Late Cenozoic Geomorphology, Geochronology and Physiography of Yuntaishan in Southern Taihang Mountain, North China

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Abstract: The late Cenozoic geomorphic features and geochronologic data of the Zhongfang River catchment in the Yuntaishan World Geopark are studied. Several quaternary geochronologic methods, including electron spin resonance (ESR), optically stimulated luminescence (OSL), thermo-luminescence (TL) and U-series are presented in this paper. The results suggest that there are two planation surfaces, named as the Taihang surface which is a peneplain of Taihang stage formed during Oligocene or Oligocene to early-middle Miocene period, and Tang-bien surface which is a mature wide valley of Tang-bien stage formed during late Miocene-Pliocene or Pliocene-early Pleistocene period and probably ended prior to 2.2–2.6 Ma based on ESR dating. After the Tang-bien stage, the incision and aggradation of the river formed six stream terraces with heights of 3–5 m, 8–12 m, 22–24 m, 28–38 m, 50–62 m and 80–85 m above the river bottom, respectively. The dating results of the alluvium sediments suggest that these terraces were formed during Holocene, 20–23 ka B.P., 110–120 ka B.P., 200–240 ka B.P., 840–1200 ka B.P. or ~450 ka B.P. and 1600–1800 ka B.P. or ~1100 ka B.P., respectively. These results indicate that episodic incision of the river, which controls the formation of the scenery in the Yuntaishan World Geopark, was mainly influenced by the periodic dry-wet climate change during late Cenozoic mountain uplift.

Key words: geomorphology, geochronology, planation surface, river terrace, late Cenozoic, southern Taihang Mountains, North China

1 Introduction

The Yuntaishan National Geopark is located in Xiwwu County in north-eastern Jiaozhuo city, Henan Province, China. It is the most wonderful scenic spot of five Geoparks in the Yuntaishan World Geopark and is located near the boundary between the second geomorphic step (the central plateau of China) and third geomorphic step of China (the eastern plain of China) in the southern Mt. Taihang (Fig. 1). Rocks in the Yuntaishan World Geopark include Archean metamorphic complex of which constitutes the cratonic basement of the North China Block (Gao et al., 2006), marine deposits of Neo-proterozoic and Cambrian-Ordovician consisting of limestones, dolostones, sandstones, shales and mudstones, coal-bearing strata of Carboniferous-Permian, loess, alluviums and pluvial deposits formed during Pliocene-Quaternary. The bedrocks all are usually horizontal or gentle dipping because there was no significant tectonic deformation since Neo-proterozoic in southern Mt. Taihang (Cui et al., 2002). During late Cenozoic, as a results of mountains uplift, rifting and climate change, the river incised in the horizontal or gentle dipping limestones, shales and sandstone strata and created numerous wonderful scenery including planation surface, canyon, river terraces and

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Fig. 1. The topographic and geomorphic sketch of the Zhifang River catchment of the Yuntaishan World Geopark.  
1, normal fault; 2, cliff; 3, gorge; 4, valley; 5, peak and its altitude; 6, the site of topographic profile; 7, the site of terrace cross profile; 8, sample locations for terrace deposits collected along Zhifang River.

waterfall in the Yuntaishan World Geopark (Zhao et al., 2005). Based on regional observations and new geochronological data, here we present some new results on the feature and geochronology of geomorphology and physiography stages in the Zhifang River catchment which is the main river system of Yuntaishan National Geopark (Fig. 1). This study offers the key factors for understanding the formation of the scenery of Yuntaishan World geopark and geomorphologic evolution of the Taihang Mountains during late Cenozoic.

2 Geomorphic Structure and Feature

The boundary between Yuntaishan and North China Plain is NE striking and consists of three subordinate topographic steps vertically strike of mountains from Jiaozhuo city or Xiuwu County to Yuntaishan (Figs. 1 and 2). The first step of the mountain area is located in northwestern Yuntaishan. It is about 800 to 1500 meters above the sea level and contains some canyons 400 to 1000 meters deep. In the area, the main mountain ridges are about 1500m high and form the boundary between the Shansi plateau and North China Plain. The second step of the mountain area is located in southeastern Yuntaishan. It is about 200 to 800 meters high with strath about 200 to 300 meters deep. The third step is piedmont alluvial plain of the Yuntaishan, which is about 80 to 150 meters high, and contains a few hills about 120 to 150 meters high as islands. These topographic steps are separated by boundary normal faults (F₁ and F₂ in Fig. 2). There are many obvious evidences for normal faulting along the boundary, such as fault escarpment, high-angle normal fault plane offset sandstone and limestone of late Proterozoic to early Palaeozoic Era, fault stria and calci-gauge, the drag deformation and fault contact of stratum. The relationships between faults, geomorphic surfaces and Quaternary deposits indicate that the normal faulting migrated to basin step by step from F₁ to F₂. The F₁ and F₂ faults which had been activated during Pliocene and early Pleistocene and the F₃, which maybe hidden in basin, have been activated since middle-late Pleistocene (Fig. 2).

