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Age and genesis of the Danxia landform on Jianglang Mountain, Zhejiang Province

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Abstract: Jianglang Mountain is situated at the transitional zone of South China fold-system, Jiangshan–Shaoxing deep fracture zone and Baoan–Xiakou–Zhangcun fracture zone. The forming of the Xiakou basin was attributed to the pull-apart fault depression by the above fractures in earlier Cretaceous, afterward, series deposits such as Guantou formation (K_1g), Chaochuan formation (K_1c) and Fangyan formation (K_1f) which belong to Yongkang group, the lower Cretaceous layer accumulated in the Xiakou basin. In late Cretaceous, the above fractures occurred to extrude and the basin began to uplift, meanwhile, amounts of tension fissures and joints were produced since Cenozoic, which accelerated water-dicing into bed-rock. Consequently, landform-building processing: weathering, eroding and collapsing etc. were prevalent as finally to develop the so-called Danxia landform. The Jianglang Mountain landscape zone of the Danxia landform to apply for world natural relics are relying on unique and unparalleled peak, sky-split valley with vivid stones and reviving of platform. What is more, there is significance of study at lithology, stratigraphy and paleo-biology. According to dating for specimen of ophitic vein through-crossing the Yongkang group of Yafeng Peak by K-Ar method, this article revealed the uplift age of red-bed basin to be 77.89±2.6 MaBP (K_2) i.e. late Cretaceous, and it is the first chronological datum of Danxia landform research in China.

Keywords: Zhejiang; Jianglang Mountain; Danxia landform; landform development; landform genesis

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1 Introduction

Presently, Chinese geomorphologists, National Construction Ministry and concerning departments are concentrating on joint-application for the World Natural Heritage, including Langshan Mountain-Wanfoshan Mountain of Hunan Province, Danxiashan Mountain of Guangdong Province, Taining of Fujian Province, Longhushan Mountain-Guifeng Mountain of Jiangxi Province and Jianglang Mountain-Fangyan of Zhejiang Province. Here is a preliminary research result of Jianglang Mountain in Zhejiang of the Danxia landform of applying for World Natural Heritage. The Danxia landform is widely developed in China but rarely distributed in other countries. Over 780 sites of the Danxia landform across China have been found by Huang Jin (1999, 1991 and 1982) in field work in last decades, also a lot of scrupulous observation on configuration of the Danxia landform was conducted. Besides, Zeng Zhaoxuan *et al*. (1978), Chen Guoda (1935), Hao Yichun *et al*. (1986) and Peng Hua (2001, 2000 and 2000) have obtained abundant fruits in field researches into geomorphologic properties of the Danxia landform and practice of tourism development. The author (Zhu *et al*., 2005; Zhu *et al*., 2000) proposed that little deep research had been conducted on basic theory and genesis upon the Danxia landform, e.g. scarce of reliable absolute age dating data. However, many literatures deduced uplift age of red bed basin only by quantitative means. Aimed at this, an ideal dating rock sample and a reliable dating datum were obtained during field survey, therefore, some new points for genesis about Danxia landform may be put forward, as concerned discussion is demonstrated below.

2 Natural background of the Danxia landform around the Jianglang Mountain area

As the nominating site of the World Natural Heritage, Jianglang Mountain is situated in southwest of Jiangshan City of Zhejiang Province, which is located at the north piedmont of the Xianxialing Mountains and border land between Zhejiang Province, Fujian Province and Jiangxi Province. Its geographic coordinate is ranged between 118°22'–118°49'E and 28°15'–28°52'N. The place of interest has core area of 8.30 km^2, buffering zone of 43.09 km^2 and 51.39 km^2 for total area. The utmost east border is at Yinyuan Village of Baishi Town, and the south border is to the south of Yangtian Village of Nianbadu town. Also, to the west of Macheao Village of Daqiao Town and to the north of Shankeng Village of Sidu Town are for the west border and the north border respectively. The study area lies in the subtropical zone with monsoon rainy climate, with annual mean temperature of 17.1℃ for and annual precipitation of 1650–2200 mm. Xu Xiake, ancient geographer of China, ever delineated Three-Sliced Stone of Jianglang Mountain as: *when approaching the Three-Sliced Stone step by step, the gigantic stone breaking into double at a blink*, *and then into three, it is changeable with visitor's footsteps and going phantasmagoric in tune with wreathed clouds*. Here is obviously an animated portraiture about it.

Geologically, Jianglang Mountain is located in the transitional zone of South China fold-system, Jiangshan–Shaoxing deep fracture zone and Baoan–Xiakou–Zhangcun fracture zone. The forming of the Xiakou basin was attributed to the pull-apart fault depression by the above fractures in earlier Cretaceous, afterward, series deposits such as Guantou formation (K_1g), Chaochuan formation (K_1c) and Fangyan formation (K_1f) which belong to the Yongkang group, the lower Cretaceous layer accumulated in the Xiakou basin (Regional Geologic Survey Group of Zhejiang, 1999). Afterwards, these fractures occurred to extrude and the sedimentary basin began to uplift in late Cretaceous. Meanwhile, amounts of tension fissures and joints were produced since Cenozoic, which accelerated water-dicing into bed-rock. Consequently, landform-building processing: weathering, eroding and collapsing etc. were prevalent as to develop so-called Danxia landform.

As to lithology, the outcrop in this region is mainly the Yongkang group of lower Cretaceous and distributed across the central and northwest area, the detailed constituents of Yongkang group are Guantou formation, Chaochuan formation and Fangyan formation (see Figure 1).

2.1 Guantou formation (K_1g)

It is the base layer of Yongkang group at lower Cretaceous and is scattered around the area. Two segments can be divided and the middle segment is lost. The lower one is sand conglomerate, sandstone, dark grey sand thin-bedded mudstone, macker and silt or fine sandstone on occasion.

