Animal diversities and characteristics of environmental change revealed by skeletons unearthed at Zhongba Site of Chongqing City, China

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Nearly 200000 animal skeletons are unearthed in the Unit T0202 from Zhongba Site of Zhongxian County. According to the analysis of 129165 specimens, these skeletons may be classified into 5 kinds, namely, Mammalia, Osteichthys, Aves, Amphibian and Reptilia, which belong to 13 orders, 28 families and 42 genera. In this paper, based on archeological dating and AMS14C data, through statistically analyzing the unearthed skeletons and studying the change of the smallest individual numbers, these research results detected the following: 1) In almost all the time of 2370―200 BC, in Zhongba region, some animals distributed widely, such as Muntiacus sp, Elaphodus cephalophus and Muntiacus sp. inhabiting in glade and grassland, Scrofa sp. and Canis familiaris raised by the ancient people, rodentia rabbit and Rattus rattus, which suggested that a fairly good ecological environment of forest and grassland was preserved at that period and the predecessors began to raise domestic animals from 1750 to 1000 BC, which has lasted until today. 2) Rhinoceros only lived during 2000―1750 BC, 1000―700 BC and 700―500 BC, which indicates that the ecological environment of grassland and wetland might be better in these phases. 3) Macaca sp. and Ursus arctos appeared only after 1750―1000 BC, which may show that the forest condition is better for animals to live during 1750―200 BC. 4) The smallest individual numbers of Bublus sp., bos sp. and otters emerged during about 2370―1750 BC, which perhaps infers that water area during the early period was wider than that of the late period. 5) Since skeletons of rhinoceros are discovered in strata of Zhongba Site during 2000―1750 BC and 1000―500 BC, according to the climate and ecology environment which rhinoceros live in now, the average annual temperature and precipitation during 2000―1750 BC and 1000―500 BC are supposed to be probably higher than that of today. Although Zhu Kezhen considered that the first low temperature period in the past 5000 years of China was between 1100 BC and 850 BC, massive pollen of Morus, Ulmus, Fagus, Quercus, Castanea, etc. were found in Dajiuhu peat at that time, which should indicate that the climate was still moderate for living things to live at least in Dajiuhu basin and Zhongba Site. 6) Because skeletons of Gervus albirostris were unearthed during 310―200 BC at Zhongba Site, based on...
Zhongba Site, animal skeletons, animal diversity, climate and ecological environment change, 2370 BC—200 BC

Zhongba Site is located at the left alluvial fan of Ganjing River about 4.5 km to northern Zhongxian County of Chongqing City. The length of the site is 350 m approximately from west to east, the width is about 140 m from north to south and the total area is about 49000 m². The main body of Zhongba Site is named after an isolated island of about 7000 m² on the right side of the river bed which is washed out by the river from year to year[1]. The site was regarded as one of the Ten Important National Archaeology Discoveries in 1999 because of a nearly complete archaeological cultural strata[2] with a history of 5000 years from Neolithic Period to Xia, Shang and Zhou to the Spring and Autumn Period, and the Warring States Period to Han Dynasty. The authors once reported the distinction on the basis of rich ancient flood deposition of the Unit T0102 in 2005[2], and this paper mainly further discusses the relationships of animal skeletons unearthed at the site of T0202, features of climate and ecological environment within 2370—200 BC.

1 Strata and chronosequence of the site

The Unit T0202 is located in the centre of Zhongba Site (Figure 1), with 10 m in length, 10 m in width and 9 m in depth. Dr. Rowa Kimon Flad from California University, Los Angeles, USA and Zhang Zhongyun from Sichuan Institute of Archaeology were in charge of this work. At that time they employed 10 local villagers and the work was continued to June 23, 2002. During excavating, new methods were used in this unit, namely, all mud is sieved by copper meshed screen with aperture of 6 mm and massive animal skeletons were discovered.

Figure 2 is the profile map of the northern wall from
the Unit T0202 with quite complete strata. There are 68 layers from top to bottom of this profile, and we studied the layers from the 18th layer to the bottom of the 68th layer (The remains of the Qin and Han Dynasties are above the 17th layer which will be discussed in another article). Table 1 lists the strata divided by unearthed utensil dating, among which the 18th layer belongs to Qin Dynasty, the 19th—33rd layers belong to the Warring States Period, the 34th—43rd layers belong to the Spring and Autumn Period, the 44th—49a, 52a and 53rd layers belong to West Zhou Dynasty, the 49b—50th layers belong to the period from the late Shang Dynasty to the early Shang Dynasty, the 52b layer belongs to the period from the late Xia Dynasty to the early Shang Dynasty, the 54th—65a layers belong to the third period of Zhongba Culture in the late Neolithic Age and the 65b—68th layers belong to the second period of Zhongba Culture in the late Neolithic Age, respectively. Samples of dating are selected from 12 layers, namely, the 18th, 33rd, 38th-b, 43rd, 46th, 48th, 49th-a, 49th-b, 50th, 56th, 64th and 68th layers, then 13 skeleton samples and 3 charcoals are dated at last through AMS$^{14}$C method in the Heavy Ion Institute of Physics of Beijing University. The dating results are calibrated by the international procedures, the version of Calib5.01$^{[3,4]}$ (Table 2). From Table 2, we can see that the age spans