In Yuntaishan, there are eight distinct geomorphic surfaces consisting of the Taihang denudation surface, Tang-hien planation and six terrace surfaces (T₁–T₆) (Figs. 2–6 and Plate I-1–6). The Taihang surface is a planation which is called by Qian Xuepu in central Taihang
Mountains near Pingshun County (Qian, 1984). It is a denudation surface similar to a peneplain preserved at a few summits and divide of hills at altitudes of 1200 to 1500 meters in Yuntaishan (Plate I-1). The relief of the Taihang surface is smooth about 100 to 250 meters on the planation. In some valley incising the Taihang surface and piedmont, the mature strath or denudation surface can be observed. This is the Tang-hien planation surface which is called by Willis in Tang-hien County located at piedmont of eastern Mt. Taihang (Willis, 1907). In the Zhifang River catchment, its typical topographic forms are the wide paleo-valleys about 90 to 120 meters above the valley bottom containing numerous and more or less extensive monadnocks about 130 to 160 meters above the valley bottom. There are often firm calcareous cemented conglomerates and speleothem observed on the floor of the Tang-hien strath (Fig. 3, Plate I-2, 3, 4).

There are six stream terraces with heights of 3–5 m, 8–12 m, 22–24 m, 28–38 m, 50–62 m and 80–85 m above the river bottom in valley or canyon incising Tang-hien strath. They have been named as T₁, T₂, T₃, T₄, T₅ and T₆, respectively (Figs. 4, 5; Plate I-4, 5). These terraces are mainly distributed in middle-downstream of the Zhifang River from the Yuntaishan waterfall to Wuchun village. The T₆ distributes near the Red stone gorge and Xi’anshan and is a rock-floored terrace on which a few meters thick calcareous cemented gravels covering on surface of limestone, sandstone or conglomerates of Tang-hien stage (Figs. 3, 4). Terrace 5 to terrace 1 (T₅–T₁) main distribute at confluence spur between tributary and mainstem and downstream. There are extensive farmlands on these terraces. They are almost all accumulation terraces and consist of thick-bedded gravels deposits. These terraces are locally rock-floored terraces in particular to T₃, T₄ and T₅, which deposits cover on conglomerates of Tang-hien stage or Paleozoic limestone (Figs. 4, 5). The form of these terraces can be relative simple, but their deposit sequences are often complicated by the facts that the accumulation is interrupted by phases of lateral erosion and accumulation phases can be covered. Based on some indexes containing stratigraphic and geomorphic relation, calcareous cemented development, consistency of gravel deposits, rubification of loess and number and size of calcareous nodular in loess intercalating or underlying terrace deposits, at least six well preserved fill-terrace deposits (T₆–T₁ deposits) and an older, consolidated gravels have been identified along the Zhifang River catchment. The oldest consolidated gravel deposits are conglomerates of Tang-hien stage and composed mainly of clast-supported, calcareous cemented, moderately sorted, sub-angular to sub-rounded gravel containing pebble to boulder-sized clasts. The strata are medium to thick-bedded and broadly distribute at bottom of
Fig. 3. The cross-section transecting the Red stone gorge of the Zhifang River in Yuntaishan (site I in Fig. 1).
1–3, same as 1–3 in Fig. 2; 4, Cambrian limestone; 5, dolostone of Ordovician; 6, calcareous cemented conglomerates of Tang-hien stage; 7, Speleothem calcilcreatia of Tang-hien stage; 8, calcareous cemented gravels deposits.

