Environmental archaeology of the Dachang region in the Daning Valley, the Three Gorges reservoir region of the Yangtze River, China

ZHANG Yun† & ZHU Cheng

1 State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China;
2 School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210093, China

Environmental archaeology of archaeological sites on both sides of the Dachang section in the Daning River, the Three Gorges of the Yangtze River, shows that riverbed evolution has a great influence on the distribution of archaeological sites during the prehistorical and historical period, and it restricts human activity and the development of ancient culture. Field investigation, dating data, paleocurrent analysis of 100 gravels on the riverbed and archaeological excavation reveal that the riverbed of the Dachang section developed in the Shuangyantang region during the early stage, after about 30 kaBP it shifted westward gradually and reached the present place. Along with the westward shift, the focus of ancient culture changed for several times. In the Western Zhou Dynasty’s period, the east riverbank of the Daning River was the main residential area. During the Han Dynasty, along with the westward shift, the living space of ancient people was no longer confined to the east riverbank and the focus of culture moved westward. Then the Zhangjiawan site became the main dwelling district. In the late Han Dynasty, the villages were flooded and the ancients had to immigrate to a high place. Tombs of the Han and the Jin Dynasties outcropped on the flood plain of the east bank because their surface sediments were eroded by several flood events and the westward shift of the riverbed.

The interactive influences between environment evolution and human civilization since Holocene are one of the important research items of modern human civilization. Studies on the law and mechanism of the interactive influences have great significance on the harmony of the man-earth relationship not only at present but also in the future. Moreover, it is one of the effective methods to reveal the interactive influence between environment evolution and human civilization and the cause and occurring law of abnormal flood events. Now the cause and occurring law of abnormal flood events, such as aridity, flood, earthquake, volcano, landslip, desertification and soil and water erosion, and the impacts on human activity have been discovered and approved by environmental archaeology of some archaeological sites.

A lot of the Neolithic sites of the Yangtze River Basin provide an extremely good condition for the research of environmental archaeology. Zhu et al. and Yu et al. revealed the relationship between the rise and fall of ancient civilization and the fluctuation of sea level.
and flood using various substitutive indices. Based on the environmental archaeology data of the Chengtoushan sites in the middle reaches of the Yangtze River, Yasuda et al. discussed the relationship between Holocene climate change and the rise and fall of ancient civilization in the Yangtze River\cite{9}. Zhou researched the varying tendency of the water level of the Jingjiang River according to the elevation height of archaeological sites\cite{10,11}. When compared with the middle reaches of the Yangtze River and the Yangtze Delta, inadequate data of archaeological sites in the Three Gorges of the Yangtze River do not contribute to the establishment of an integrated system because a lot of sites are still at the stage of excavation. Although the researches on environmental archaeology are still in the starting phase, there are more exploratory achievements than ever. For example, Wang discovered five flood events appeared in this region since Holocene on the basis of the comparison of stratum at the Zhongbaodao sites with many silty sand layers, excavated utensils, stone inscriptions, tablet inscriptions, ancient buildings and historical record\cite{12}. Zhu et al.\cite{3,13} have published several articles about environmental archaeology in the Three Gorges of the Yangtze River under the support of the National Natural Science Foundation of China.

Originated from the Xintianba of Gaolou village, the south piedmont of Daba Mountain, Wuxi County, Chongqing City, the first section of the Daning River is a narrow and crook water course, and then it enters into the Small Three Gorges at the Dachang section. Finally it flows into the Yangtze River from Wushan County. At the middle stage of Wushan and Wuxi County, Dachang Town was located in the broad area of the Daning River\cite{14}. Being a famous ancient town with a history of 1000 years, it was ever the base area of Zhang Xianzhong who was one of the Chairmen of the peasant insurrectionary in the last phase of the Ming Dynasty. On both sides of the river were the Zhangjiawan site and Shuangyantang site. Dachang Town was situated in the interacting zone of the Eastern Daba Mountain, eastern Sichuan Province and the fold belt of Sichuan, Shanxi and Hubei provinces. As a result of the interaction of exogenic and endogenic agents, rugged topography formed and the flat area only developed in the valley or the large karstic low-lying with the relative height less than 20 m. The main soil type is purplish soils, developed in purplish red sandstone and shales. The vegetation is subtropical and temperate vegetation. It is subtropical humid monsoon climate with mean average temperature of $15-16{}^\circ\text{C}$ and annual precipitation of $1000-1300$ mm. Rainstorms often occur in summer and soil is eroded by flood, resulting in a lot of landslips and landslides\cite{15}.