Table 1 The relative strata age of the Unit T0202 from Zhongba Site according to the archaeology utensils

<table>
<thead>
<tr>
<th>Name of culture</th>
<th>Period/time</th>
<th>Strata</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ganjinggou Culture</strong></td>
<td>The Fourth Period (the Qin Dynasty, 221BC—207BC)</td>
<td>18, 17</td>
</tr>
<tr>
<td></td>
<td>The Third Period (the Warring States, 472BC—221BC)</td>
<td>33—19</td>
</tr>
<tr>
<td></td>
<td>The Second Period (the Spring and Autumn Period, 770BC—476BC)</td>
<td>43—34</td>
</tr>
<tr>
<td></td>
<td>The First Period (Xi Zhou Dynasty, 1121BC—771BC)</td>
<td>53, 52a, 51b, 49a—44</td>
</tr>
<tr>
<td><strong>Sanxingdui Culture of eastern Chongqing City</strong></td>
<td>The Second Period (late Shang Dynasty to early Xi Zhou Dynasty, 1765BC—771BC)</td>
<td>50, 49b</td>
</tr>
<tr>
<td></td>
<td>The First Period (late Xia Dynasty to early Shang Dynasty, 2207BC—1765BC)</td>
<td>52b</td>
</tr>
<tr>
<td></td>
<td>The Third Period (the late Neolithic age before 2207BC)</td>
<td>60—54</td>
</tr>
<tr>
<td></td>
<td>The Second Period (the late Neolithic age after 2207BC)</td>
<td>63—61a, 65a—64a, 66—65b</td>
</tr>
<tr>
<td><strong>Zhongba Culture</strong></td>
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<td>68—67</td>
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Table 2  AMS$^{14}$C data and calibrated results of strata in the Unit T0202

<table>
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<tr>
<th>Sampling number</th>
<th>Layer</th>
<th>Material</th>
<th>Laboratory number</th>
<th>Uncalibrated AMS$^{14}$C data (a BP)</th>
<th>Calibrated AMS$^{14}$C data (BC (1σ scope))</th>
<th>Mid value of calibrated AMS$^{14}$C data (BC)</th>
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<tbody>
<tr>
<td>BA01361</td>
<td>18</td>
<td>bone</td>
<td>FCN 0104-2</td>
<td>2380±70</td>
<td>544—389</td>
<td>466</td>
</tr>
<tr>
<td>BA01357</td>
<td>18</td>
<td>bone</td>
<td>FCN 0006</td>
<td>2430±80</td>
<td>556—404</td>
<td>480</td>
</tr>
<tr>
<td>BA01420</td>
<td>33</td>
<td>bone</td>
<td>FCN 2136</td>
<td>2460±60</td>
<td>595—504</td>
<td>549</td>
</tr>
<tr>
<td>BA01373</td>
<td>38b</td>
<td>bone</td>
<td>FCN 2275</td>
<td>2540±60</td>
<td>648—549</td>
<td>598</td>
</tr>
<tr>
<td>BA01429</td>
<td>43</td>
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<td>2490±70</td>
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<td>652</td>
</tr>
<tr>
<td>BK2002045</td>
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<td>charcoal</td>
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<td>2730±85</td>
<td>943—806</td>
<td>847</td>
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<td>48</td>
<td>bone</td>
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<td>946</td>
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<tr>
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<td>bone</td>
<td>FCN2728</td>
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<td>1512—1212</td>
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<tr>
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<td>49b</td>
<td>bone</td>
<td>FCN 2613-1</td>
<td>3100±60</td>
<td>1435—1301</td>
<td>1368</td>
</tr>
<tr>
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<td>charcoal</td>
<td>FCN 2658</td>
<td>3210±120</td>
<td>1636—1375</td>
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<td>bone</td>
<td>FCN 2975-4</td>
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<td>1906</td>
</tr>
<tr>
<td>BA01390</td>
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<td>bone</td>
<td>FCN 2958-1</td>
<td>3590±60</td>
<td>2033—1880</td>
<td>1956</td>
</tr>
<tr>
<td>BA02028</td>
<td>64</td>
<td>bone</td>
<td>FCN 3329</td>
<td>3660±100</td>
<td>2147—1901</td>
<td>2024</td>
</tr>
<tr>
<td>BK2002048</td>
<td>64</td>
<td>charcoal</td>
<td>FCN 3320</td>
<td>3800±70</td>
<td>2347—2136</td>
<td>2241</td>
</tr>
<tr>
<td>BA01403</td>
<td>68</td>
<td>bone</td>
<td>FCN 3582-6</td>
<td>3840±60</td>
<td>2350—2204</td>
<td>2277</td>
</tr>
<tr>
<td>BA01398</td>
<td>68</td>
<td>bone</td>
<td>FCN 3582-1</td>
<td>3880±90</td>
<td>2471—2274</td>
<td>2370</td>
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</table>

