Recognition of natural deformation during the excavation of ancient remains and tombs is important for tracing or enriching historic and prehistoric deformation records. Recently, the earthquake agencies, in cooperation with the cultural relics and archaeological institutions, conducted a special excavation investigation to the Gaixia remains archaeological scene in Guzhen, Anhui Province. Faults and fissures were discovered there, which, as demonstrated by the preliminary study, are the traces of two stratum dislocation events of the same period, at a time approximately corresponding to the late Dawenkou culture stage. This work may improve the recognition of earthquake relics in the cultural stratum of humanity in the East China region.

Key words: Gaixia; Archaeological; Dawenkou culture; Seismic deformation

INTRODUCTION

In recent years, with the large-scale economic construction in Eastern China, such as highways, high-speed railways and other major projects under construction, rescue excavations have been conducted at a large number of ancient sites and tombs, which made it possible to identify and trace the natural deformation history over thousands of years in Eastern China. With the opportunity for large-scale archaeological and prospecting excavation, taking full advantage of archaeological fine chronostratigraphic technology, the earthquake departments, in collaboration with archaeological departments, collected and catalogued the Quaternary deformation traces occurring in the prehistoric and historic cultural strata and obtained tectonic activity information.
from factual observation data in each site. In view of this and in the light of new theories on the behavior of tectonic activities, seismologists and archaeologists conducted an overall investigation of archaeological sites in the Jianghuai region located between the South China block and North China block under the sponsorship of the Scientific Research Special Project of Earthquake Study (200808064) and the Science and Technology Key Problem Plan Project of Anhui Province (08010302204). This paper reports the progress of special excavations on the Gaixia archaeological site in Haocheng Town, Guzhen County, Anhui Province.

1 THE BASIC FEATURES OF THE REMAINS

The Gaixia Remains are located on the east of the Tancheng-Lujiang fault where an earthquake of magnitude $M_s 5.5$ occurred in 1829. On its west is the Guzhen-Fengtai fault where an earthquake of magnitude $M_s 6.5$ in 1831 in Fengtai and an earthquake with $M_s 5.0$ in 1979 occurred in Guzhen. On its south is the NW-trending Guohe fault where an earthquake of $M_s 6.0$ occurred in Guoyang in 1481 and $M_s 5.5$ occurred in 1525 in Bozhou (Fig. 1).

![Fig. 1](image)

A sketch of regional geology and seismicity of the Gaixia remains area

The Gaixia remains are located at Bawangcheng village in Haocheng town, 24 km east of Guzhen county, the central battlefield in the conflict between the Chu and Han States in ancient China and the site of the decisive battle of Gaixia of 202 B.C. With an area of about 150 thousands square kilometers, there are earth walls around the main part of the remains which are 2m to 3m above the outer surface. The inner terrain is higher on both sides and lower in the middle. On the west and north sides of the remains is the Tuohu River which flows from the west through the western remains swerves at the northwest corner and finally flows to the east along the north side of the remains.

In the first half of 2007, the Cultural Relics and Archaeological Institute of Anhui conducted a thorough exploration and excavation on the “Gaixia Battle” remains and the moat surrounding it. The existence of cultural relics from the two periods has basically been proven; the late
Neolithic and Qin–Han Dynasties. Important cultural relics such as city walls, city gates, moats, roads, drainage systems, beacon towers, wells and ash pits were found belonging to the Late Dawenkou Culture period. In addition, the rich relics of the Qin–Han Dynasties indicate the former prosperity in these dynasties. Both the cultural relics of the late Neolithic and Qin–Han Dynasties indicate that there had been a considerable extent of layout planning before these two periods of urban building.

In order to clarify the specific age, the floor width and construction methods of the ancient city wall, archaeologists excavated another trench (serial number: 2008GGTG3, and TG3 for short) in March 2008, with a length of 40 m and width of 3 m, about 70 m away from the excavation. The trench extends from the city wall to the inner moat, which completely reveals the whole section of the city wall and some of the cultural layers in the inner wall.

According to the analysis on the current situation of the excavation, the Gaixia city wall was built mainly using heaping and local tamping methods. In addition, during the fine dissection on the city wall, archaeologists found that the city wall of the Han Dynasty was built directly on the earlier city wall. Tamping layers on the wall are clear, including 8 layers in the earlier city wall relics. This means the wall was built in two periods, the prehistoric Late Dawenkou Culture period and the Han Dynasty.