Fig. 4. The cross-section transecting the Zhifang River valley in the Yuntaishan (site II in Fig. 1).
1, limestone; 2, as 6 in Fig 3; 3, calcareous cemented alluvium; 4, gravel deposits cemented calcium carbonate; 5, alluvial gravels; 6, loess.
Table 1 Geochronological results on terraces and deposits of Quaternary in the Zhifang River catchment

<table>
<thead>
<tr>
<th>Serial</th>
<th>Location</th>
<th>Description</th>
<th>Composition</th>
<th>Method</th>
<th>Age (ka B.P.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>513-1-1</td>
<td>L1</td>
<td>Spelothem of Tang-hien stage, exposed on flank of bedrock strath.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>2583.57</td>
</tr>
<tr>
<td>322-2</td>
<td>L2</td>
<td>Calcarete of Tang-hien stage, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>606</td>
</tr>
<tr>
<td>512-1-1</td>
<td>L3</td>
<td>Calcarete of Tang-hien stage, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>2324.26</td>
</tr>
<tr>
<td>325-2</td>
<td>IV</td>
<td>Calcarete of Tang-hien stage, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>750</td>
</tr>
<tr>
<td>322-1-1</td>
<td>L2</td>
<td>Calcarete of Tang-hien stage, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>317</td>
</tr>
<tr>
<td>325-1-3</td>
<td>L3</td>
<td>Calcarete in middle of profile of T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1709.55</td>
</tr>
<tr>
<td>325-1-2</td>
<td>L2</td>
<td>Calcarete in upper of profile of T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1759.02</td>
</tr>
<tr>
<td>321-2-1</td>
<td>L3</td>
<td>Calcarete in middle of profile of T4 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1057.50</td>
</tr>
<tr>
<td>321-1-5</td>
<td>III</td>
<td>Calcarete of T4 stage, overlain by T5 deposits.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1643.48</td>
</tr>
<tr>
<td>318-1-1</td>
<td>L7</td>
<td>Calcarete of colluvium at piedmont, see Fig. 2.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1151.59</td>
</tr>
<tr>
<td>317-4-1</td>
<td>II</td>
<td>Carbonate-cemented gravel deposits in upper T4.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>908.75</td>
</tr>
<tr>
<td>324-1-2</td>
<td>I</td>
<td>Carbonate-cemented gravel deposits in upper T5.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>451</td>
</tr>
<tr>
<td>321-4-1</td>
<td>II</td>
<td>Carbonate-cemented gravel deposits in upper T4.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1195.81</td>
</tr>
<tr>
<td>324-2</td>
<td>L4</td>
<td>Carbonate-cemented gravel deposits, 1m below top of T4.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>845.92</td>
</tr>
<tr>
<td>324-2</td>
<td>L4</td>
<td>Carbonate-cemented gravel deposits, 1m below top of T4.</td>
<td>Calcareous cement</td>
<td>ESR</td>
<td>1245</td>
</tr>
<tr>
<td>324-4</td>
<td>III</td>
<td>Sand-silt deposits in middle of T4.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>216.2±2.06</td>
</tr>
<tr>
<td>514-3-1</td>
<td>Dan River</td>
<td>Sand-silt deposits in middle-lower of T4.</td>
<td>Silt</td>
<td>TL</td>
<td>78.1±6.7</td>
</tr>
<tr>
<td>325-4</td>
<td>IV</td>
<td>Carbonate-cemented gravel deposits, in middle of T4.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>214.0±13.2</td>
</tr>
<tr>
<td>325-3-1</td>
<td>IV</td>
<td>Calcareous nodular of Loess, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>117.1±6.5</td>
</tr>
<tr>
<td>325-3-2</td>
<td>IV</td>
<td>Calcareous nodular of Loess, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>272</td>
</tr>
<tr>
<td>326-6</td>
<td>L6</td>
<td>Loess, overlain by T4 deposits.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>183</td>
</tr>
<tr>
<td>517-3-1</td>
<td>III</td>
<td>Sand-gravel deposits in middle of T4.</td>
<td>Silt</td>
<td>TL</td>
<td>54.4±2.4</td>
</tr>
<tr>
<td>326-3</td>
<td>L5</td>
<td>Carbonate-cemented gravel deposits, in upper T4.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>213±2.1</td>
</tr>
<tr>
<td>323-2-3</td>
<td>III</td>
<td>Sand-gravel deposits in middle-lower section of T4.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>95.5±2.5</td>
</tr>
<tr>
<td>327-1</td>
<td>L8</td>
<td>Sand-gravel deposits in upper T4.</td>
<td>Calcareous cement</td>
<td>U-series</td>
<td>33.2±3.0</td>
</tr>
</tbody>
</table>