from 2370 BC to 466 BC. Our analysis indicates that the chronological order of strata by AMS$^{14}$C method is basically consistent with archaeological chronology. According to the research convention, when the data obtained with $^{14}$C method are inconsistent with the utensil dating, the latter is more valuable, therefore, this paper also abides by this principle.

2 Types and quantity of animal skeletons and distribution

Nearly 200000 animal skeletons got from all mud sieved by copper mesh screen with aperture of 6 mm are unearthed in the Unit T0202. According to analysis on 129165 specimens, these skeletons may be classified into 5 kinds, namely, Mammalia, Osteichthys, Aves, Amphibian and Reptilia, which belong to 13 orders, 28 families and 42 genera totally[5—8] (Table 3, Figure 3), in which there are the following families: Bovidae, Suidae, Cervidae, Canidae, Ursidae, Mustelidae, Hysteridae, Leporidae, Rhinocerotidae, Cervus albirostris, Trachypithecus sp. and Rhinopithecus sp., etc. Some animals in this area have died out or are nearly on the edge of extinction, for example, Rhinocerotidae, Cervus albirostris, Trachypithecus sp. and Rhinopithecus sp., etc. The earlier research[1, 9] has proven that the site can continue for 5 ka because it is an ancient salt industry site. In addition, there are traces burned or chopped on almost all skeletons through scene discrimination, which indicates that they were discarded by salt-making workers who ate wild animals from hunting and fishing nearby. So many types of unearthed skeletons indicate that people had no choice of the source of animal food at that time. Therefore, these massive unearthed animal skeletons give important evidence to the environmental evolution in this area.

Three obvious variety phases of animal skeleton types and quantity in unit T0202 may be divided according to statistics of animal skeletons and the strata ages (Table 4), namely, phase I is in about 2370—1750 BC, phase II is nearly between 1750 and 1000 BC, and phase III is in about 1000—200 BC. Phase I and phase III may be also divided into sub-phases.

According to zoologic classification statistics for each stage, fish and mammalian skeletons occupy the overwhelming majority in those unearthed skeletons from the Unit T0202 (Table 5). In addition, of the 129165 skeletons 124543 belong to these two classes accounting for 96% of the total. Otherwise, the rest such as Aves, Amphibian and Reptilia only occupy 4%.