Just inside the Dawenkou Cultural layer on both walls and the bottom of TG3, seismologists and archaeologists discovered faults and fissures (Fig. 2).

![Plan of the TG3 prospecing trench fault and fissure of the Gaixia remains](image)

**Fig. 2**

Plan of the TG3 prospecing trench fault and fissure of the Gaixia remains

2 DISCOVERY AND ANALYSIS OF THE TENSION-SHEAR FAULT IN THE CULTURAL LAYER

When excavating to the grey-black ash layers on the city wall, seismologists and archaeologists found fault dislocation phenomena. According to this clue, the surface of the layer was carefully scraped for further identification and confirmed the range of fault dislocation.
The dislocation is located in the west segment of TG, about 15.4m to the west wall. According to the change of quality and color of the soil and the slice analysis of the samples from the dislocation site, it is confirmed that the dislocation is under the 17th layer of city wall (numbered “wall layer 17” where the “wall” means the heap-up of the city wall remains. “17” means the 17th layer of the wall) and the dislocation extends downward from layer 18 including a raw soil layer (undisturbed soil). A fissure with width 2mm ~ 4mm can be seen on both the plane and the profile. The fault plane is very clear on the bottom of the soil layer gradually thinning out upwards in layer 17. The soil in the fissure is grey clay and is different from the color of soil layer on its sides symmetrical in thickness and tallying completely with each other. The western side of the fault plane is 3.8cm higher than the eastern side. The fault plane strikes 353° dipping steeply to the east with an angle of about 60° and comparatively straight with a slight curvature. The highest point of the fault plane on the north wall is 1.79 meters from the ground surface and extends into the raw soil layer. The highest point on the south wall is 1.68 meters to ground surface and also extends downward into the raw soil layer. From layer 18 downwards 12 layers (excluding the raw soil layer) on the north wall are offset; the fault plane penetrates the layers of 18, 33, 36, 37, 39, 40, 41, 47, 54, 51, 68, and 70 of the heaped-up wall as well as the SN-trending narrow channel G6 (G represents channel the same hereinafter). The offset on the north part of the trench shows normal faulting with the hanging wall falling (Fig. 3). From layer 18 downwards to raw soil layer a total of 10 layers (excluding raw soil layer) on the south wall were also offset by normal faulting with the hanging wall falling (Fig. 4).

![Fig. 3](image)

**Fig. 3**

Tensile–shear fault on the northern wall of trench (the left is photo of the northern wall, the right is sketch of the northern wall viewing N)

The linear fault outcrop was found at the bottom of the trench by southward and eastward overlooking photography which shows a clear color band in the NNW-trending extension in the raw soil layer. The fissure is narrow with a width of about 2mm ~ 3mm. The irregular light color soil on the southwest side extends to the east and is interrupted by the fault but the corresponding part has not been found in the eastern side (Fig. 5). Accordingly it is inferred that a substantial horizontal displacement has occurred on the fault.
3 DECEPTION AND ANALYSIS OF FISSURE IN THE CULTURAL LAYERS

The fissure in TG₃ was discovered at a distance of 19.8m ~ 20.2m to the west wall with a width of 4cm trending NS in the middle of TG₃ found in wall layer 47. The fissure opening on the north wall is at the top of K₄ (K represents the pit) and in wall layer 42 which penetrates the wall layers of 42 43 45 47 (49) 48 52 53 55 60 61 and 66 and runs downwards into the raw soil.
layer. Running upward in $K_4$, it bifurcates into the east and west branches with a light-colored fissure filling containing sand in a flame-like arrangement (Fig. 6). The fissure is about 1.9 m ~ 2.1 m below the ground surface with non-uniform width and crooked strike of plane and the general strike of the fissure is about 12° extending nearly vertical under the ground surface. The fissure opening on the south wall is located at the top of $K_4$ and in wall layer 42 which penetrates downwards into the layers of 42, 43, 44, 45, 46, 47, 49, 50, 55 and 61 ending in layer 66 in the soil. Running upwards in $K_4$, it shows upward spewing flow-like lineaments as marked by a light-colored soil layer composed mainly of silty fine sand (Fig. 7).