Note: the numbers of location and samples are corresponding to those of the sites in Figs. 1–5.

strath of Tang-hien stage or are exposed underneath the T4–T5 deposits (Figs. 2–5; Plate I-3). The T4–T5 deposits are primarily composed of unconsolidated to calcareous cemented, clast-supported, moderately sorted, sub-angular to rounded, locally imbricated, pebble to boulder gravel. They are characterized by medium to thick-bedded gravel deposits with planar-turbular and trough cross-bedding and tabular to lenticular bedding. There are usually medium to thick-bedded loess containing numerous calcareous nodular about 5 to 25 centimeters diameter intercalating the gravel deposits adjacent to hill slope or tributary spurs (Figs. 4, 5; Plate I-6). The advancing of consolidated of calcareous cemented gravel deposits and the improvement of number and size calcareous nodular in loess are key criterions to identify T4 to T5 deposits. The gravel deposits of T4 are almost all consolidated by calcareous cemented, but gravel deposits of T4–T5 are only well consolidated in upper section or top of terrace, medium consolidated in middle-lower section to T5, poorly consolidated in middle-lower section to T4 and T3, locally consolidated on top and unconsolidated in middle-lower section to T2. The deposits of T1 are the youngest unconsolidated alluvium containing sands and gravels. Because younger accumulation phases can cover older phases, the deposits of older phases are often intersected or overlain (Figs. 4, 5).

3 Geochronology of Geomorphic Stages

On the basis of the distinguishing on relative age of surficial deposits, electron spin resonance (ESR), U-series, thermo-luminescence (TL) and optically stimulated luminescence (OSL) methods were used to date surficial deposits covering on different landforms. The ESR and U-series are used to date non-pedogenic calcium carbonate in gravel deposits and calcareous nodular in loess. The TL and OSL are used to date silts and sands in gravel deposits and loess. The deposits of same terrace have been dated by more one technique to constrain the ages of terrace and geomorphic stages (Table 1). Theoretically, the actual time of terrace accumulation is often older than the ESR and U-series ages of non-pedogenic calcium carbonate and younger than OSL ages of sands and silts in deposits, but the discrepancies of age results between geochronometers or different samples collected from same terrace deposits are sometimes evident in geochronologic data from the Zhifang River catchment (Table 1). Here, after taking into account some factors influencing age results of deposits, including limits of different dating techniques themselves, the probably disturbance of samples after deposition, we preliminary bracket the timing of accumulation and incising for different terraces and Tang-hien surface according to the dating results of terrace deposits and discuss the possible correlation between river incision mountain uplift and climate change.

There are two ESR dates bracketing the ended timing of the Tang-hien conglomerates to about 2.2–2.6 Ma (Table 1), but three other dates (317–750 ka), lying in middle-Pleistocene, are obvious younger and may be resulted from recrystallization of non-pedogenic calcium carbonate after formation of deposits or geomorphic surface. The four ESR
results provide minimal ages for $T_8$ of 1100–1800 ka B.P. (Table 1) and three of them yield relatively concordant dates of 1600–1800 ka, but one result (1057.5 ka) is a little younger because possible recrystallization after deposition. Four ESR results of $T_7$ deposits, two from the Zhifang River and two from the Qingtian River which is a tributary of the Dan River in north-western Bo’ai County and a scenic spot of the Yuntaishan world geopark, bracket the down-cutting timing range of $T_7$ to 450–1200 ka B.P., and the more reliable timing to 840–1200 ka B.P. because of possible recrystallization of calcium carbonate in terrace deposits. There are four dates for $T_6$ deposits. The U-series age coming from the Zhifang River and one OSL date from the Dan River give relatively concordant ages and provide minimal ages for $T_6$ of 200–240 ka B.P. corresponding with marine isotope stage (MIS)-7. In comparison, the ESR and TL ages from the Zhifang River obviously are overestimate and underestimate respectively for $T_6$ because of possible contaminated rock clasts, disturbance of deposits or other inconspicuous reasons. The U-series date from $T_5$, deposits and two ESR ages from calcareous nodular of loess underlying $T_5$ deposits constrain the incision timing of $T_5$ about 110–120 ka B.P. corresponding with MIS-5 and coinciding with the phenomena of $T_5$ gavels bedding overlying loess containing $S_1$ or $S_2$ paleosol horizon at location L6 in Fig. 1. The OSL and TL dates from $T_5$ deposits and loess underlying $T_5$ gravel deposits are obvious underestimate because of some problems on dating technique or disturbance of deposits. The U-series and OSL dating results indicate deposition timing for $T_2$ deposits at about 22–96 ka B.P. corresponding with MIS-4 to MIS-2 and the incision timing of $T_2$ at about 20–23 ka B.P. Based on geomorphic feature of $T_2$ and regional comparison, the TL date from $T_1$ deposits is obvious incompatible with the dates from $T_2$ deposits and ought to be an overestimate for $T_1$. It suggests that the $T_1$ is formed during Holocene. Because it is actually difficult to accurately explain the reasons for the discrepancies between dates in same terrace, the incision timing of $T_2$ and $T_3$ is also possible later to about 1100 ka B.P. and 450 ka B.P. respectively.

