Identifying Paleoflood Deposits Archived in Sanfangwan Site, the Tianmen of the Jianghan Plain, Central China

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Abstract — Paleoflood study was carried out in the Sanfangwan Neolithic Site in the Tianmen of the Jianghan Plain. Two layers of paleoflood deposit were identified in the Holocene archaeological sequence of Sanfangwan Site. Chronology of the flood event was established by AMS¹⁴C dating, checked by archaeological remains retrieved from the sequence. The result shows that paleoflood event occurred between 4913–4600 cal. a BP (i.e. middle and late Qujialing cultural period). Both the sedimentary criteria and the analytical results show that this paleoflood deposit may be sourced from suspended sediments of floodwater of Hanjiang River. It indicates that the initial purpose of the Shijiahe city wall construction in Sanfangwan Site may also be close related to the threat of Hanjiang River floods. We cannot simply consider this construction was a passive defense against foreign invasion.

Keywords - Jianghan Plain, Sanfangwan Site, paleoflood deposits, grain size, micro-morphology of zircon

I. INTRODUCTION

The Jianghan Plain of the middle Yangtze River valley is an area with a long history of floods. Identification of disaster-induced sediment layers, especially paleoflood deposits in the archaeological strata have been a research subject for a long time [1-5]. In recent years, a number of protective archaeological excavations have been conducted in this area. We took part in the excavation of Sanfangwan Site in Tianmen, which was coordinated by Hubei Provincial Institute of Cultural Relics and Archaeology. Some sediment layers induced by paleofloods were found. In this paper, comparative research of AMS¹⁴C dating, grain size and micro-shape of zircon was performed to identify paleoflood deposits in Sanfangwan Neolithic Site. It involves the accurate recovery of magnitudes and ages for the largest floods to have actually occurred during the past millennia in the Jianghan Plain, and can be used for flood assessments and the perception of flood hazard to those at risk [2].

II. SITE DESCRIPTION AND SAMPLING

The Sanfangwan Neolithic Site is located north of the Shihe Town, the Tianmen City in Hubei Province (Fig. 1). The research unit T1610 is situated in the south-central of the excavation area, with clear cultural accumulations. In addition to the city wall ruins, the stratum can be divided into 15 layers (Fig. 1). The 1–4 layers are the modern cultivated or disturbed deposits; while the 5–11 layers are the Shijiahe cultural deposits. Under the 11th layer, there are the city wall ruins of the Shijiahe Neolithic Site. Overlying by these city wall ruins, there are 3 natural deposit layers nearly 1 m thick from 13th to 15th layers, which contain rich charcoals suitable for AMS¹⁴C dating. Research on the properties of these natural deposit layers is conductive to reveal the information of paleofloods containing in archaeological strata. Therefore, 48 samples for grain size analysis, 6 samples for micro-morphology of zircon, and 1 sample for AMS¹⁴C dating were collected from 3 natural deposit layers between 330–430 cm in unit T1610 of Sanfangwan Site with the help of the Hubei Provincial Institute of Cultural Relics and Archaeology.

III. AGE AND CHARACTERISTICS OF PALEOFLOOD DEPOSITS

A. Profile, Ages and Grain Size

The investigation on the spot reveals that below the Shijiahe cultural layers, there are three natural deposit layers containing no cultural remains in the excavation unit T1610 of Sanfangwan Site, which are similar to those of the Zhongba Site [1]. The three natural deposit layers (Fig. 1), from top to bottom, are composed of cinerous silt, yellowgrey silt and grey silt, respectively. Abrupt vertical change in grain size, colour, texture and structure can be found. Among them, the 14th and 15th layer are horizontally bedded, with rust and disturbance ripple in deposits. But in the 13th layer, there is no significant vertical change in texture, structure, grain size and colour. It also has no typical sedimentary feature of paleofloods such as the horizontal bedding and disturbance ripple. Therefore, the 13th layer may be lacustrine sediments, for the river flooding deposit should be composed of silt or silty-fine sand with light colour and less organic matter. The colour of the 13th layer is rather dark with higher organic matter content. The 14th layer in the bottom of the Sanfangwan Site may be paleoflood deposits, while the 15th layer may also have experienced the impact of floods, especially the upper layer.

The AMS¹³C dating was jointly conducted in the Laboratory of AMS-¹³C Sample Preparation, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, and the State Key Laboratory of Nuclear Physics and Technology, Peking University. All radiocarbon ages were calibrated using the computer software CALIB 6.0.1 [6]. Based on the dating result (AMS¹³C age is 4350±30 a BP, 2σ calibrated age is 4913±62 a BP) of charcoal from the 15th layer, the sedimentary time of the lower three natural deposit...
layers belongs to the mid-late Qujialing cultural period (4.9~4.6 ka BP). This coincides well with the archaeological dating of pottery remains and the strata overlying relationship in the Sanfangwan Site.

Figure 1. Geographic location and stratigraphic profile of the Sanfangwan Neolithic Site.