Figure 4 shows the change of the total animal proportions main animal skeletons occupied in different phases in the Unit T0202, which indicates the following features: 1) There are certain similarities in skeleton quantity change of Mammalia, Osteichthys, Aves, Amphibian and Reptilia, namely, quantity of phase III 4 which is the most, followed by phases III1, III2, III5, II,
<table>
<thead>
<tr>
<th>Class</th>
<th>Order</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
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<td>Artiodactyla</td>
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<td>Bos Linnaeus</td>
<td>Bos sp.</td>
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<tr>
<td></td>
<td></td>
<td>Bubalus H. Smith</td>
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<tr>
<td></td>
<td>Cervidae/Cervinae</td>
<td>Cervus</td>
<td>Cervus albirostris</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Cervus elaphus</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cervus sp.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Elaphodus Milne-Edwards</td>
<td>Elaphodus davidianus</td>
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<tr>
<td></td>
<td>Muntiainae</td>
<td>Elaphodus Milne-Edwards</td>
<td>Elaphodus cephalophus</td>
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<tr>
<td></td>
<td></td>
<td>Muntiacus Rafinesque</td>
<td>Muntiacus reevesi</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Muntiacus sp.</td>
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<tr>
<td></td>
<td>Hydropotinae</td>
<td>Hydropotes Swinhoe</td>
<td>Hydropotes inermis</td>
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<tr>
<td></td>
<td>Suidae/Suinae</td>
<td>Sus Linnaeus</td>
<td>Sus scrofa</td>
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<td></td>
<td></td>
<td></td>
<td>Sus sp.</td>
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<td>Canis familiaris</td>
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<td>Vulpes sp.</td>
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<td>Felidae</td>
<td>Nyctereutes Temminck</td>
<td>Nyctereutes procyonides</td>
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<td>Ursus arctos</td>
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<td></td>
<td>Mustelidae/Mustelinae</td>
<td>Martes Pinel</td>
<td>Martes sp.</td>
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<td>Lutrinae</td>
<td>Lutra Brisson</td>
<td>Lutra Lutra</td>
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<td>Leporidae</td>
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<td>uncertain species</td>
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<td></td>
<td></td>
<td>Macaca sp.</td>
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<td></td>
<td>Colobinae</td>
<td>Rhinopithecus Milne-Edwardso</td>
<td>Rhinopithecus sp.</td>
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<td>Trachypithecus sp.</td>
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<td>uncertain species</td>
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<td>Rattus Fischer</td>
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<td>Caudata</td>
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<td>Andrias davidianus</td>
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<td>Reptilia</td>
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<td>uncertain species</td>
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<td>Acipenserida</td>
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<td>Acipenser sp.</td>
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<td>Aristichthys nobilis</td>
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<td>Cypriniformes</td>
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<td>Megalobrama sp.</td>
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<td>Megalobrama Peters</td>
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<td>Squaliobarbus Gunther</td>
<td>Squaliobarbus carcul</td>
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<td>Silurus</td>
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<td>Serranidae</td>
<td>Siniperca Gill</td>
<td>Siniperca sp.</td>
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</table>
Figure 3  Pictures of partial animal skeletons unearthed in unit T0202. (a) Right down thighbone of *Cervus albirostris*; (b) Metacarpus of *Rhinoceros*; (c) mandible of *Macaca mulatta*; (d) up molar of big *Cervus* sp.; (e) left shoulder bone of small *Cervus sup*.; (f) Metacarpus of *Bos* sp.; (g) up molar of *Bos* sp.; (h) right shoulder bone of big *Cervus* sp.; (i) scapula of little *Cervus* sp.; (j) left scapula of big *Cervus* sp.; (k) antler of *Muntiacus* sp.; (l) molar of little *Cervus* sp.; (m) scapula of moderate *Cervus* sp.; (n) right down mandible of little *Scrofa* sp.; (o) left metacarpus of *Cervus* sp.; (p) right m1m2 fore-tooth of *Cervus elaphus*; (q) cervical vertebra of moderate *Cervus* sp.; (r) dius of *Macaca mulatta*; (s) mandible molar of *Muntiacus* sp.; (t) cuspid of *Muntiacus* sp.
Table 4  Division phases depending on the variety of animal skeleton types and quantity in the Unit T0202

<table>
<thead>
<tr>
<th>Archaeological age</th>
<th>Phases</th>
<th>Sub-phases</th>
<th>Layers of T0202</th>
<th>Age (BC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The third to the fourth period of Ganjinggou Culture (the Warring States Period to Qin Dynasty)</td>
<td>5</td>
<td>19—18</td>
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<td>310—200</td>
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<td>380—310</td>
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<td>29—23</td>
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<td>500—380</td>
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<td>42b—30</td>
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<td>700—500</td>
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<td>The first period of Ganjinggou Culture (the west Zhou Dynasty to the Spring and Autumn Period)</td>
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<td>47—43</td>
<td></td>
<td>1000—700</td>
</tr>
<tr>
<td>Sanxingdui Culture in eastern Chongqing City to the first period of Ganjinggou Culture (Shang Dynasty to the west Zhou Dynasty)</td>
<td>□</td>
<td></td>
<td></td>
<td>51b—48</td>
</tr>
<tr>
<td>Zhouba Culture (the late Neolithic age to the late Xia Dynasty—early Shang Dynasty)</td>
<td>3</td>
<td>56—52a</td>
<td></td>
<td>2000—1750</td>
</tr>
<tr>
<td>The third period of Zhongba Culture (the late Neolithic age)</td>
<td>□</td>
<td></td>
<td></td>
<td>60b—57</td>
</tr>
<tr>
<td>The second—the third period of Zhongba Culture (the late neolith)</td>
<td>1</td>
<td>68—61a</td>
<td></td>
<td>about 2370—2250</td>
</tr>
</tbody>
</table>