2.2 Chaochuan formation (K_1c)

Its bottom is gravel sandstone and intermediate or coarse sandstone. The middle sector is amaranth lumpish sandstone, sandy mud of conglomerate with river phase. And the upper sector is amaranth sand mudstone cross-bedding with sandstone conglomerate. Moreover, the sedimentary strata of Chaochuan formation are sandwiched with lava, basalt, rhyolite and volcanic clastic rock.

2.3 Fangyan formation (K_1f)

It is key body of the Danxia landform of Jianglang Mountain. Its constituents are amaranth or light grey lumpish conglomerate in mega-thickness (Figure 2), between it is sandstone, sand conglomerate with lens or igneous rock. It should be a suite of sedimentary strata derived from alluvial fan, valley, lake plain, to delta zone.

3 Characteristics of the Danxia landform for Jianglang Mountain

Three aspects of reason for the World Natural Heritage of Jianglang Mountain in the viewpoint of geomorphologic specialists, which are demonstrated as below in the course of recent research.

3.1 Grand and unique solitary peak, lane-valley in old-age

Of the 8 candidate sites of the Danxia landform for the World Natural Haritage, Jianglang Mountain exclusively belongs to the type in old age. Around it is lowland within the Cretaceous strata, but the Three-Sliced Stone of Jianglang Mountain stands against the blue sky. Among the Three Sliced Stones, Langfeng Peak is 824 m in height, while Yafeng Peak and Lingfeng Peak are corresponding to 737.4 m and 765.0 m. Their base is Big lane-valley,