The layers on the two sides of the fissure are asymmetrical. Taking the north wall as an example (Fig. 6), the wall layers 55 and 60 on the west side of the fissure suddenly disappeared and formed a steep fault section; but their corresponding layers 48, 52 and 53 on the east side have similar soils in color and texture to layer 47 which suggests that maybe they were built in the same period but later than layer 55 and 60. From layer 62 downwards the layers on both sides of the fissure basically correspond but the fissure traces are obvious. There is a large ground deformation near the fissure and the surface of the raw soil layer has caved in obviously; the bottom of the soil layer below wall layer 66 on both sides of the fissure on the south wall correspond to the mid-upper layer (47th layer) but the soil properties in the middle show a large difference (Fig. 7). It indicates that the fissure may have formed with the process of the upward soil migration.

The fissure on the north wall ends in layer 8 and the 17th layer (layer 18 is missing) is directly overlying layers 25 and 26. Though the two walls are artificially heaped up layers and the distribution of some layers is inconsistent and difficult to compare precisely it is clear from Fig. 8 that the fissure ends in the bottom of wall layer 28. If extending layer 28 westward the top plane will be under layer 18 so the fissure is certainly earlier than the fault on the west side (the latter penetrates layer 18 and ends in layer 17).

Based on the above reasoning the fault dislocation of the heaped up wall and the fissure deformation are all caused by geological processes but their occurrence time varied. The fault dislocation occurred in the period when layer 18 was the surface of the wall but the fissure occurred when layer 42 was the surface of wall so the time of the fault dislocation is later than the fissure.
The fault and fissure appear in the same culture layer, both featured with tension deformation and occurring in the culture layer of plastic clayey soil. Thus they should be the remains of fast rupturing and in particular, there are traces of upward movement of sand along the fissure (e.g., the flame-like lineament as mentioned above) as a typical mark of stick-slip motion (Sibson, 1983; He Yongnian et al., 1985; Yang Zhu'en, 1986; Yao Daquan, 2004). According to the combination of the cultural relic pieces in the culture layer, this culture layer belongs to the Late Dawenkou Culture period. However, they still have differences: first, the former results from tensile shear, shown as a tensile fault and the latter results from stretching, shown as a tensile fissure. Secondly, they end on the bottoms of different overlying cultural layers. The fissure is younger than the fault and they may represent two stick-slip events. The specific times are pending further study.

4 CONCLUSION AND DISCUSSION

In conclusion, the two kinds of natural deformation phenomena, faults and fissures, discovered in the cultural relics layers belong to the Late Dawenkou Culture period but the fissure formed earlier than the fault. Observation of the fault and fissure section plane shows the characteristic of fast deformation which represent the tectonic strata deformation of two stages.

Analysis of the seismogeological environment of the remains shows that the remains lie on the NNE-trending Tancheng-Lujiang fault. According to historical records, several earthquakes of \( M_s 5.0 \sim M_s 6.0 \) occurred in the vicinity of the fault. Our discovery of the prehistoric earthquake remains enriches the information of neotectonic activity in this area.

In East China where Anhui Province is located, reliable earthquake records of \( M_s > 5.0 \) can only be traced back to 670 years ago (Huang Weiqiong, 1994) which is far away from the target of a complete time sequence of earthquakes needed for earthquake prediction. The above discovery and understanding would have an obvious pioneering and instructive significance for revealing the deformation history and deformation characteristics since the late Neolithic Age and the objective
Fig. 8

The fault and tensile fissure on the northern wall. Above is a photo of the northern wall viewing towards NW, below is a sketch of the northern wall.

estimation of the seismicity and seismic trend of the relevant regions. It is also significant for promoting the cooperation of multi-disciplines and integrating resources to explore the information extraction methods for the research of tectonic activity patterns in the Central and Eastern China areas.

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About the Author

Yao Daquan, born in 1956, is a research professor at the Earthquake Administration of Anhui Province. He received his Master’s degree in Tectonic Geology from Hefei Polytechnic University in 1987. He is engaged mainly in the research of seismo-geology and its applications. He has systematically proposed the theory of microscopic indicators of stick-slip and creep-slip in the deformation materials of active faults based on precise comparison. He is now focusing on differentiation and study of pre-historical earthquakes and paleoearthquakes. E-mail: daquany@aheq.gov.cn