Table 5  Animal skeleton quantities in different phases of the Unit T0202

<table>
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<tr>
<th>Phase</th>
<th>Sub-phase</th>
<th>Aves</th>
<th>Percent (%)</th>
<th>Reptilia</th>
<th>Percent (%)</th>
<th>Mammalia</th>
<th>Percent (%)</th>
<th>Fish</th>
<th>Percent (%)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>20</td>
<td>0.27</td>
<td>31</td>
<td>0.42</td>
<td>3703</td>
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<td>2</td>
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<td>0.06</td>
<td>23</td>
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<td>2017</td>
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<td>3820</td>
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<td>5864</td>
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<tr>
<td>3</td>
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<td>51</td>
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<td>122</td>
<td>0.78</td>
<td>6308</td>
<td>40.4</td>
<td>9114</td>
<td>58.4</td>
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<td>Sum</td>
<td></td>
<td>75</td>
<td>0.26</td>
<td>176</td>
<td>0.61</td>
<td>12028</td>
<td>41.6</td>
<td>16615</td>
<td>57.5</td>
<td>28894</td>
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</table>

<table>
<thead>
<tr>
<th>Phase</th>
<th>Sub-phase</th>
<th>Aves</th>
<th>Percent (%)</th>
<th>Reptilia</th>
<th>Percent (%)</th>
<th>Mammalia</th>
<th>Percent (%)</th>
<th>Fish</th>
<th>Percent (%)</th>
<th>Sum</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>193</td>
<td>4.64</td>
<td>195</td>
<td>4.69</td>
<td>1598</td>
<td>38.45</td>
<td>2170</td>
<td>52.21</td>
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<tr>
<td>Sum</td>
<td></td>
<td>193</td>
<td>4.64</td>
<td>195</td>
<td>4.69</td>
<td>1598</td>
<td>38.45</td>
<td>2170</td>
<td>52.21</td>
<td>4156</td>
</tr>
</tbody>
</table>

I1 and I2. 2) According to the total animal proportions in different periods of the time, Mammalias are the most in phases I1, I2 and I3, followed by Osteichthys, and Aves are the least; in phase II and phase III, Reptilias are (According to Table 3, Testudinatare is dominant in Reptilias.) the most, followed by Aves and Mammalia are the least. It is believed that abundant Osteichthys and Reptilias should relate to expansion of water surface, but increase of mammalia should connect with the expanding or well growing forest and the expansible grassland area and the Aves increase also relates to expansion of forest area. The above changes of different animal skeleton quantities can suggest change characteristics of ecological environment in local areas in different time.

According to proportions the main animal skeletons occupy in the equivalent strata in the Unit T0202 (Figure 5), the following can be found: 1) The fish skeleton change has two peak values and low values, thereinto, the first peak value appears in the I2 stage and the second peak value appears in the III2 stage. As a whole, the proportion of the fish skeleton occupies in various stages...
Figure 5 Proportions of the main animal skeletons in the equivalent strata in T0202.

is higher than others. 2) The mammalia skeletons are the most in stage I1, then, they decline undulately gradually, but increase slightly in stage III5. 3) Reptilia and Aves do not change obviously in all stages.

Table 6 gives the smallest individual number of mammal in various stages. It can be known that *Bos* sp. and *Bubalus* sp. only appeared in phase I1 and Phase I2. *Cervus albirostris* and *Hydropotes inermis* only appeared in phase III5. *Elaphurus davidianus* appeared in phase I1 and phase III5. *Cervus elaphus* appeared in phase III2. *Cervus* sp., *Elaphodus cephalophus* and *Muntiacus* sp. appeared in each phase, moreover, the smallest individual number distribution at various phases is quite even (almost about 2 or so). Rhinocerotidae mainly appeared in phase I3, phase III1 and phase III2. *Scrofa* sp. and *Canis familiaris* raised by people also appeared in each phase. *Vulpes* sp. appeared in phase I1, and they are not discovered hereafter. *Ursus arctos* appeared all the time after phase II. *Macaca mulatta*, *Rhinopithecus* sp. And *Macaca* sp. most appear.

<table>
<thead>
<tr>
<th>Species</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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</thead>
<tbody>
<tr>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
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<td>0</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td><em>Elaphodus cephalophus</em></td>
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<tr>
<td><em>Hydropotes inermis</em></td>
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<td>2</td>
<td>1</td>
<td>3</td>
<td>7</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>4</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
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<td><em>Ursus arctos</em></td>
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<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
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<td><em>Meles meles</em></td>
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<td><em>Macaca mulatta</em></td>
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</tr>
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<td>1</td>
</tr>
<tr>
<td><em>Rattus rattus</em></td>
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<td>2</td>
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<td>6</td>
<td>10</td>
<td>12</td>
<td>17</td>
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<td>6</td>
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<td><em>Rhizomys sinensis</em></td>
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</tr>
<tr>
<td><em>Rhizomys</em> sp.</td>
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<td>0</td>
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<td>3</td>
</tr>
<tr>
<td>Total Number</td>
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<td>9</td>
<td>10</td>
<td>8</td>
<td>11</td>
<td>15</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>

