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# Mountain Evolution and Environmental Changes of Huangshan (Yellow Mountain), China

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Abstract: Huangshan (Yellow Mountain) is located in southern part of the lower reaches of the Yangtze River. The highest Lotus Flower peak is 1,864 m above sea level. Formative ages of the Huangshan and its granite, process of mountain geomorphic evolution from the Eocene to Quaternary, environmental changes of Quaternary, formative origin of beautiful peaks and fascinating rocks were studied and the questionable "Pleistocene glaciation" was also discussed in this paper.

Key words: mountain evolution, environmental changes; questionable "Pleistocene glaciation," Huangshan, China

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Huangshang (Yellow Mountain) is located in southern part of the lower reaches of the Yangtze River, 30°31'N and 118°11'E. Its highest Lotus Flower peak is 1,864 m above sea level. It is one of the ten celebrated scenic spots in China and was included in the World Natural and Cultural Heritage List by UNESCO in 1990. One of the major reasons for including it in the list is because of Huangshan's important value for geological and geomorphic scientific researches.

In the thirties, Lee (1936) proposed the "confirmatory evidence of Pleistocene glaciation from the Huangshan"[1]. In the sixties, the first author questioned the problem of Pleistocene glaciation at the south of the Yangtze River, including Huangshan and Lushan[2,3]. The problem has become an important controversial problem in Chinese earth science[4,5].

Huangshan bas now become a famous travel region in the world. At the same time, the disputed problem of Pleistocene glaciation at Huangshan has also aroused the interest of many geographers and geologists. Since the eighties, the geological and geomorphic scientific researches of Huangshan have made a great advance. For examples, the Pre-Cambrian paleo-geographical studies, the radiometric dating of the Huangshan Granite, the folding age of the cover strata of the Huangshan Granite, the granitic inclusion and folding relation with the subduction of Paleo-Pacific pIate, the formation of the Paleogeomorphic surface at top and the geomorphic evolution process, analysis of sporo-pollen assemblages from red boulder clay, grain analyses and SEM analyses of red boulder clay, the calculations for temperatures and snow height of line in the last cold period of the Late Pleistocene, studies on the formation of those beautiful peaks and fascinating rocks at the mountain top, analyses of fracture distribution in granite in relation to valley development using Landsat image analyses, a new calculation of the area of exposed Huangshan Granite, and discovery of a new granitic stock from the image, and so on Base on research results mentioned above, the mountain evolution process and Quaternary envi-

ronmental changes of the Huangshan region are discussed systematically in this paper. Meanwhile, the problem of questionable "Pleistocene glaciation from Huangshan" is also discussed here.