Based on the dating results of terrace deposits, we suggest that the conglomerates and strath surface of Tang-hien stage were formed prior to 2.2–2.6 Ma. Terraces 1 to 6 were formed during Holocene, 20–23 ka B.P., 110–120 ka B.P., 200–240 ka B.P., 840–1200 ka B.P. or ~450 ka B.P. and 1600–1800 ka B.P. or ~1100 ka B.P., respectively. But unfortunately, we haven’t obtained the dating results of Taihang planation surface because the relative deposits of planation surface aren’t preserved in Yuntaishan area. However, we suggest the planation surface was formed during whole Oligocene or Oligocene to early-middle Miocene period based on previous research in Taihang mountains area (Qian, 1984; Wu et al., 1996; Wu et al., 2001).

4 Physiographic Stages and Geomorphic Evolution

Based on the evidences for geomorphology and geochronology of the Zhifang River catchment and referring to others research on phsiography of northern China (Willis, 1907; Wang, 1937; Bian, 1940; Liu, 1962; Qian, 1984; Li et al., 1989; Yuan et al., 1995; Wu et al., 1996; Wu et al., 2001). Here we drew the longitudinal profile of the Zhifang River (Fig. 6) and summarized the physiographic stages and history of geomorphic evolution of the Yuntaishan during late Cenozoic (Figs. 2, 6).

(1) The Taihang epoch is a cycle of erosion and possible comprising all of the time of Oligocene and much of Miocene following Paleocene-Eocene Taihang mountains uplifting corresponding to rifting of North China basin. The
cycle of erosion was very long for completing peneplanation of mountains and forming planation surface of Taihang stage.

(2) The Yuntai epoch is a new added physiographic stage between Taihang and Tang-hien stage comprising middle-late Miocene or late Miocene. In this stage, river incision and tectonic activity are prominent, and the entrenched meander and canyons were produced following Miocene mountains uplifting resulted from normal faulting of F₁ fault among Taihang Shan boundary fault zone. In the Zhifang River catchment, the NE striking bedrock cliffs paralleling to F₁ fault, 500 to 600 meters high between the first and second topographic step, cliff-like valley above the Tang-hien surface, the 200 to 300 meters high stream knickpoints between upstream and mainstream, and the Yuntai waterfall caused headward erosion or retreat of stream knickpoints following uplift are all geo-heritages formed during the incision stage (Figs. 1, 2, 6; Plate I-2, 4).

(3) The Tang-hien stage occurred during Pliocene and possible continued to early Pleistocene. It is an accumulation stage after mountains uplift of the Yuntai stage. In this stage, the normal faulting became weak and gradually migrated toward F₂ fault. The river reduced the relief of valley and formed the mature strath or denudation surface (Tang-hien surface) through widen valley and aggrading thick conglomerates in the Zhifang River valley (Figs. 2, 6; Plate I-2, 4).

(4) The Incision of Fenhe stage and accumulation of early Nihewan stage, being roughly equivalent to Fen-ho epoch of Willis (Willis, 1907), comprise whole early-early Pleistocene and possible partly middle early-Pleistocene (about 2.2 to 1.6 or 1.1 Ma). In the stage, the normal faulting of F₁ fault stopped and the strath underneath T₆ and T₇ deposits were formed.