a) 0 denotes no discovery; 1—21 denote the quantities of the discovered spices.
inhabiting in glade and grassland, *Scrofa* *Muntiacus* region, some animals distributed widely, for instance, 1) In most cases between phases I1—II5, in Zhongba region, some animals distributed widely, for instance, *Muntiacus sp.*, *Elaphodus cephalophus* and *Muntiacus sp.* inhabiting in glade and grassland, *Scrofa* sp. and *Canis familiaris* raised by the ancient people, rodentia rabbit and *Rattus rattus*, which suggested that a fairly good ecological environment of forest and grassland was preserved at that time and the predecessors began to raise domestic animals from phase I1 till today. 2) Rhinoceros only appeared in phase I3, phase III1 and phase III2, which indicates that the ecological environment of grassland and wetland might be better in these phases[10], so the influence of human hunting was slim and rhinoceros could enjoy their lives. 3) *Macaca* sp. and *Ursus arctos* came along only after phase II, which may show that the forest condition is better for animals to live in phases II—III5. 4) The smallest individual number of *Bublus* sp., *bos* sp. and otters emerged in about phases I1—I3, which perhaps infers that water area during the early period was wider than that of the late period.

3 Environmental evolution features revealed by the unearthed extinct animal skeletons

The unearthed skeletons in the Unit T0202 include extinct animals of locality, for instance, Rhinoceotidae, and *Cervus albirostris*, etc. We may use the principle of “the present is the key to the past” to discuss the climate and the ecological environment in Zhongba area during 2370 BC—200 BC through analyzing their present distribution and habit.

3.1 Rhinoceotidae

The Rhinoceotidae skeletons were discovered in strata of phase I3 (2000 BC—1750 BC), phases III1—III2 (1000 BC—500 BC) at Zhongba Site (Table 3, and Figure 3), but now, only *Rhinoceros unicornis*, *R. sondaicus* and *Diceros rhinus sematraensis* are the existing Asian Rhinoceotidae, most of which distribute in damp and exuberant jungly grasslands or dense forests in tropical and sub-tropical areas in South Asia[8], such as India (with average annual temperature of 26.9[, and average annual precipitation of 1800 mm), Java (with average annual temperature of 27.6[, and average annual precipitation of 2263 mm), Sumatra (with average annual temperature of 27.1[, and average annual precipitation of 1500 mm), Myanmar (with average annual temperature of 27.4[, and average annual precipitation of 2681 mm) and Thailand (with average annual temperature of 27.8[, and average annual precipitation of 1498 mm). As a whole, Rhinoceotidae lives in the areas with average annual temperature of over 25[, and average annual precipitation of 1500—2000 mm. But the average annual temperature of Zhongba of Zhongxian County at present is 18[ and the annual precipitation is about 1198 mm. Since Rhinoceotidae had extincted all over China, we may primarily speculate that the average annual temperature and average annual precipitation of Zhongba in 2000—1750 BC and 1000—500 BC were higher than those of today according to the present distribution and living condition of Rhinoceotidae.

It is worthy to note that Mr. Wenhuanran’s research results about the historic changes of Rhinoceotidae in China[10] coincide with the fact that skeletons of Rhinoceotidae were found at Zhongba Site during 2000 BC—500 BC, which indicates that it was warmer in 4 ka—2.5 kaBP than today, so there were abundant Rhinoceotidae living in the upper and middle reaches of the Yangtze River. Since then it became cold gradually. In the first thirteen years of Zhenguang of Tang Dynasty (A.D. 797) and in the last year of Zhenguang (the early 9th century), Rhinoceotidae presented by tropical countries died in the Royal Zoo because of cold weather[10]. Therefore, the records mentioned above in history are consistent with the circumstances showed by skeletons of Rhinoceotidae unearthed in strata of Zhongba Site and may certify each other.

3.2 Cervus albirostris

Skeletons of *Cervus albirostris* unearthed at Zhongba Site are in phase I5 (310—200 BC) (Tables 3 and 6, and Figure 3). *Cervus albirostris*, also named after Yellow-buttock Deer and White-nose deer, is special species in Qinghai-Tibetan Plateau. The first specimen of *Cervus albirostris* was found by Przewalski[31] in the west of Gansu Province during his third exploration into eastern Tibet in 1876. In 1884, Przewalski got two specimens[12] in his fourth exploration into Qinghai Province. In 1892, Throld got one specimen around Lasa
(average annual temperature is 7.5°C and average annual precipitation is 420 mm)\textsuperscript{[13]}. The major distribution regions of *Cervus albirostris* are in prairie with elevation between 4000 and 5000 m and they also distribute along the rivers in the region with elevation between 2000 and 3000 m in the basins of the Yangtze River, Lancang River, Nuijiang River and Yarlung Zangbo River with average annual temperature of −5°C—5°C generally and annual precipitation of 200—700 mm\textsuperscript{[14]}. The main foods of *Cervus albirostris* are plants of Cyperaceae, Gramineae, Leguminosae, etc., which are dominant superiorly in meadow prairie, the brush and the thin forest prairie\textsuperscript{[13]}. From the situation of ecological environment of modern *Cervus albirostris*, we may infer that the average annual temperature and the annual precipitation must be lower during 310—200 BC than those of today, which is confirmed by the TOC research\textsuperscript{[15]} of Zhongba Site strata.