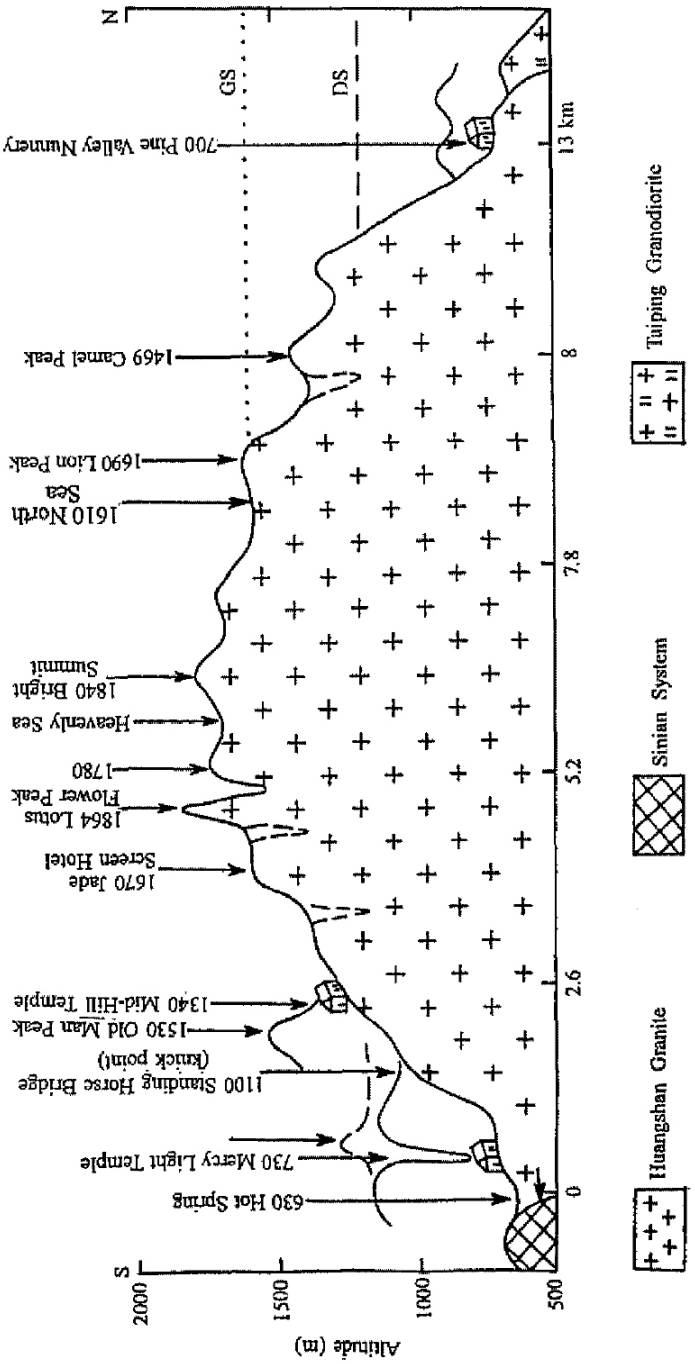
## 1 Formation of Huangshan Granitic Pluton and Its Germ of Huangshan

The Sm-Nd and U-Pb isotopic dating results of ophiolite and Pre-Cambrian granite show that this region was located at north margin of the peninsula of Jiangnan Paleo-land about 900 Ma[7,8]. The region subsided to a sea basin after about 700 Ma and accumulated marine sediments in the Early Paleozoic Era. The regions raised to a land about 400 Ma and then subsided again to a sea basin where rocks of the Carboniferous, Permian and Triassic systems accumlated. The region was uplifted to become a land after the Late Triassic Period about 200 Ma. The covering sedimentary strata were folded and magmagranite was intruded in the deep crust due to the subduction of Paleo-Pacific plate at a low angle under the southeastern margin of the Asian continental lithosphere in the Cretaceous Period[9]. Sedimentary covering strata formed parlell folds with NE-SW plunging axes. The Huangshan region is located at the juncture of the limb of Jiexi anticlinorium with the Taiping synclinorium[10]. The fold of covering strata and granitic magma intrusion are synchronous. The newly obtained $^{40}Ar$-$^{39}Ar$ isochron ages show that the Taiping Granodiorite is about 137 Ma old and formed in the Middle Yenshan movement of the Early Cretaceous Period[11]. Its exposed area is 478 $km^2$ from Landsat image analyses. The Huangshan Granite is about 125 Ma and is located south of the Taiping Granodiorite and south of the northern piedmont of Huangshan (Figure 1). It was formed in the Late Yenshan movement of the Late Cretaceous Period and has an exposed area of 226 $km^2$. A granitic stock at top of the Huangshan is called the Shizilin (Lion Peak) Granite. Its Rb-Sr isochron age is about 123 Ma and its exposed area is 10 $km^2$. We found another granitic stock with an exposed area of 11 $km^2$ to the south of the Shizilin Granite (Figure 2). The above mentioned dating results imply that the period of formation of the grantic pluton was at the budding stage of Huangshan. Therefore, we considered that: (1) the granitic magma intrusion is not from the Indo-China movement of Late Jurassic, but was intruded during the Middle-Late Yenshan movement of the EarlyLate Cretaceous; (2) the regional folds with granitic magma intrusion are synchronous and formed also in the Cretaceous Period; and (3) the regional folds and granitic magma intrusion are relation to the subduction of the Paleo-Pacific plate.