Authors have ever made some researches on environmental archaeology of the Zhangjiawan site and Shuangyantang site, located on both sides of the Daning River, the Three Gorges of the Yangtze River in 2000 and 2001. And some papers have been published\cite{16-18}. In this paper, in terms of geography, archaeology and history, the relationship between environmental evolution and human civilization can be extracted in combination with two sites, and the relationship between fluvial landform and archaeology culture is particularly discussed.

1 Distribution of archaeological sites in the Daning River

Fifty-one archaeological sites (Figure 1) were excavated on both sides of the Daning River according to some published literatures of archaeology periodical and monograph and inner literatures from archaeological departments\cite{19-23}\cite{1-3}. They are Paleolithic sites (such as Jiangdongzui site), Neolithic sites (such as Oujialaowu site, Weijialiangzi site and Pipazhou site), sites in the Xia, Shang and Western Zhou Dynasties (i.e. Ba Culture) (such as Jiangdongzui, Pipazhou and Shuangyangtang sites), sites in the Eastern Zhou Dynasty (such as Liujia, Lanjiazhai, Zhangjiawan, Lijiamatou, Jiangdongzui, Oujialaowu, Pipazhou and Zhajialiangzi sites), sites in the period of the Northern and Southern Dynasties (such as tombs of Jiangdongzui, Pipazhou, rock tombs and overhanging coffins on both sides of the Small Three Gorges of Daning River), sites in the Sui

and Tang Dynasties (such as Lanjiazhai and Zhangjiaowan) and sites in the Song and Ming-Qing Dynasties (such as Dachang ancient town, Wushan ancient town, Shuangyantang site, Linjiamatou site, Tujiaba site and Pipazhou sites)\cite{19}.

The upper reaches of the Daning Valley, located at the east edge of the Sichuan basin, are intermountainous valleys, and the middle and lower reaches are the Dachang basin surrounded by the Daba and Wushan Mountain. Hence, it is a close environment with little influence of extreme climate changes, which is suitable for human living. Moreover, being the largest broad valley in the Three Gorges of the Yangtze River, the Daning valley was composed of intermountainous valleys, all levels of platforms and terraces with fertile soil, which provided excellent agricultural environment and habitat for ancients. Furthermore, complex landform also provides a favorable living environment for various animals and vegetation. Accordingly, types of ancient culture were also very abundant from the Paleolithic Age, Neolithic Age, Xia, Shang, Western Zhou, Han and Jin, North and South, Sui and Tang, Song to Ming-Qing Dynasty\cite{19}.

When compared with other regions of the Three Gorges of the Yangtze River\cite{24}, there were more sites in historical times than in the early cultural stage, which concentrated in the middle and upper reaches, especially Dachang Town from Wuxi to Shuanglong County. Secondly, early culture disappeared in these regions, but it was mainly distributed in the lower reaches of the Yangtze River. Thus it can be seen that Neolithic culture and other early cultures only influenced its lower reaches. In addition, the sites in the Daning River were characterized by the adjacent region, similar date and the same cultural meaning. In particular, brown rope figure pottery (or basket figure) with hackle months (typical feature of flat bottom and needle bottom), gray pottery and familiar bronze wares in the Central Plains Area were
excavated at Shuangyantang, Pipazhou, Qili and Luojiayuanzi sites, indicating that a typical culture, Fangguo culture with the characteristics of moltening bronze wares, existed in the Daning Valley. Accordingly, being the north-east channel of the Hanjiang and the Yangtze River, the Daning River had a great influence on culture communication.

2 Study area and methods

2.1 Study area

Zhangjiawan site in the Eastern Zhou and Han Dynasties (west riverbank) and Shuangyantang site and Lijiamatou site (east riverbank) in the Western Zhou Dynasty were located on both sides of the Dachang section of the Daning River.