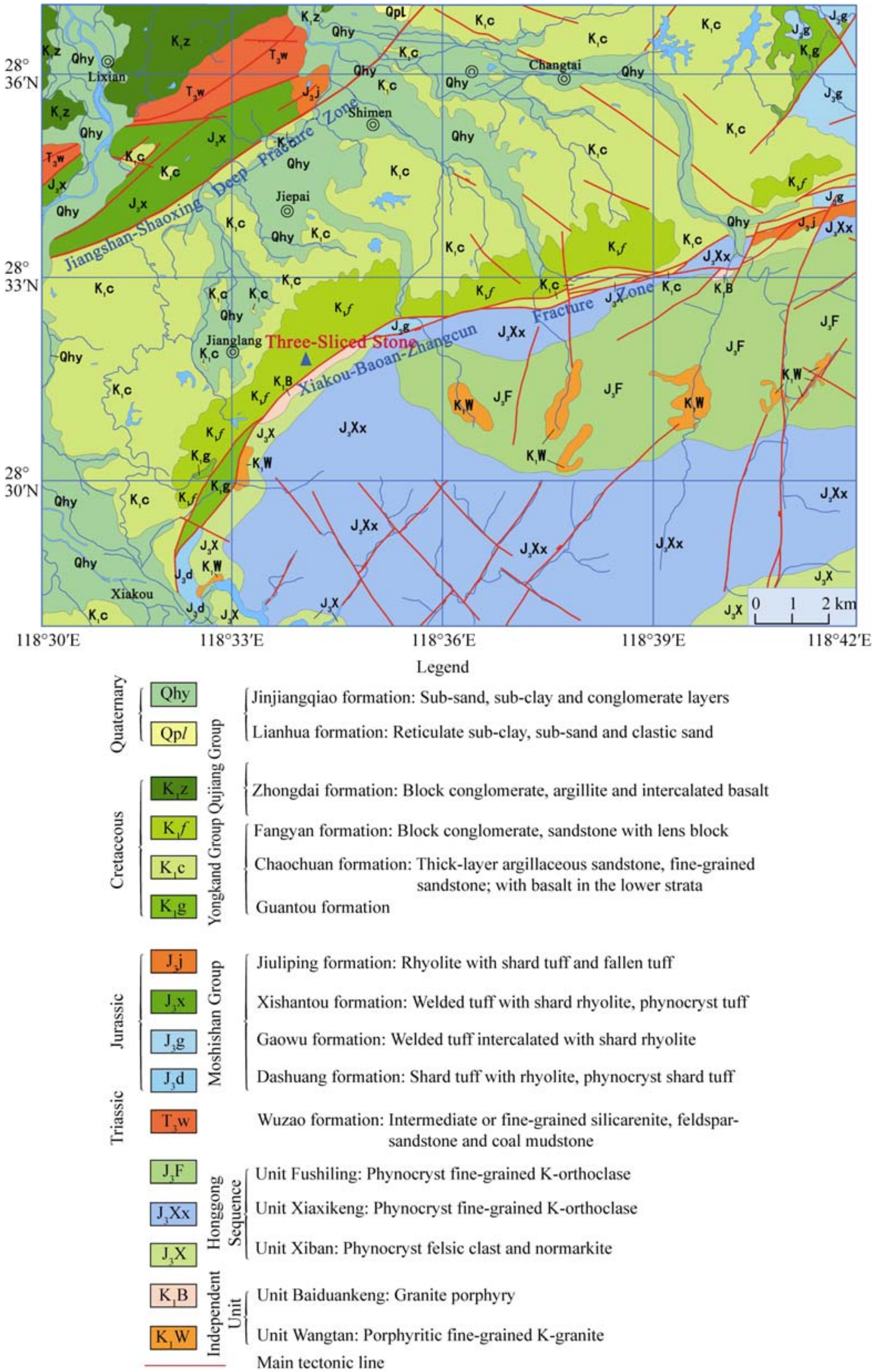

Figure 1 Geological map of Jianglang Mountain region

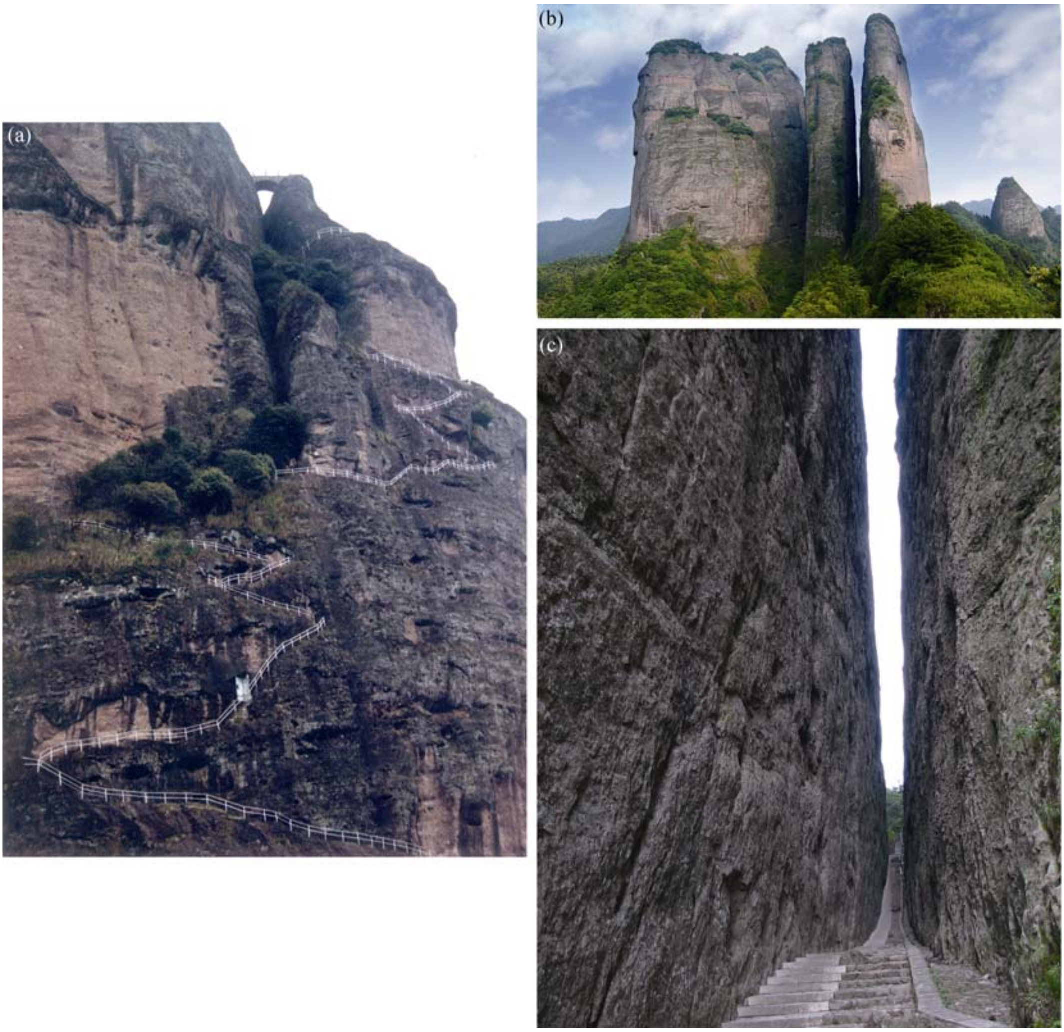

Figure 2 Characteristics of the Danxia landform, Jianglang Mountain

Small lane-valley and Dengtian Platform (Figure 2a) at about 500 m above sea level, on which the three sliced stones are erected shoulder by shoulder at respectively 369.1 m (Langfeng Peak), 286.6 m (Yafeng Peak) and 268 m (Lingfeng Peak) in height with the dyke-shaped rock peak (Figure 2b). Between Yafeng Peak and Lingfeng Peak is the first rank lane-valley all over the China with 308 m in length by 298 m in height by 3.5–4.3 m in width on the floor and about 10 m on the ceiling, along the sharp cliff iron-like lane-valley in one's awestruck motion (Figure 2c). This peculiar scenery in old age is incomparable across China and even rare in the world.

3.2 Unique platform revival phenomenon and lithologic research significance

In geomorphology, it would be two levels of planation surface of the Big and Small lane-valley floor at 500 m above sea level. Meanwhile, the broad alluvial plane around the Jianglang Street and Yafeng area tells a history of tectonic stable period. As to the 4.8 m and 8.0 m (relative height) second level terrace, which implies tectonic uplift in recent period, i.e.

there exists platform-reviving phenomenon. And re-uplift of the Three-Sliced Stone on base of Big and Small lane-valley floor at 500 m is obviously evidence for revival. It is related to adverse thrust along Jiangshan–Shaoxing patch belt in recent inland plate neo-tectonic movement, which attributes, correspondingly, to continuous diving rush from the Pacific Plate toward the Euro-Asian Plate. That is to say, the Three-Sliced Stone experienced double episodes even three episodes of rising events. So it is worth further researching on point of complexity of evolution episode and peculiarity.

Result of Jianglang Mountain standing upright against the sky is close to its lithologic properties. When the Fangyan formation deposited in Cretaceous, the deep fracture continued operating, also magma kept gushing up, volcanic vein was formatted finally in the Fangyan formation. That is why many ophitic outcrops can be seen in the Yongkang group (Figure 3), and both sides of Yafeng Peak see ophitic vein are for instance. These vertical formation of diabase across the Yongkang group reflected intensity of tectonic uplift, secondly, magma mainly went along tension joints and thirdly, particularly ophitic texture and plagioclase, dark minerals assemblage etc. forming sufficiently hard to resist to weathering. Those rock veins along the tension fissures play a role of cementing and reinforcement, simultaneously, reflecting magmatism in elder age of the Danxia landform in Jianglang Mountain. In addition, conglomerate with volcanic detritus enhances anti-weathering degree on account of high temperature acting and then cooling like quenching.