Grain size distribution was analysed using a Malvern Mastersizer 2000 laser analyser at the Nanjing Normal University (Fig. 2). The clay (< 4 μm) contents of the 14th and 13th layer range between 15.75% and 23.83%. The 15th layer is characterized by the highest clay concentration (17.91~32.33%, mean 25.86%). However, the clay content above 396 cm is lower (17.91~22.54%, mean 19.62%). The silt (4~63 μm) contents of the 14th and 13th layer are higher...
(75.11–83.89%, mean 78.54%), but the 15th layer is characterized by the lowest silt concentration (mean 73.73%), with the exception above 396 cm in high contents (77.17–81.47%, mean 79.71%). These data indicate that the sediment property of three natural deposit layers all belongs to the clayey silt and suspended silt is the principal part of these layers in the Sanfangwan Site. And more importantly, the 14th and the upper part of 15th layer are characterized by the highest sand (> 63 μm) concentration (Fig. 2), with great variation amplitude and several peak values. There are also many resemblances of grain size frequency distribution curves between above possible paleoflood deposit layers and the 2010 flood deposit layer of the Hanjiang River [7-8]. The best explanation is that they have a common material source. These results show that the 14th and the upper 15th layer formed under strong hydrodynamic conditions, and suffered from the impact of paleoflood events. It coincides well with above-mentioned judgements.

**TABLE I.** ZIRCON SHAPES FROM UNIT T1610 OF SANFANGWAN NEOLITHIC SITE

<table>
<thead>
<tr>
<th>No.</th>
<th>Depth (m)</th>
<th>Columnar (%)</th>
<th>Well Rounded (%)</th>
<th>Cubic Dipyramid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-46</td>
<td>3.36</td>
<td>28.77</td>
<td>3.65</td>
<td>59.82</td>
</tr>
<tr>
<td>13-42</td>
<td>3.44</td>
<td>35.48</td>
<td>4.11</td>
<td>54.24</td>
</tr>
<tr>
<td>14-35</td>
<td>3.58</td>
<td>43.27</td>
<td>3.63</td>
<td>48.61</td>
</tr>
<tr>
<td>14-27</td>
<td>3.74</td>
<td>45.49</td>
<td>4.14</td>
<td>45.11</td>
</tr>
<tr>
<td>15-16</td>
<td>3.96</td>
<td>44.30</td>
<td>5.65</td>
<td>43.21</td>
</tr>
<tr>
<td>15-8</td>
<td>4.12</td>
<td>42.39</td>
<td>7.00</td>
<td>43.62</td>
</tr>
</tbody>
</table>

Figure 2 shows that shapes of zircons in the samples of the possible paleoflood sediments (14-35, 14-27 and 15-16) are abraded into nearly orbicular shape from cubic dipyramid. Shapes of zircons in the samples of the 13th layer (13-46 and 13-42, non-flood layer) are obviously cubic dipyramid, which are different from those in the flood layers. This difference is caused by the weak hydrodynamic handling of the 13th layer with features of near provenance. Shapes of zircons in the samples of the lower 15th layer (15-8) are also abraded into nearly orbicular shape, with paleoflood impact. From the analysis above, it can be decided that the 14th yellow gray soil layer is paleoflood deposits, while the 15th gray silt layer may also have experienced the impact of floods. The high psephicity of zircons shows that there are the relics influenced by the paleofloods. However, the 13th cinerous mud layer shall be lacustrine sediments, which may have experienced a limnetic environment with moderate flow rate or shallow water. This is also consistent with the field observation and inference by the archaeological team of Sanfangwan Neolithic Site [10].

**Figure 3.** Percentage variation of clay, silt and sand in the Sanfangwan stratigraphic profile.

**B. Micro-morphology of Zircon**

Zircon is one of the most common heavy minerals with rather large density and hardness, which make it very resistant from erosion. Therefore, examining surface micromorphology of zircon is an important method to judge the sedimentary characteristics [9]. From Table I we can see that the shape of columnar and well rounded reaches the highest in the 14th and 15th possible paleoflood deposit layer (46.9%–49.95%). In contrast, the origin shape of cubic dipyramid reaches the highest in the 13th layer (54.24%–59.82%), and the shape of columnar only ranges between 28.77% and 35.48%. Meanwhile, there are also resemblances on the shapes of zircon between above possible paleoflood deposit layers and the modern flood deposit layer of 1981 in Zhongba Site, as well as the modern flood deposit layer of 2004 in Yuxi Site in the upper Yangtze River [1, 9]. Shapes are mostly semi-spherical, edge angles of the other samples are obviously rounded.
IV. Conclusions and Discussion

On the basis of archaeological chronology and AMS$^{14}$C dating, a variety of experimental evidences indicate that the 14th yellowgray soil layer in the bottom of Sanfangwan Site is paleoflood deposits, while the 15th gray silt layer may also have experienced the impact of floods, especially the upper layer, but the 13th cinerous mud layer shall be lacustrine sediments, which may have experienced a limnetic environment with moderate flow rate and shallow water. The chronological results show that paleoflood event occurred between 4913–4600 cal. a BP (i.e. middle and late Qujialing cultural period) in the Sanfangwan Site. The area of Sanfangwan Site in Tianmen still belongs to the center position of the Luohansi irrigated area of Hanjiang River. Thus, there are close relationships between paleoflood deposits at the bottom of the Sanfangwan site and the Hanjiang River floods during prehistoric era. The initial purpose of the Shijiahe city wall construction in Sanfangwan Site may also be close related to the threat of Hanjiang River flooding.
floods. We cannot simply consider this construction was a passive defense against foreign invasion.

Flood events of the Hanjiang River recorded in historic documents are abundant. However, in the strata of Sanfangwan Site, there are only two flooding events related to the Hanjiang River flooding. The reason is that: only when every level of flood events is higher than or equal to the ancient surface of Sanfangwan Site, can slack-water deposits be retained. Due to the low water level and deposit position, normal slack-water deposits have often been eroded by subsequent floods, and cannot be long-term preservation. Only the great flood covered surface of the site, can relatively thick slack-water deposits be retained in the archaeological strata. Certainly, the subsequent natural denudation or human activities may make paleoflood deposits absent or their thickness change.

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