Zhangjiawan site in the Eastern Zhou and Han Dynasties (31°16′25″N, 109°46′40″E, 142–149 m) was situated at the third team, Xingchun village, Dachang Town, Wushan County, Chongqing City, 20 km south of Wushan County and 1 km southeast of Dachang Town. As one of the important sites in the Dachang Basin, it lies on the first terrace of west riverbank of the Daning River. Strata of the western wall of T911 profile (the first excavation in 2000) (Figure 2) are described as follows. (1) In the 1st layer at depths of 10–15 cm, some modern ceramic shards, remnant ironwares and modern tile shivers were excavated from the chocolate brown cultivated layer. (2) The 2nd layer was 25–35 cm in depth, and it was a brownish red sandy gravel layer with obvious sedimentary rhythm and various subround and subangular gravels in different grain size. The smallest diameter of the fine gravel was 1–2 mm, while the biggest could reach 1–2 cm. Its sedimentary structure was two layers of coarse gravels alternated by three layers of fine gravels. (3) The 3rd layer was 15–20 cm in depth, and it was the slightly hard light red clay boulder alternated by promiscuous coarse sandy gravels with the inclusion of a lot of yellowish green weathered materials. There were various subangular gravels in different grain size bigger than 4 cm or smaller than 1–2 mm. (4) The
4th layer was 10—25 cm in depth, and it was slightly hard brownish yellow promiscuous clay boulder with a certain amount of yellowish green weathered materials and coarse subangular gravels in different grain size of 1—70 mm. (5) The 5th layer was 0—13 cm in depth, and it was an unconsolidated deep brownish red silty sand layer alternated by a few thin particles. (6) The 6th layer was 15—20 cm in depth, and it was unconsolidated brownish red promiscuous clay boulder with various subangular gravels in different grain size, in which the bigger diameter was 7—8 cm, and the smaller one only reached several millimeters. (7) The 7th layer, 10—20 cm in depth, was the brown thin fine silty sand layer, and it had obvious sedimentary rhythm with thin sands on the top and at the bottom and coarse sands in the middle. Subangular and subround gravels prevailed there. (8) The 8th layer was 12—16 cm in depth, and it was light hard grayish red clay with fine gravels, small quantities of tiles and potteries. Porcelains of the Southern Song Dynasty were unearthed in some profiles. Archaeologists thought it was a disturbance sediments layer. (9) In the 9th layer with depths of 10—20 m, there existed a lot of grayish brown ceramic shards containing thin sand, clay grayish ceramic shards with figures mainly of rope, chord and zonal grid stria besides no figures. Tiles were excavated from the black gray clay layer containing charcoal and baked earth. Wares can be identified as pots, basins and earthen bowls. In addition, a lot of remnant iron residues, bones and teeth of animals, bronze loops, finger rings, half-liang money, bronze triangle arrows, wuzhu coins and iron farm implements such as iron swords and iron spades were found. This layer was named the cultural layer in the Eastern Han Dynasty by the archaeology department. (10) The 10th layer was 20—31 cm in depth, and it was a slightly hard grayish red clay layer with a few gravels. And a large amount of tiles, sandy and clay grayish brown pottery debris and remnant brick, body and teeth of animals were unearthed in this layer. Wares can be identified as pots, basins, earthen bowls, retorts, grates, networks, spins and wheels. It was called the cultural layer in the Western Han and Xin-Mang Dynasties by the archaeology department. Under the 10th layer was a purple red sandy gravel immature layer at depth of 40 cm with sedimentary chaotic melange of gravels, clay and silt. A lot of subangular gravels were bigger than 10 cm. According to the ancient Chinese coins unearthed in the 9th layer and using the dating method of cultural relic comparison, the age of T911 was estimated to date from the Han Dynasty (206BC—220AD).

The Shuangyantang site in the Western Zhou Dynasty (31°17′20″N, 109°46′40″E, 140—145 m) was located at the northwest of Longxing village, Dachang Town, Wushan County, Chongqing City, 3.5 km east of Da-chang Town. It faces the Daning River on the west, the Hongshan Mountain on the east and Qili Bridge on the north, and is situated on the first terrace of the east riverbank of the Daning River with flattish topography. The stratum of the western wall of T439 profile, Shuangyantang site (Figure 2) was divided into 7 layers. (1) The 1st layer was 15—20 cm in depth, and it was a grayish brown cultivated layer with sand, gravel and modern tile debris. (2) The 2nd layer was 15—28 cm in depth, and it was a slightly hard light red silt layer with a few gravels in small grain size and a few modern ceramic shards. (3) In the 3rd layer at depths of 25—35 cm, small quantities of graves in small grain size, a few modern ceramic shards and tile debris were excavated in the light brown silt layer. (4) The 4th layer was 24—40 cm in depth, and it was a grayish red clay boulder layer containing subangular and subround coarse gravels in large grain size. Small quantities of ceramic shards in the Ming and Qing Dynasties, “Qianlong tongbao” in the Qing Dynasty, and ceramic shards, iron swords, tiles and wood blocks in the Han Dynasty were unearthed in the alluvial layer, which might be formed from red sediments flooded by mountain torrent during that time. (5) The 5th layer was 40—80 cm in depth, and it was a grayish black clay layer containing abundant sandy ceramic shards with coarse rope figure. Li with lace was the dominant pottery. The age of the cultural layer was dated to the Western Zhou Dynasty by the archaeology department. (6) The 6th layer was 30—80 cm in depth, and it was a grayish yellow immature layer containing silty sandstone and sandy siltstone. Below the 6th layer was the ancient fluval facies gravels bed with high degree of roundness.