3.3 Scientific values for event-stratigraphy and paleo-biology research

Around Jianglang Mountain area, the Guantou formation (K_1g), Chaochuan formation (K_1c) and Fangyan formation (K_1f) contain some paleo-biologic information such as mussel, Conchostracans and ostracods etc. fossils from lacustrine phase. Likewise, on Oct. 26th 1977 the Xiakou Basin is abundant of dinosaur fossils and so, there is wide significance for dinosaur extinction and stratigraphic comparison researches (Ding *et al.*, 1999). A suite of dinosaur fossils was found in Jinjiaoyi Village at the foot of piedmont of Jianglang Mountain, obtaining rumpbone, phalange and vertebrae etc. 30 specimens in sum at about 200 kilograms. On June 27th, 1999 another situs found dinosaur fossils in West Circle Road in Jiangshan City. As a result, there is a key area for research into relationship between evolution of paleo-biology and regional environment.

4 K-Ar dating for ophitic vein sampled from small lane-valley of Jianglang Mountain

Although domestic and abroad scholars concluded that Jianglang Mountain is an elder-typed Danxia landform relying on field survey, and the re-uplift of the Three-Sliced Stone based on Big and Small lane-valley at about 500 m to be as symbol of platform revival, it is but a quantitative presumption. The author sampled two ophitic specimens (Figure 3) in the volcanic vein in the Small lane-valley in December 2007 and committed to the State Key Laboratory of Geologic Institute of the State Earthquake Bureau to date by K-Ar method. Using coefficients: $\lambda=5.543\times10^{-10}$/a, $\lambda_e=0.581\times10^{-10}$/a, $\lambda_\beta=4.962\times10^{-10}$/a, $^{40}K/K=1.167\times10^{-4}$/gram-molecule/gram-molecule. After testing repeatedly, the dating result is 77.89±2.6 MaBP (late Cretaceous K_2). This is first dating datum for formation of the Danxia landform in China according to the issued literatures.

5 Discussion on development of the Danxia landform

Generally, inner force from tectonic movement and weathering denudation from outer force co-operate to produce the Danxia landform. As to forming of the Danxia landform, two periods are the development for deposits formation of the Xiakou depression basin and the lacustrine basin uplift since Cenozoic period. The lacustrine depositional environment in Mesozoic supplied material conditions for lithification. Since late Jurassic, especially Cretaceous red beds and series of rupture structures were produced, the growth story of the Danxia landform started.

5.1 Faults and joints

Large scale of ruptures around Jianglang Mountain area goes mainly in direction of NE, NNE and nearly NS in response to field survey. For the Three-Sliced Stone, it is ranged in III-shapedness with close relationship to extension of corresponding ruptures. It is Shishang Village–Hemu fracture zone and Baoan–Xiakou–Zhangcun fracture zone which belong to the southwest section of Jiangshan–Shaoxing deep fracture zone that control the landform pattern and ridge range (Figure 1). Vertical scratches on the fault surface whose dip is 215º–220ºSW and dip angle is at 80º–85º near Xiakou basin in earlier Cretaceous in Changtai Town indicate the upper block falling and lower block rising suggesting mechanic property of tenso-shear. Figure 4 shows distribution of joints around Jianglang Mountain. Obviously, two groups of joints in orientation of NW–SE and NE–SW form main frame. And the Three-Sliced Stone is under the control of NW–SE joints, hence forming the “three-mountain and double-valley” landscape (Figure 3). Additionally, the strike of valleys, lane-valleys and sky-split valleys around the Jianglang Mountain area is most consistent with NW, NW and nearly NS joints (Table 1).

5.2 Dilapidating process

Dilapidation is an important processing for the formation of the Danxia landform. In the area of Jianglang Mountain, landslip, collapse and fallen rocks can be seen everywhere, moreover, dilapidation of cliff and lane-valley are usually accreted, e.g. fallen rocks in Big and Small lane-valley (Figure 5) and big rock beneath the Levitated Temple. These prove that dilapidating is a key step for the Danxia landform.

5.3 Differential weathering process

Besides landform of split sky, lane-valley and valley with relation to dilapidation, flat caves’ growth is related to dilapidation from differential weathering. Table 2 and Figure 6 are appraisal results of specimens (K_1f) sampled from Jianglang Mountain with polarization microscope. Table 3 lists oxides concentration of specimens measured by ARL-9800 X-ray fluorescent spectrometer (made by ARL Co., Switzeraland) at Contemporary Analytical Center of Nanjing University. Some characteristics can be summed as below based on Table 2, Table 3 and Figure 6.

Figure 3 Features of dolerite vein running through the Yongkang group of Yafeng Peak

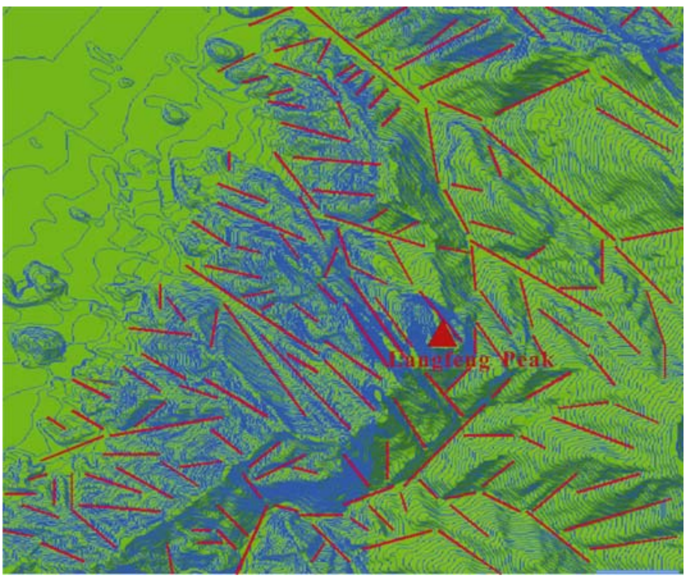

Figure 4 Joints distribution in Jianglang Mountain region

(1) Volcanic gravel and rock detritus of Fangyan formation (K_1f) account for high proportion, and SiO_2 content is relatively high between 44.9%–75.8% implying its anti-weathering capability. This is one of reasons for the Jianglang Mountain towers straightly for long.

