess, revealing a continuous loess-paleosol sequence from the modern deposit of loess (L0) to the ancient paleosol (S0, 0-11,000 years) and then to the loess (L9) (as shown in the first figure below). During this field trip, you will visit a profile near the landslide site (as shown in the second figure below), which has a good correlation with the standard profile.

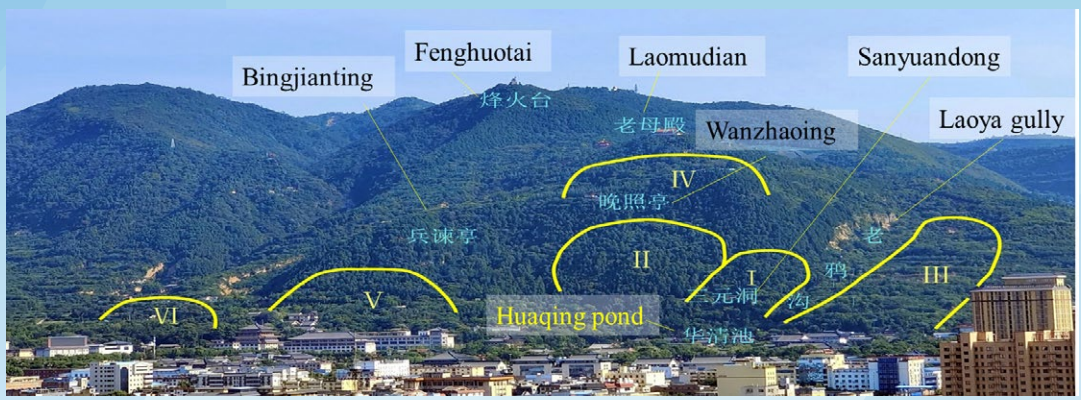


Typical Geological Profile of the Loess-Paleosol Sequence on the South Bank of the Jing River (Professor Liu Dongsheng)

Loess-Paleosol Sequence on the North Side of the Xi'an Loess Plateau

Lishan Landslide

The Lishan landslide is located on the northern slope of Lishan within the Huashan Palace scenic area. It stretches approximately 220m east of Donghuayuan and 150m west of Mudangou, reaching north to Huashan Pool and south to 50m north of Laomudian, covering an area of about 0.5km2. The Lishan landslide poses a direct threat to the safety of the Huashan Palace scenic area, the Railway Ministry Lintong Sanatorium, Lintong Lixing Cableway Co., Ltd., Huayuan Half-Mountain Hot Spring Hotel, and the eastern military camp area. Based on the landform morphology, deformation characteristics, and the potential harm to Huashan Pool, the landslide is divided into six zones: I, II, III, IV, V, and VI (as shown in the figure below).



Lishan Landslide and its Zoning

Terracotta Warriors of the First Chinese Emperor (Qin Shihuang)

Emperor Qin Shihuang's Mausoleum Site Museum (The following first picture) is the largest on-site museum in China. It displays the Terracotta Warriors & Horses (The following second picture), 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 labors 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 following the past ritual 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.

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

Terracotta Warriors & Horses and the Bronze Chariots

Horses of the Chinese First Emperor (Qin Shihuang) Mausoleum

Register for the trip

	Date	Route	Topic	Price
No.1	9.26	Dujiangyan & Yinxiu	Water conservancy projects, earthquake disasters, and geological hazards	120 USD
No.2	9.26-27	Luding	Co-seismic landslides and selection of major project sites	300 USD
No.3	9.26-27	Badong & Sanxia	Three Gorges Water Conservancy and Hydropower Project and reservoir landslide disasters	420 USD
No.4	9.26-27	Xi'an	Urban ground fissures and loess landslides	350 USD

For more information or register for the trip, please visit
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If you have any question or need any help,
please feel free to contact *info@iaeg2023.org*