(5) The Red-stone gorge epoch comprise mostly all time since middle-late early-Pleistocene (about 1.6 or 1.2 Ma). This is a key stage for geomorphic process during Quaternary in the Yuntaishan area. In the stage, the normal faulting migrated to F₂ and F₃ faults and resulted in mountain uplifting and following river rejuvenated. River showed monotone downcutting in the Red stone gorge valley because of stream cutting in

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Fig. 6. The longitudinal profile of the Zhifang River catchment.
1–5, as symbols in Fig. 3; 6, Carboniferous-Permian shale; 7, alluvium of Pleistocene period; 8, Holocene deposits; 9, speculative surface.
Sinian sandstone, but showed episodic downcutting and accumulation correlation with alternating ice ages and interglacial stages during Quaternary in under-stream of the Zhifang River and other large rivers where stream cutting in relative soft of limestone and shale of Cambrian-Ordovician period and formed multi-generation terraces. Based on the geochronological evidences for the Yuntaishan area (Table 1) and other researches on river terraces and physiography of the North China (Bian, 1940; Liu, 1962; Li, 1989; Yuan, 1995), we suggested that the formation of T5 to T1 of the Zhifang River catchment are roughly corresponding to that of terraces of the Yellow River and physiographic stages of the North China. For example, the formation of T5 corresponding with accumulation of late Nihewan stage and incision of Huangshui stage, and the accumulation of early Zhoukoudian, late Zhoukoudian and Malan stage and incision of Tongchuan, Qingshui and Banqiao stage, corresponding with accumulation and incision of T5 to T3 respectively, and formation of T1 also corresponding with two stages called accumulation of Gaolan stage and latest incision in Holocene (Wu et al, 1996). In the Zhifang River catchment, many geo-heritages are formed during river incising stages corresponding the Red-stone gorge epoch, such as isolated peaks a few tens meters high in valley and accumulation and incision of terraces of T5 to T1, the gorges entrenching the Tang-hien surface which resulted from stream incising hard red sandstone on the upthrow block of F1 fault (typical such as the Red stone gorge), numerous small waterfall a few to tens meters high on the valley floor corresponding with small rock-knickpoints which were resulted from river cutting on strata interbedded hard and soft rock.

5 Conclusions

Based on geomorphologic method and geochronologic data of the Zhifang River catchment in southern Taihang Mt., the geochronological framework of late Cenozoic physiography and geomorphology for the Yuntaishan is constructed. The results show that there are two planation surfaces, named as the Taihang surface which is a penplain formed during whole Oligocene or Oligocene to early-middle Miocene period, and the Tang-hien surface which is a mature wide valley formed during late Miocene-Pliocene or Plioene-early Pleistocene period and probably ended prior to 2.2–2.6 Ma based on ESR dating. After the Tang-hien stage, the incision and aggradation of river formed six stream terraces with heights of 3–5 m, 8–12 m, 22–24 m, 28–38 m, 50–62 m and 80–85 m above river bottom from young to old respectively. The dating results of alluvium suggest that these terraces were formed during Holocene, 20–23 ka B.P., 110–120 ka B. P., 200–240 ka B.P., 840–1200 ka B.P. or ~450 ka B.P. and 1600–1800 ka B.P. or ~1100 ka B.P. respectively. The results indicate that episodic incision of river, which controls the formation of scenery in the Yuntaishan World Geopark, mainly influenced by periodic dry-wet climate change under the background of late Cenozoic mountain uplift and boundary normal faulting between mountain and basin. Because of limit dating of deposits sampled from terraces and caves and the discrepancies between the geochronological data, detailed down-cutting and accumulation processes of river in Quaternary and accurately incision timing of river and planation surfaces are not well constrained, but this research on geomorphic evolution of Yuntaishan have provided an important window for understanding the details on geomorphic evolution for southern Mt. Taihang during late Cenozoic.

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**Plate I**
1 the Taihang planation preserved at summit of the Yuntaishan with altitude of 1300 to 1400 meters.
2 the Tang-hien surface and T4 around the Red stone gorge.
3 the conglomerate deposited in the Tang-hien stage.
4 the Tang-hien surface and river terraces of the Zhifang River catchment.
5 the terraces 2 to 4 of the Zhifang River.
6 the gravel deposits of terrace 3 and the underlying loess.
Plate I

1. Taihang planation

2. Tang-hien surface
   Red-stone gorge

3. Tang-hien denudation surface and the monadnocks

4. Strath of Tang-hien stage
   Farmland on T4
   Farmland on T5
   Tang-hien denudation surface and the monadnocks

5. The calcareous-cemented gravels of T6
   Loess-containing calcareous nodular

6. Loess-containing calcareous nodular