(2) Proportion of igneous gravel in Fangyan formation is 60%–70%, and main types include ignimbrite, acid fulgurite (rhyolite), intermediate fulgurite (andesite). After volcanism

Table 1 Main joints distribution of Fangyan formation (K_1f) in Jianglang Mountain region

No.	Sampling site	Longitude/E Latitude/N	Above sea level/m (GPS)	Joint strike
1	Big lance valley	118°33.883′ 28°33.701′	497	325°NW–345°NW
2	Split sky valley	118°33.695′ 28°31.944′	525	315°NW
3	Valley below Wentian Pavilion	118°33.944′ 28°31.761′	829	15°NW–20°NW
4	Baibu valley	118°33.166′ 28°32.284′	464	240°SW
5	Small split sky valley	118°33.957′ 28°32.244′	310	255°SW
6	Split sky at Zipao valley	118°34.004′ 28°32.276′	315	20°NW
7	Split sky at Canglongchuxia valley	118°34.018′ 28°32.347′	290	330°NW
8	Valley below the Levitated Temple	118°32.344′ 28°33.319′	346	360°N
9	Waterfall at the Zhulin Temple	120°10.387′ 28°54.338′	159	170°SE
10	Cliff of eastern wall of the Yafeng Peak	118°33.883′ 28°33.701′	497	X-shaped strike ① 345°NW, dip angle 84° ② 160°SE, dip angle45°
11	Cliff of western wall of the Yafeng Peak	118°33.695′ 28°31.944′	525	Oblique joint surface strike 325°NW, dip angle 22°
12	Creeping rat on the cliff	118°33.228′ 28°31.685′	622	Oblique joint surface strike 290°NW, dip angle22°

like quenching course in steelmaking process, these volcanic gravels become incomparably hard and highly anti-weathering.

(3) The tuff detritus in Fangyan formation (K_1f) is composed of magmatic detritus, crystal detritus and base materials. Most detritus has de-vitrification phenomenon with quartz detritus at 15%. Also, the welded erosion is common, showing the rock with property of resistance to weathering for compact density.

(4) The content of SiO_2 of both ophitic vein (Figure 5) on one side of Yafeng Peak and ophitic rock wall outcrop on Dengtian Platform is comparatively low, however, the peculiar ophitic texture, plagioclase and dark minerals form hard rock mass.

(5) Sandstone ingredient of the Fangyan formation is apt to be eroded. Its major gelatin material is calcite which accounts approximately for 20%–25%, so water erosion is frequent. Besides, there are packed pore space structure which may be products of water erosion. On the other hand, the rock has stomatic texture, especially in rhyolite detritus, which is apt to argillize intensively. Consequently, weatherproof ability of sandstone is relatively poor.

Additionally, Table 4 (Geochemistry and Geophysics Survey Institute of Zhejiang, 1990; Hunan Institute of Geology, 1987) shows that the compression strength of conglomerate is high and stable usually keeping at about 118.9 Mpa, and sandstone is at between 69.2–171.7 Mpa, siltstone, however, at the lowest level of 12.2–63.4 Mpa.

According to the above appraisal results, here are several cognitions: (1) The rock mass composed of conglomerate and volcanic detritus has high compression-resistant and weatherproof capability, but the rock mass of sandstone, calcite sandstone and detritus sandstone

Table 2 Result of thin section identification (polariscope) for K_1f formation of Jianglang Mountain

Number	Sampling site	Altitude (a.s.l.)/m	Rock character	Optical orientation	Lithologic characteristics through micropolariscope	Serial number
2	Langfeng Peak	742	Fine sandstone	Polarization /×4 Orthogonality/×10	Sand-formed fabric with 5% conglomerates (only one conglomerate in the litho-slide at 5 mm in diameter); clastic grains are in poor psephicity and sorting as well as with sharp edges, and their size are mainly ranged from 0.1–0.5 mm. These clastic constituents include detritus, quartz, feldspar, and a little biotite. The bigger size grains are almost volcanic detritus, in which conglomerates are pelleted rhyolite clasts (acid igneous lava) made from 8% of feldspar, 42% of quartz and 30% of fill. The packing materials are 5% of iron oxides, 10% of argillaceous cement, 5% of calcite cement and 10% of fine silt. Moreover, the calcite cement is heterogeneous distribution and mostly in mixture with ferro-oxides or in patch conformation.	Figure 6a
18	Zhonggu Cave, Langfeng Peak	527	Conglomerate	Orthogonality/×4	Main structure appears in conglomerate with a proportion of 60%, however the percentage for gravels and cement are respectively 30% and 10%. The gravels are in weak sorting and moderate psephicity, accounting for about 90%. Their size ranges between 2–10 mm, that of grains from 0.2–2.0 mm. Constituents of gravels are quartz and feldspar with a total proportion of about 75%. The igneous detritus are mainly welded tuff, acid lava; in which the welded tuff is typical that it looks distinct pseudo-fluxion structure compositing of plastic shard, quartz and feldspar crystal detritus. Andesite clasts are made from semi-directional lath-shaped plagioclase, xenomorphic granular dark minerals, of which there are 10% of calcite cement and a little of iron oxides.	Figure 6b
20	Zhonggu Cave, Langfeng Peak	527	Calcareous sandstone	Orthogonality/×4 Orthogonality/×10	The sample slide shows middle-fine sand-shaped structure with intermediate sorting, and their sizes are arranged between 0.1–0.4 mm as well as different psephicity in which volcanic detritus is relatively good but adverse to quartz. The detritus probably takes 70% of the whole rock including acid volcanic detritus (35%), quartz (20%), feldspar (15%, mainly are acid plagioclase and striped feldspar) and zircon on occasion. Cements are calcite or iron oxides. Granular gap takes up 20% and in part sees calcite cement welding. Apparently, the rock gap is as a result of calcite erosion.	Figure 6c
23	Western side of Yafeng Peak	523	Welded tuff	Orthogonality/×4	The rock slide is composed of jelly detritus, crystal detritus and host crystal. On one side of the slide, the jelly minerals account for about 70% but the other side with little of that. Their shapes are erratic striped or flame-shaped in semi-directional arrangement at 0.5–5 mm in length by 0.1–1.5 in width. All the detritus seems in-vitrified phenomenon demonstrating feather-shaped fabric. The crystal detritus part is about 30%, in which feldspar is 15%, quartz 15%. Most is high quartz with well-grown pyramidal face and cylindrical surface. Feldspar in the sample includes perthite, orthoclase, and orthoperthite, in which orthoperthite is twin-crystal and strip structure. The host material is about 40%. Because the pseudo-fluxion structure is blurred, the sample may be a weak welding degree.	Figure 6d
25	Vein at western side of Yafeng Peak	523	Diabase vein	Orthogonality/×4	The rock sample has ophitic and inter-grained structure composed of plagioclase (60%) and dark minerals(40%). These plagioclase are euhedral streak-shaped with 0.2–0.8 mm in length, mostly with twin-crystal and complex twin crystal. The dark minerals are semi-euhedral or xenotopic granular which is packed in feldspar gap and have been eroded. In addition, their angle of extinction is around 40°.	Figure 6e
36	Eastern side of Lingfeng Peak	575	Shard tuff	Polarization /×10	The sample is shard tuff structure and its main constituents are shard, crystal detritus and fillings. Of which, the shard takes up 68% in shape of bow, cambered surface with multi-angle. The size of these detritus is from 0.1 to 0.2 mm with felsitic texture, its form can be observed clearly by uni-polarization scope. Detritus is 12%, and 0.1–1.2 mm in size, but 0.5–1.0 mm is common size. Its components are feldspar, quartz and biotite, in which the feldspar accounts for 8%, quartz 2% and biotite 2%. Fillings is about 20% with main elements of fine volcanic dust, between the granular is blurred boundary.	Figure 6f