The upper 4th layers were modern layers. The excavated materials were characterized by cultural characteristics of the Western Zhou Dynasties, such as pots with lacey mouths, needle-bottom cups and calyxes peculiar to Ba and Shu region. Moreover, two augural
shells were excavated with the rectangle-dimpled grains inside, which represented the technique of the middle and late of the Western Zhou Dynasty. And according to the dating method of cultural relics comparison, the age of this layer was estimated to date to the Western Zhou Dynasty (1100 – 770BC). The $^{14}$C age of charcoal seed (No. ZK-2827) collected from the southern wall of the 5th layer in T13 profile in April, 1994 was dated to (2790±68) aBP, i.e. 840BC with the calibration age of 910 – 806BC$^{1}$, corresponding to the middle and late stages of the Western Zhou Dynasty. The TL age of samples collected from 8 to 18 cm above ancient fluvial facies gravels was dated to (28.72±2.44) kaBP, and accordingly, it is concluded that the age of the grayish yellow immature layer was about 30 kaBP$^{2}$.

2.2 Methods

Fifteen samples collected from T911 profiles in Zhangjiawan sites and six samples collected from T439 profile in Shuangyantang site were analyzed for grain size by the instrument of SKC-2000 in the Key Lab of Coast and Island, Nanjing University.

3 Results and interpretations

3.1 Data of grain size and flood

Structure and tectonics of sediments by wind and flow water can provide us with the information about energy and water of sediment environment. River terrace and its sediments are one of important terrestrial sedimentary records for Quaternary deposit environment, in which sediment stratum contains the information about climate change of inland and edge regions$^{[25]}$.

(i) The grain size characteristics of the Zhangjiawan site. In general, coarse sediments mainly deposit in a strong sediment-interacting environment, while fine sediments often appear in a weak sediment movement. Higher proportion of gravels and lower values of clay were the common characteristics of the western wall in T911 profile. Gravel percentages reached a maximum of 94.9% in the 2nd layer, while the values were more than 40% in other natural layers (Figure 3), indicating a strong sediment-interacting environment in all natural layers. As shown in Figure 3 and Table 1, the average granularity of samples in the 2nd layer ($Z_{10\text{E}}, Z_{10\text{D}}, Z_{10\text{C}}, Z_{10\text{B}}, Z_{10\text{A}}$) and samples in the 7th layer ($Z_{5\text{D}}, Z_{5\text{C}}, Z_{5\text{B}}, Z_{5\text{A}}$) alternately changed from coarser to thinner from above downward. Secondly, the $\sigma_1$ value was less than 1 in the samples collected from the 2nd layer, suggesting a high degree of sorting. Moreover, from above downward it was characterized by alternate values of $\sigma_1<0$ and $>0$ for the samples collected from the 2nd layer, and $\sigma_1<1$ and $>1$ s for the samples in the 7th layer, reflecting an alternated change from good sorting, better sorting, poorer sorting, good sorting, and better sorting to poorer sorting, better sorting or poorer, corresponding to the grain size change in filed investigation. In view of the values of skewness coefficient, $Sk$ were mostly in the range of $0.3 – 1.0\phi$ with extremely positive skewness for samples in some layers except the immature layer and the 6th and 9th layers. The sharpness coefficient $Kg$ was characterized by the alternated change between wider and narrower for the samples collected from the 2nd layer from above downward. Similarly, the alternation change between wide, narrow and moderate appeared in the samples of the 7th layer. Whereas it is very wide for the samples in the immature layer and very narrow for the samples in other layers.

Table 2 shows the relationship between grain size, transport mode and breakpoint for the samples of T911 profiles at the Zhangjiawan site, which is expressed as follows: (1) contents of bed load were higher (71% – 95%) for the samples in the 2nd and 7th layers except sample $Z_{5\text{A}}$, indicating a weak hydro-dynamics. Moreover, combined with data of granularity parameters, high degree of gravel roundness and obvious sedimentary rhythm for these two layers reflected a fluvial sedimentary environment. In addition, using the sedimentary environment formula proposed by Suhu$^{[26]}$,

$$Y = 0.2825Mz - 8.7604\sigma_1^2 - 438932Sk + 0.0482Kg,$$

where if $Y < 9.8433$ it is turbidity deposit, and it is fluvial deposit if $Y > 9.8433$. Results showed that $Y$ values were higher than 9.8433 for other samples in the 2nd and 7th layers except $Z_{5\text{D}}$ sample in the 7th layer, suggesting two diluvial layers. (2) Sediments in the 11th

1) C14 Laboratory, Institute of Archaeology, Chinese Academy of Social Sciences (CASS). Dating report of radiocarbon (twenty three). Archaeology, 1996, 7