4 Comparison of skeletons unearthed in the Unit T0202 of Zhongba Site with pollen records of Dajiuhu peat

Dajiuhu basin with 1760—1700 m above the sea level lies in the valley basin in the mountain area (109°56′—110°11′E, 31°24′—31°33′N) in Shennongjia, west Hubei Province. The area is 16 km\textsuperscript{2}, average temperature is 7.2°C with highest temperature of 17.1°C in summer and lowest temperature of −21.2°C in winter. The rainfall is about 1500 mm per year. This area is seldom disturbed by human activities for few people live there, with marsh stratum and turf deeply imbedded pervasively. There are plenty of pollen fossils in the stratum strata, which can record the environment evolution information. The sampling was done in 2 cm space interval in the 297 cm thick turf stratum, and 148 samples were collected. A total of 10 bulk peat samples from different levels were dated using the accelerator mass spectrometry facility in the Institute of Heavy Ion Physics, Peking University. To obtain reliable radiocarbon dates, the samples were pretreated in the Institute of Earth Environment, Chinese Academy of Sciences, following the method described by Zhou et al.\textsuperscript{[16]}. The bulk peat samples were repeatedly treated with HCl-NaOH-HCl, and then rinsed with distilled water through a 60-µm mesh to remove sedge roots. The residual cellulose fragments with sizes less than 180 mm were picked out and dried for radiocarbon dating. Radiocarbon dates were calibrated using the CALIB 5.0 computer software\textsuperscript{[3,4]}. The calibrated radiocarbon dates were rounded to the last 10 years and were expressed as an age range with a 1σ standard deviation. According to Table 7, the AMS\textsuperscript{14}C ages of the peat core in this place are consistent with the strata relations and the age inversion phenomenon does not appear.

Through identifying, it is found that the pollen is rich and the species are abundant in this peat sediment, belonging to 137 (family) genera. Comparing the main pollen types (Figure 6) in Dajiuhu peat during 3200 BC—200 BC with the unearthed animal skeletons in unit T0202 of Zhongba Site, we may get some information as follows: 1) Before 2500 BC, the Dajiuhu region experienced longtime suitable climate, namely, the vegetation grew luxuriantly, and the total pollen of trees, bushes, moderate and dry fresh herb is very high. An event of climate and ecological environment worsening of short duration appeared between 2400 BC and 2500 BC when pollen concentration reduced obviously, and