Figure 5 The phoenix like block at Danongxia valley between Langfeng Peak and Yafeng Peak

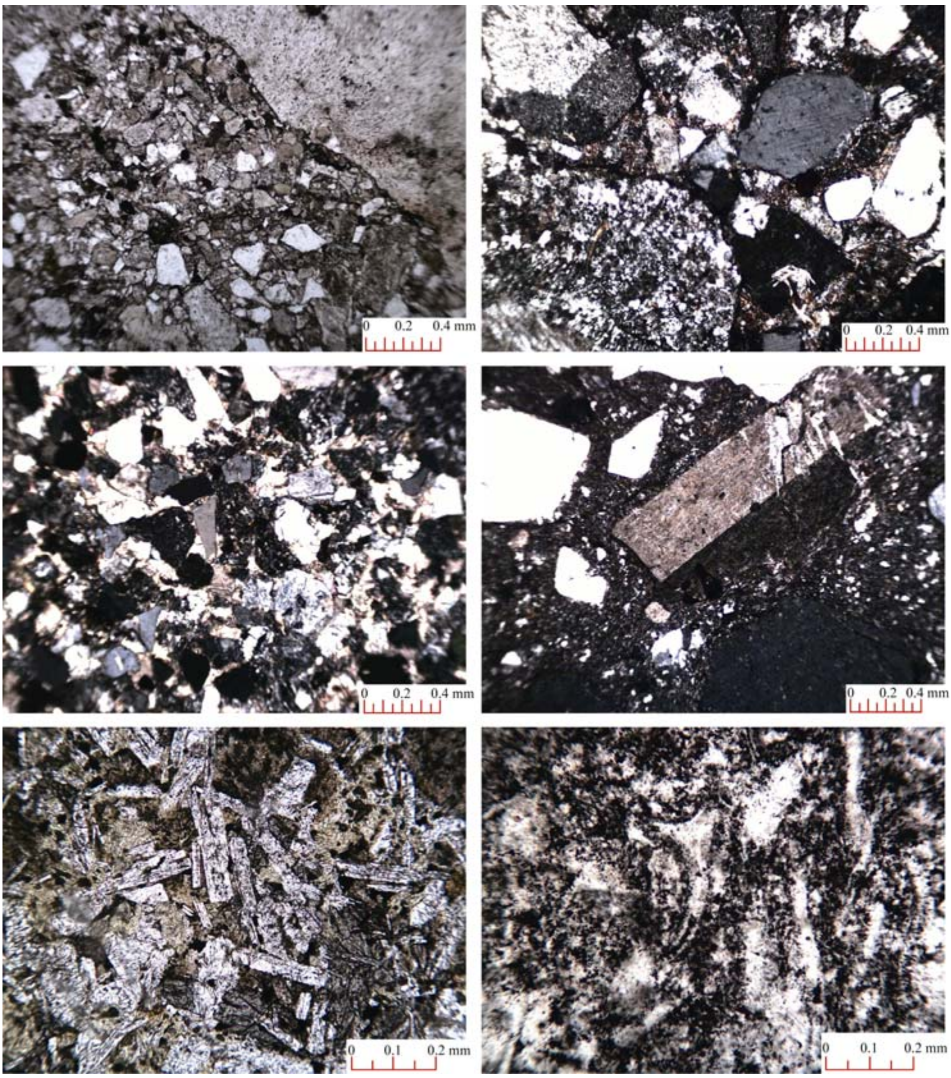

Figure 6 Photograph of thin section identification (polariscope) for K_1f formation of Jianglang Mountain

Table 3 Results of oxide content by X-fluorescence spectroscopy method for K_1f bedrock in Jianglang Mountain