2) Measured by the Institute of Crustal Dynamics, the State Seimological Bureau
layers were composed of gravel and sand filled with silt and clay. The grain size of gravels was less than 30 cm, mostly in the range of 10—20 cm, which was thinner than those in the upper layers. In addition, its probability cumulative curves showed a pattern of 3—4 segments. Since the site was situated at the foot of Zhangjiapo Mountain, field investigation and lithology analysis reflected that its immature layer came from the slope weathering materials with the same lithology of purple red Jurassic sandstone as the Zhangjiapo Mountain. According to above results, it can be concluded that the immature layer was slope deposit, whose source was detrital sediments of Zhangjiapo Mountain. (3) Most of gravels were subangular in the 3rd, 4th and 6th layers, indicating a short transportation distance. Secondly, the pattern of probability cumulative curves was three segments. In addition, the proportion of bedload was 56% with the coarse breakpoint of $-0.5\Phi$, while that of mixed load was 15% and suspend load was 81% for Z9 sample. For Z6 sample, the proportion of bed load was 81% with the coarse breakpoint of $-1\Phi$, while that of mixed load was 8% and suspend load was 11%. And for Z6 sample, the proportion of bed load was 71%—81% with the coarse breakpoint of $-1.5—0.7\Phi$, while that of mixed load was 15%—7% and suspend load was 12%—14%. Thus it can be seen that the deposition of a lot of slope

![Figure 3](image)

**Figure 3**  Contents and parameters of granularity of T911 profile, Zhangjiawan site.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Stratum</th>
<th>Depth (cm)</th>
<th>Average granularity $M_z$ ($\Phi$)</th>
<th>Standard deviation $\sigma_1$ ($\Phi$)</th>
<th>Skewness coefficient $Sk$ ($\Phi$)</th>
<th>Sharpness coefficient $K_g$ ($\Phi$)</th>
<th>Median grain size $M$ ($\Phi$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z10-E</td>
<td>2</td>
<td>18</td>
<td>-0.08</td>
<td>0.57</td>
<td>1.0</td>
<td>-0.89</td>
<td></td>
</tr>
<tr>
<td>Z10-D</td>
<td>2</td>
<td>28</td>
<td>0</td>
<td>-0.17</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z10-C</td>
<td>2</td>
<td>31</td>
<td>-0.57</td>
<td>0.40</td>
<td>-1.75</td>
<td>-1.70</td>
<td></td>
</tr>
<tr>
<td>Z10-B</td>
<td>2</td>
<td>36</td>
<td>-0.66</td>
<td>-0.58</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z10-A</td>
<td>2</td>
<td>38</td>
<td>-0.35</td>
<td>0.47</td>
<td>-4.50</td>
<td>-1.30</td>
<td></td>
</tr>
<tr>
<td>Z9</td>
<td>3</td>
<td>51</td>
<td>1.82</td>
<td>2.59</td>
<td>1.21</td>
<td>0.09</td>
<td>-0.75</td>
</tr>
<tr>
<td>Z8</td>
<td>4</td>
<td>70</td>
<td>0</td>
<td>0.45</td>
<td>0.50</td>
<td>-0.88</td>
<td></td>
</tr>
<tr>
<td>Z8-B</td>
<td>6</td>
<td>100</td>
<td>0.20</td>
<td>1.39</td>
<td>1.97</td>
<td>-0.25</td>
<td></td>
</tr>
<tr>
<td>Z8-A</td>
<td>6</td>
<td>106</td>
<td>1.53</td>
<td>2.17</td>
<td>1.03</td>
<td>1.20</td>
<td>0.50</td>
</tr>
<tr>
<td>Z8-D</td>
<td>7</td>
<td>115</td>
<td>-0.36</td>
<td>-0.27</td>
<td>0.50</td>
<td>-1.47</td>
<td></td>
</tr>
<tr>
<td>Z8-C</td>
<td>7</td>
<td>119</td>
<td>1.34</td>
<td>2.29</td>
<td>0.30</td>
<td>0.76</td>
<td>2.80</td>
</tr>
<tr>
<td>Z8-A</td>
<td>7</td>
<td>125</td>
<td>-0.13</td>
<td>0.81</td>
<td>1.00</td>
<td>-1.50</td>
<td></td>
</tr>
<tr>
<td>Z8-B</td>
<td>7</td>
<td>128</td>
<td>3.07</td>
<td>2.52</td>
<td>0.30</td>
<td>1.08</td>
<td>-0.10</td>
</tr>
<tr>
<td>Z11-11</td>
<td>11</td>
<td>215</td>
<td>2.11</td>
<td>2.64</td>
<td>1.00</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Z11-12</td>
<td>11</td>
<td>225</td>
<td>2.48</td>
<td>2.56</td>
<td>0.47</td>
<td>0.58</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Table 1 Parameters of grain size of T911 profile, Zhangjiawan site.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Stratum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth (cm)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 4](image-url)
suspend load was only 6%–16%, while mixed load was in the range of 40%–55% with a thin breakpoint of 4%–5%, which were consistent with the characteristics of fluvial sediments in field investigation. Visher had ever demonstrated that it was jet transportation if the coarse breakpoint was lower than 2.25Φ. But in the layer it was about 2.5–3.3Φ, indicating a weak diluvial-alluvial deposit. (2) In the 4th layer, a quite lower content of bed load and higher values of mixed load with double leap deposit. (3) In the 4th layer, a quite lower content of bed load without suspend load for the samples of S10 and S5 but coarse grain size, poor sorting, and higher mixed load. The higher mixed load indicated a strong hydro dynamics.