### Table 7 AMS\textsuperscript{14}C data and calibrated results in Dajiuhu peat

<table>
<thead>
<tr>
<th>Laboratory number</th>
<th>Sample number</th>
<th>Depth (cm)</th>
<th>Material</th>
<th>Content of graphite carbon (mg)</th>
<th>¹⁴C age (a BP)</th>
<th>Calibrated age (1σ, cal.)</th>
<th>Mid value of calibrated AMS\textsuperscript{14}C data (BC)</th>
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</thead>
<tbody>
<tr>
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<td>DJ</td>
<td>25—26</td>
<td>peat</td>
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<td>510±30</td>
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<td>50—51</td>
<td>peat</td>
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<td>1940±30</td>
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<td>250—251</td>
<td>peat</td>
<td>3.21</td>
<td>12400±35</td>
<td>12543 BC—12254 BC</td>
<td>12398BC</td>
</tr>
<tr>
<td>XLLQ1640</td>
<td>DJ</td>
<td>280—281</td>
<td>peat</td>
<td>1.97</td>
<td>12650±35</td>
<td>13106 BC—12867 BC</td>
<td>12986BC</td>
</tr>
<tr>
<td>XLLQ1641</td>
<td>DJ</td>
<td>296—297</td>
<td>peat</td>
<td>1.96</td>
<td>13290±35</td>
<td>13979 BC—13630 BC</td>
<td>13804BC</td>
</tr>
</tbody>
</table>
Figure 6  Pollen concentration diagram of peat strata in Dajiuhu peat of Shengnongjia between 3200 and 200 BC.
the event obtained by the domestic scholars\[^{17,18}\] from other peat and strata of archaeological sites also indicates the existence of the event with low temperature around 4200 aBP. 2) The Dajiuhu peat here (Figure 6) spans the 1st warmer time (3000—1100 BC), the first lower temperature time (1100—850 BC) and the second warmer time (770—0 BC) in the past 5000 years in China\[^{19}\]. Although the animal skeletons in the Unit T0202 of Zhongba Site are not excavated to the strata before 2370 BC, the predominant pollens of trees and shrubs are high, and that of aquatic herb, fern, Gramineae and Ranunculaceae are also high between 3200 and 500 BC, which indicates the most suitable climate with warm and moist in the first warm time during the past 5000 years. 3) Skeletons unearthed in the Unit T0202 span 2172 years (AMS\[^{14}\]C Age), among which phases I1, I2, I3, II, II1, II2, III1, III4 and III5 are the first and the second warm periods in China in the past 5000 years, spanning 1870 years wholly. The whole 250 a with 100 a in the last period of phase II and 150 a in phase III1 (1000—700 BC) is the first lower temperature time in China in the past 5000 years. In addition, because Zhongba Site is in the valley of the upper course of the Yangtze River, belonging to middle subtropics, the influence of low temperature is not obvious, and the population before Warring States Period was less, so natural plants destroyed by humans were also limited, which was the genuine reason why abundant animal skeletons can be unearthed in strata between 2370 and 200 BC. 4) Comparing all the stage from phase I1 to phase III5, and between phases I1 and I2 the pollen concentration is the biggest followed by phase I3. The time of phase II spans longtime, during which other trees and shrubs are less correspondingly except Morus and Rutaceae, therefore the animal skeletons are also rare in this phase. But in the middle of phase II, Morus had two growth peaks and Rutaceae had one growth peak. According to Table 6, the smallest individual of Rhizomys sp. appeared twice in Phase II. Rhizomys sp. mainly ate bamboo, while the existence of bamboo indicates that the temperature at that time was not too low. The first low temperature in the past 5000 years appeared in Phase III1. Figure 6 shows that pollen concentration of Abies increased at that time, but at the beginning of phase III1, Morus still had a short high speed period of growth. For the aquatic herb, the pollen concentration was at the highest level in phases I1—I3, and then declined obviously after phase I3, which indicates that the climate has the tendency to become dry. As a whole, there exists plus correlation between plant growth peak and type and quantity of animal skeletons. For example, from phases I1 to I2, the pollen concentration is higher, accordingly, the quality of animal is larger. In phase III2, the pollen concentration of Morus, Ulmus, Quercus, Castanea, etc. is high, therefore, the environment of climate and ecology are better, so the smallest individual number of animals reaches to 15.

5 Conclusions

(1) Change of the smallest individual numbers indicates: 1) In most time between phases I1 and III5, in Zhongba region, some animals distributed widely, such as Muntiacus sp., Elaphodus cephalophus and Muntiacus sp. sp. inhabiting in glade and grassland, Serofa sp. and Canis familiaris raised by the ancient people, rodentia rabbit and Rattus rattus, which suggested that a fairly good ecological environment of forest and grassland was preserved at that period and the predecessors began to raise domestic animals from phase I1 till today. 2) Rhinoceros only lived in phase I3, phase III1 and phase III2, which indicates that the ecological environment of grassland and wetland might be better in these phases\[^{10}\], so the influence of human hunting was slim and rhinoceros could enjoy their lives. 3) Macaca sp. and Ursus arctos lived only after phase II, which may show that the forest condition is better for animals to live in phases II—III5. 4) The smallest individual number of Bublus sp., Bos sp. and otters emerged in about phases I1—I3, which perhaps infers that water area during the early period was wider than that during the late period.

(2) Since skeletons of rhinoceros were discovered in strata of Zhongba Site in phase I3 (2000—1750 BC) and phases III1—III2 (1000—500 BC), according to the climate and ecology environment where rhinoceros live now, the average annual temperature and precipitation during 2000—1750 BC and 1000—500 BC are regarded to be probably higher than that of today. Although Zhu Kezhen considered that the first low temperature period in the past 5000 years in China was between 1100 and 850 BC, massive pollens of Morus, Ulmus, Fagus,
Quercus, Castanea, etc. are found in Dajiuhu peat at that time, which should indicate that the climate was still moderate for humans to live at least in Dajiuhu basin and Zhongba Site.

(3) Because the skeletons of Gervus albirostris were unearthed in phase II5 (310—200 BC) in Zhongba Site, based on the climate and the ecological environment where those animals live now, the average annual temperature and the average annual precipitation in Zhongba area between 310 and 200 BC should be lower than those of today, which is confirmed by the TOC research of Zhongba Site strata.

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