No.	Sampling site	Lithology	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)
2	Langfeng Peak	Detritus sandstone	64.9	15.6	3.37	3.33
5	Langfeng Peak	Conglomerate	56.1	14.5	3.49	10.9
18	Zhonggu Cave	conglomerate	66.8	16.4	3.06	1.65
20	Zhonggu Cave	Calcite sandstone	60.2	16.2	4.58	5.96
21	Huixianyan Rock	Sandstone	64.5	14.9	2.68	5.13
23	Western cliff of Yafeng Peak	Welded tuff	75.8	12.3	1.91	0.353
24	Western cliff of Yafeng Peak	Detritus sandstone	70.1	15.2	2.74	0.608
25	Vein of western cliff of Yafeng Peak	Diabasic vein	44.9	19.1	10.1	7.74
27	Northern part of western cliff of Yafeng Peak	Breccia	65.8	15.5	4.21	1.39
28	Southern part of western cliff of Yafeng Peak	Volcanic detritus sandstone	68.9	15.0	2.82	1.59
36	Southern part of eastern cliff of Lingfeng Peak	Shard tuff	57.4	20.9	3.68	2.21
40	Southern part of Lingfeng Peak	Gravel sandstone	63.1	16.5	2.96	5.06
41	Southern part of Lingfeng Peak	Conglomerate	62.5	18.3	3.31	3.83

Table 4 Mechanical characteristics of sandstone for the Danxia landform in Jianglang Mountain

Index item	Conglomerate	Sandstone	Siltstone
Compression strength/Mpa	118.90	69.20–171.70	12.2–63.4
Malactic index	0.57	0.59	------------

are comparatively soft, correspondingly with low compressive strength and weatherproof ability. Such the inter-layered strata with soft and hard stratigraphic characteristics exert far-reaching influence upon dilapidation and formation of the Danxia landform. (2) Both field survey and appraisal under polarization microscope found proportion of pore in conglomerate is larger than that of sandstone so that infiltrating water easily runs through conglomerate layer and stagnates on surface of sandstone with poor infiltration. Because of amounts of calcite of gelatin in sandstone (Table 2 and Figure 6), the infiltrating water contains carbonate dioxide from air so the water includes ions like CO_3^{2-}, HCO_3^{1-} as to dissolve calcite component and the result is fast weathering in sandstone, then is so-called differential weathering between conglomerate and sandstone and last the dilapidation phenomenon happens. If the differential weathering happens among thin layers, there can see concave sandstone layer and convex conglomerate layer accompanying lots of rocky niches on cliff (Figure 7). Table 5 demonstrates the geometrical data of main flat caves in Jianglang Mountain area, e.g. Huixianyan Cave, whose base rock belongs to Fangyan formation, is near Langfeng Peak with 11.85 m deep, 27.17 m wide and 4.8 m high, and Figure 7b sees some big fallen rocks (Figure 7b).

It should be point out that the dilapidation and flat-cave processing of differential weathering run through every stage of the Danxia landform.

5.4 Relationship between tectonic uplift and mountaintop surface

In a panoramic view, three level mountaintop surfaces are very pellucid (Figure 8):

(1) The first level is at about 800–900 m a.s.l., e.g. the mountaintop surface of the

Figure 7 Landscape formed by differential weathering and collapse in Jianglang Mountain

Figure 8 Three class summit surfaces in jianglang Mountain

Three-Sliced Stone (824 m) and that between Southeast Forest Farm and Qingtangkeng (878 m).

(2) The second level is at about 500–600 m, e.g. base rock of the Three-Sliced Stone i.e. the floors of Big and Small lane-valley (497–525 m a.s.l.), Peak Tower's top (478 m), and that of to northwest of Jianglang Mountain (591 m), Mt. East Forest Farm (531 m) etc.

(3) The third level is at about 20 m or so. This level is mainly lowland at the piedmont, e.g. Qingshantou (215 m) to the west of Jianglang Mountain, Baishatu (212 m), Maoxiang (207 m), Baikeng (179 m), Anli (188 m), Linggangkou Peak surface (231 m) and Yujiawu (215.8 m) etc.

Table 5 Features of main flat caves for K_1f formation in Jianglang Mountain

No.	Sampling site	Longitude/E Latitude/N	a.s.l./m	Depth/m	Width/m	Height/m	Orientation
1	Huixian Stone	118°33.841′ 28°31.933′	460	11.85	27.17	4.80	350°NW
2	Tiangong Cave	118°33.936′ 28°31.807′	546	9.15	14.50	4.50	240°SW
3	Jingxin Stone Room	118°33.934′ 28°31.864′	568	8.67	15.73	4.60	30°NE
4	Zhonggu Cave	118°33.901′ 28°31.875′	527	24.73	20.23	3.16	20°NE
5	Xiaohuixian Stone	118°33.957′ 28°32.244′	260	4.35	20.5	3.77	285°NW
6	Levitated Temple	118°33.957′ 28°32.244′	366	6.70	30.4	9.80	270°W

The three-level mountaintop surfaces represent different denudation stages in variant tectonic movements around the Jianglang Mountain area. In the study region it is scanty of sediments in the upper Cretaceous and Paleogene, but according to the existing red beds in Cretaceous, it would infer that first denudation surface was built in late Oligocene (episode after the Himalayan movement); the second denudation surface was formed in the earlier Quaternary and the third denudation surface (piedmont surface) was constructed in the middle Quaternary (middle Pleistocene–late Pleistocene).

The base rock of the Three-Sliced Stone is about 500 m a.s.l., and its lower boundary is similar to the second denudation surface showing that the Three-Sliced Stone has been formed in its rudiment before Quaternary, but two uplift episodes making it grand and proud.

That the history about Jianglang Mountain ever experienced a three-stage uplift can be also evidenced by valley section and knick-point. Field survey found that the three levels of knick-points would mark off different uplift heights in the development of the Three-Sliced Stone: the first level of knick-point is on top of the Langfeng Peak (824 m), the second level of knick-point on Dengtian Platform (580 m) and on rock threshold of Gucun–Yujiawu (250 m) is the third one. The height of knick-point is identified with that of corresponding denudation surface. What is more, valleys below the second level point e.g. Dengtian Platform, Zhilong and the front of Levitated Temple are mostly in “V-shaped” pattern. Meanwhile, near Sujialing to the south piedmont of Jianglang Mountain develops the second grade terrace (relative height at 4.8 m and 8 m), also the Shishangcun–Hemu fracture zone is in activity after early Pleistocene and rivers began to cut clastic sediments of Tangxi formation. Above all, neotectonic fractures around the area have inherited and attached to some previous properties and Jianglang Mountain might be still uplifting.