The above grain size features showed that S1 sample with some suspend loads in thin grain size was the eolian sediment influenced by a weak hydro dynamics, but coarse grain size, poor sorting, and higher mixed load without suspend load for the samples of S10 and S5 reflected they were the eolian sediment altered by strong flowing water, which was similar to the terrace loess layer of the north bank of lower reaches of the Yangtze River and grayish yellow silt layer in Baohuashan region, Nanjing. Moreover, samples of S26 and S22 were also influenced by flowing water and they were fluvial sediments.

### 3.2 Fluvial evolution and the distribution of archaeological sites

(i) Disturbance of archaeological culture. Most archaeological excavation showed that generally the cultural layer should deposit continually in a stable surrounding environment. But an obvious interruption of the cultural layer appeared in this region. Tang-Song interruption layer was deposited on the cultural layers in the Western Han and Eastern Han Dynasties of Zhangjiawan site. Whereas above the Western Zhou cultural layer was the interruption layer of the Han and Qing Dynasties in Shuangyantang site, indicating a distinct abrupt climate change. In view of the distribution of two sites on both sides of the Daning River, it is concluded that it maybe relates to fluvial evolution and river flood of the Daning River.

(ii) Plaeo-fluvial gravel layer. Grayish yellow immature layer was located under the cultural layer in the Western Zhou Dynasty of Shuangyantang site. The bottom layer (1.24–1.44 m under the surface) was fluvial gravels with depths more than 2 m (based on the inner data and excavated data of oil drilling in Chongqing City). However, in Zhangjiawan site under the 10th layer was a deep reddish brown immature layer containing sand, gravel, clay and silt with non-sorted bigger angular gravel in grain size more than 10 cm. In addition, the drilling results showed paleo fluvial gravels were not found in Zhangjiawan site (still slope deposit, Figure 5). These field drilling data demonstrated that at first the riverbed developed at Shuangyantang, and after 30 kaBP it shifted westward and to the present place.

(iii) Fabric analysis of paleo gravels—Paleocurrent analysis. The analysis of paleocurrent includes the measurement of paleocurrent direction, the calculation, explanation and application of data. 100 gravels from the paleo gravel layer were selected to do the measurement of fabric analysis. Then, the fabric data were plotted as smoothed rose diagram with the most inclination of the principal axis less than 20° by deleting some abnormal values.

As shown in Figure 6, paleocurrent measurements suggested a clear indication of the northwest paleocurrent direction, indicating that at the early stage the riverbed located at Shuangyantang site. Because the gravels are arranged with an obvious direction influenced by stable flowing water, the biggest flat surface of flat gravels inclines to the upper reach of the river.

### Table 3 Relationship among granularity distribution, transportation mode and breakpoint for the samples of T439 profiles in Shuangyantang site