6 Summary of the development of the Danxia landform in Jianglang Mountain

In sum, the development stages of the Danxia landform can be delineated as Figure 9.

(1) The formation of the Danxia landform has experienced the construction of the Xiakou basin, depositing of red beds, tectonic uplift of the layers, tectonic development, dilapidation, differential weathering, formation of flat caves and weathering-denudation-conveyance etc.

(2) Two fracture zones of the Shishangcun–Hemu zone, southwest section of Jiangshan–

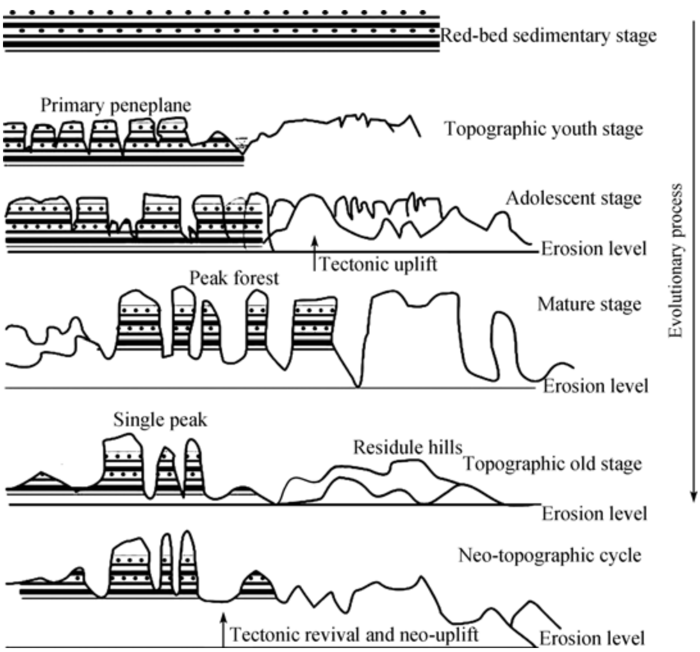

Figure 9 Establishment of Danxia landform in Jianglang Mountain

Shaoxing deep fracture zone, and the Baoan–Xiakou–Zhangcun zone, to the southeast of Jianglang Mountain, control the main geologic and geomorphic frame. Tectonic symbols reveal that it was just the tension from the fractures to herald the Xiakou basin, then strata of Guantou formation (K_1g), Chaochuan formation (K_1c) and Fangyan formation (K_1f) started to deposit, i.e. a suite of sedimentary strata represented terrestrial resource detritus combination which includes alluvial fan, limnic plain, and delta deposits. Dating of ophitic sample from west side of Yafeng Peak by K-Ar method shows that the two mentioned rips happened to squeeze and Xiakou basin began to rise during 77.89±2.6 MaBP (K_2) of late Cretaceous. Meanwhile, the layer of Fangyan formation was outcropped gradually, the suspended surface round the rock body became in figure, correspondingly, the rock body produced numerous tension joints for release of stress. On the other hand, magmatism made lava extend along these tension fissures, so metamorphism produced diabase, space-grained structure, plagioclase and dark minerals combination whose resistance to weathering is strong. These veins not only reinforced the whole rock, but reflected platform revival of the Danxia landform for the Jianglang Mountain in elder period as well.

(3) Since the Cenozoic age the strata in the Xiakou basin have formed lots of joints in process of the basin uplift, whose major trends are in NW, NE, or nearly NS. In addition, there are X-shaped joints and oblique joints. Just these joints through rock speed up the weathering process. Consequently, series story of the growth on the Danxia landform such as vertical joints, sky-split valley, lane valley, canyon etc. was on the pipeline.

(4) According to lithological appraisal through microscope, the assemblage of conglomerate and volcanic detritus is so hard that it has stronger compressive and anti-weathering abilities than sandstone calcite, sandstone and clastic sandstone. Such interbedded strata with soft and hard layers induced differential weathering and dilapidation which is the main activities for the formation of the Danxia landform, as well as the reason for flat caves and rock niches on the cliff.

(5) There exists three-level mountaintop surface i.e. 800–900 m for the first level, 500–600 m for the second level and 200 m for the third level. Correspondingly, three-leveled knick point has each similar height representing three level planation surfaces during stable tectonic phase. For scarce of upper Cretaceous and Paleogene sediments, but there are Cretaceous red beds so as to infer that first denudation surface was built in late Oligocene (episode after Himalaya movement); Second denudation surface was formed in earlier Quaternary and third denudation surface (piedmont surface) was formed in the middle Quaternary (middle Pleistocene–late Pleistocene). Nowadays, the valleys below the second knick point are V-shaped, and second grade terrace are developing around Sujialing to the south piedmont of Jianglang Mountain, suggesting that Jianglang Mountain still keep rising slowly.

(6) In Jianglang Mountain area, flat-topped, round-capped and top-spired peaks, variant caves, rock niches etc., superbly polar peak, precipitous cliff, split sky fissure and mysterious lane-valley etc. are scattered here and there, magic landscapes will make a traveler heartquake at each step. In bird view on top of Langfeng Peak, there are mild hills extending in silhouette, winding rivers running in meandering rhythm, and so the Three-Sliced Stone is more outstanding on the background of low hills and wide plain with broad river valley as a result of lateral cutting of the rivers here.

(7) As the growth phase is concerned, Jianglang Mountain is in its elder period. In view of this, aesthetics or geology is the Danxia landform of Jianglang Mountain unparalleled and irreplaceable for its unique and peculiarity around China or world.

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