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Sample</th>
<th>Depth (cm)</th>
<th>Bed load</th>
<th>Mixed load</th>
<th>Suspend load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>S26</td>
<td>30</td>
<td>36</td>
<td>1–4</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>S22</td>
<td>55</td>
<td>40</td>
<td>1–4</td>
<td>33</td>
</tr>
<tr>
<td>4</td>
<td>S18</td>
<td>90</td>
<td>15</td>
<td>1–2.2</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>S10</td>
<td>168</td>
<td>44</td>
<td>1–2.3</td>
<td>30.5</td>
</tr>
<tr>
<td>6</td>
<td>S1</td>
<td>205</td>
<td>32</td>
<td>1–2.5</td>
<td>37</td>
</tr>
<tr>
<td>6</td>
<td>S5</td>
<td>232</td>
<td>55</td>
<td>1–3.3</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content (%)</th>
<th>Granularity range (Φ)</th>
<th>Slope (°)</th>
<th>Content (%)</th>
<th>Granularity range (Φ)</th>
<th>Slope (°)</th>
<th>Content (%)</th>
<th>Granularity range (Φ)</th>
<th>Slope (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>1–4</td>
<td>34</td>
<td>48</td>
<td>4–5</td>
<td>78</td>
<td>16</td>
<td>5–6</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>1–4</td>
<td>33</td>
<td>54</td>
<td>4–5</td>
<td>62</td>
<td>6</td>
<td>5–6</td>
<td>38</td>
</tr>
<tr>
<td>15</td>
<td>1–2.2</td>
<td>28</td>
<td>67</td>
<td>2.2–5</td>
<td>19–53</td>
<td>18</td>
<td>5–6</td>
<td>18</td>
</tr>
<tr>
<td>44</td>
<td>1–2.3</td>
<td>30.5</td>
<td>44</td>
<td>1–2.3</td>
<td>26</td>
<td>6</td>
<td>5–6</td>
<td>18</td>
</tr>
<tr>
<td>32</td>
<td>1–2.5</td>
<td>37</td>
<td>56</td>
<td>2.5–4</td>
<td>10</td>
<td>6</td>
<td>5–6</td>
<td>18</td>
</tr>
<tr>
<td>55</td>
<td>1–3.3</td>
<td>35</td>
<td>68</td>
<td>3.3–5</td>
<td>13</td>
<td>32</td>
<td>5–6</td>
<td>20</td>
</tr>
</tbody>
</table>
(iv) Hole cave remains. A row of circle hole cave remains, arranged in a straight line with the orientation from southeast to northwest, was found on the paleo fluvial gravels in Shuangyantang site (Figure 5). The distance between holes, a total of 11, was about 3 m, and its diameter ranged between 20 and 30 cm and its depth was 20—30 cm above the gravel layer. No charcoal and wood crumbs were found in these hole remains, and in addition, they were arranged in a straight line with the total length of 70—80 m, indicating they might be a water retaining dam for flood control, not architectural post holes. Therefore, it can be deduced that the early riverbed was located at the western riverside of these holes in Shuangyantang site. A groove with the depth of 20—50 cm at the origin of these holes filled with ash soil was speculated to have an effect of draining.

(v) Tombs in the Han and Jin Dynasties. Tombs in the Han and Jin Dynasties were excavated on the east side of the flood plain of the Daning River by the Institute of Archaeology, Chinese Academy of Social Sciences (CASS)(Figure 5). Studies on buried remains showed that there was a relatively large-scale family tomb with higher status during the periods of Eastern Han Dynasty and slightly later stages. It has the same age as the cultural layer in the Han dynasty, reflecting it had some relation to Zhangjiawan site. In general, it is impossible that ancestors buried their family on the floodplain. Therefore, it is estimated that the flood plain was covered by thick loose sediments, which were eroded by several flood events and the westward shift of riverbed.

4 Discussion and conclusions

4.1 Geomorphology evolution at the Dachang section, the Daning River

According to the above field investigation and archaeological excavation, it is concluded that a series of changes have taken place in fluvial geomorphology of Dachang section, the Daning River and the riverbed ever shifted westward during the prehistorical and historical period, which has a great influence on the distribution of archaeological sites and ancient culture. During the period of about 30 kaBP, the riverbed of Dachang section developed on east side of Shuangyantang region. Then it began to shift westward and deep-incised, and as a result, the first terrace formed. During that time corresponding to Wurm glaciation in Europe and Dali glaciation in China in the late Pleistocene, the susceptibility and geochemical records for these samples in Shuangyantang sites showed that it was a cold and dry climate, and a grayish yellow immature layer deposited on the first terrace and flood plain[17].

Figure 5 Cave hole remains and tombs during the Han and Jin Dynasties in Shuangyantang and Zhangjiawan site. (a) Fluvial gravels bed in Shuangyantang site; (b) no fluvial gravels bed in Zhangjiawan site; (c) cave hole remains; (d) tombs in Han and Jin Dynasties.
During the early stage of the Western Zhou Dynasty, the riverbed was located near the cave hole remains of Shuangyantang site because the place of cave hole remains reflected the location of riverbed during that time. Thicker cobblestone layer was deposited by frequent flood. And a humid climate and frequent human activity in the second loess resulted in the formation of cultural layer in the Western Zhou Dynasty. In the Han Dynasty, the west riverbank of Daning River became the main residential area, and tombs were built near the riverbanks. Due to several flood events and the westward movement of riverbed, tombs of the Han and the Jin Dynasties outcropped on the flood plain in the east riverbank (Figure 7). In addition, the highest altitude of tombs in the Han and Jin Dynasties of Shuangyantang site was only 9 m above the withered water surface, only about 2 m higher than the flood plain. Local people narrated that sites and tombs were often submerged during a perennial normal flood season. At present the living area is adjacent to the river, instead of the inside of current flooded area, so it can be concluded that the river-
bed has shifted westward during that time.

4.2 Environment evolution and human activity

The 5th layer of T911 profile in Zhangjiawan site, the 2nd and 3rd layers of T439 in Shuangyantang sites were fluvial alluvium with well-sorted slit, which were the remaining suspend materials after flood. A large amount of gravels with high degree of roundness and obvious sedimentary rhythm was speculated to be the proluvial layer. In the Western Zhou Dynasty, along with the westward shift, the living area was no longer confined to the east riverbank, and the focus of culture shifted westward. Zhangjiawan site became the main dwelling district. In the late Han Dynasty, the villages were submerged and ancestors had to migrate to the high place to settle down. County annals, such as Wushan and Wuxi, and historical data about flood for the past 2000 years in Sichuan Province recorded the historical flood in this region after the Han Dynasty[30,31].

In addition, the 3rd, 4th and 6th layers of T911 profile in Zhangjiawan site and the 4th layer of T439 profile in Shuangyantang site were characterized by typical slope deposits with non-bedding disorderly subangular gravels. It is likely that the deposition of slope sediment resulted from large area slope runoff induced by brief torrent flood. According to the correlation of stratigraphy and dating, they mostly formed after the Han Dynasty. It is possible that ancestors fell trees and cultivated excessively during the late Han Dynasty and the recent period, which resulted in the destruction of forest trees. Moreover, frequent torrent flood often leads to the loss of water and soil. Slope sediments on the Zhangjiapo Mountain were eroded by mountain torrent in the condition of concentrated rainfall, and as a result, purple red sandy gravels deposited on the cultural layer of the Han Dynasty. Furthermore, frequent river flood compels ancestors to move to a high attitude region and the cultural layer of the Han Dynasty was interrupted. For the reason, after the Han Dynasty, no culture layer formed, but a large amount of slop sediments deposited in this region due to torrent flood. Remains of human activity in Ming and Qing Dynasties were also found on the Zhangjiapo Mountain by archaeological investigation. According to the record in Han Shu – Geography, ten thousand Qin people immigrated to this region, resulting in the great increase of population to 899227 in the fifth year of Yonghe after Ba and Shu Empires were extinguished by Qin Empire. In the Ming Dynasty, people from Hubei and Guangzhou also immigrated here. In the Han Dynasty, Sichuang became the granary in China. In particular, during the period of Han Wudi, one of the emperors of Han Dynasty, the southern part of the Yangtze River was relieved of millet from Ba and Shu regions[32]. Many iron spades were excavated in Zhangjiawan site, indicting a quite developed agriculture. In addition, animal bodies of tooth and leg bones of large livestock were also unearthed from the ash pits, reflecting that agriculture production can provide enough food for breeding livestock besides daily demand. Moreover, quite a few remnant ironwares (swords, spades, hoes, pricks and picks, etc.) and iron residues showed that ancestors have engaged in the casting of metal. Obviously, along with the development of agriculture and handicraft industry, forest vegetation was inevitably destroyed and the loss of water and soil increased. On the basis of the statistic data, the area of water and soil loss during the historical period accounted for 30% of total soil area[31]. The Article of Five Elements in The Old History of the Five Dynasties recorded that during the period of 933AD (the fourth year of Changxing in the Tang Dynasty) in July a landslide occurred in Jia Mountain, and the river flood submerged a lot of resident people in Kuizhou City. There were correlative documents in the Catastrophic Sign of The Article of Five Elements and Peizhou Annals, The history of Yuan Dynasty[31]. Wushan County Annals[14] also recorded that in the 13th year of Han Wudi (101AD) and in the 2nd year of Taiyuan of the Jin Dynasty (377AD) frequent landslides occurred there. In 1960, 1967, 1969, 1979, 1882, 1983, 1985, there was a large-scale landslide in this region. Accordingly, historical documents and archaeological sites reflected that since the historical period this region was characterized by frequent torrent flood.

The above researches on the relationship of environment evolution and human activity give us two cautions. At first, river flood has an obvious impact on ancient people. Flood disaster is mostly harmful to human beings, resulting in the interruption of culture layer. Secondly, human fell trees and cultivated excessively, undoubtedly, leading to the destruction of natural environment and the disturbance of the self-recovery and

1) Department of History, Nanjing University. The second excavation of Zhangjiawan site in 2000, 2000
self-organization of environment. Therefore, frequent river flood and mountain torrent disaster after the Han Dynasty reflect the complexity of relationship between human and nature.

21 The Working Team of the Three Gorges, the Yangtze River, Institute of Archaeology, CASS. Excavation of Weijiajiangzi site, Wushan county, Sichuan Province. Archaeology (in Chinese), 1996, 8: 1—18