## 2 Formation of Paleo-geomorphic Surfaces at the Summit of Huangshan

The sedimentary strata of covering folds were degraded and eroded during uplift of the granitic pluton. The covering strata were removed and the lower granite was exposed and formed ancestral Huangshan- granitic mountains during the First Episode of Himalayan Movement from the Late Eocene Epoch to the Early Oligocene Epoch, about 45-35 Ma[12]. The graniitic mountains were eroded to a late mature stage of geomorphic development during a long-term relative stable age in the Middle-Late Oligocene Period. The landscape with about 200 m of relief consisted of relic hills (such as Lotus Flower peak, Bright Summit and Celestial peak) and shallow depressions (such as North Sea and Heavenly Sea) constituted the first paIeo-denudational surface (or gradational surface) at summit. The formative period of the surface, about 30 Ma B.P., has been called the Bright Summit stage by Huang[13]. The height of the remnant of the surface at present is 1,600~1,800 m above sea level (Figure 1 and TabIe 1).

The First denudational surface was uplifted and dissected by streams during the Second Episode of the Himalayan Movement in the Early-Middle Miocene Period, about 26~15 Ma and the central high part of the First paleo-denudational surface formed middle-lower mountains. These mountains were eroded by streams to full maturity and formed the Second denudational surface with lower mountains and wide valleys with relief of 200~500 m during the Middle Pliocene. The formative period of the Second surface is about 5 Ma and has been called the Old Man Peak stage by Huang (1995)[9]. The altitude of this Second (lower) denudational surface at present is from 1,200 m to 1,500 m above sea level (Figure 1 and Table 1).




GS—Lowest part of paleo-gradational surface (1 600 m); DS—Lowest part of denudational surface (1 100~1 200 m)

**Figure 1 S-N geomorphological section across Huangshan**

Table 1 Tectonic movement and geomorphic evolutional process of the Huangshan region

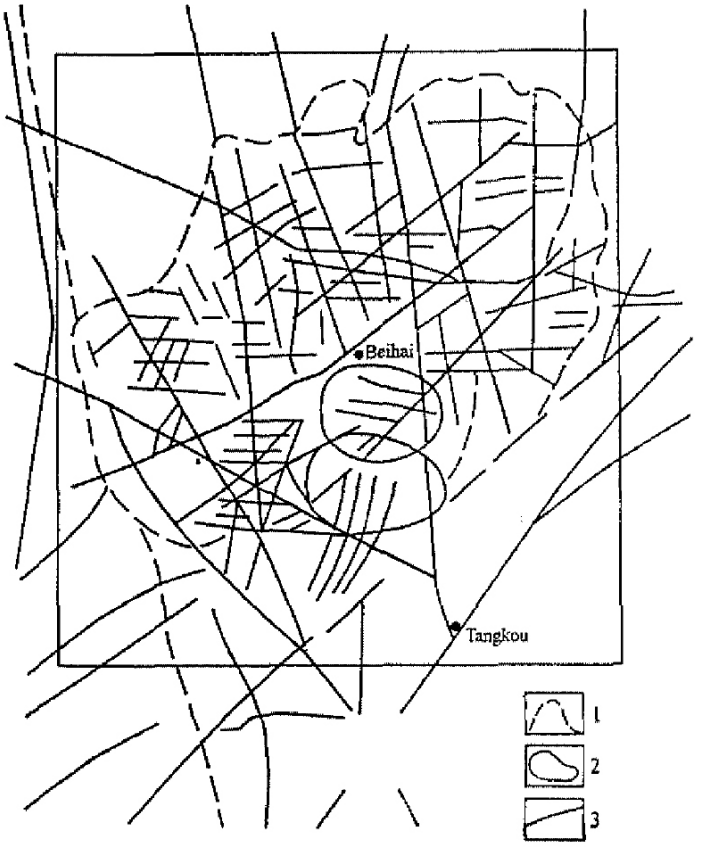
| Era B.P. (Ma) | Orogeny Himalayan Movement | Crustal Movement | Relief Features | Erosion Cycle |
|---|---|---|---|---|
| Q | Neotectonic movement | Uplifting stage of fault block | Middle mountain and canyon (the highest peak 1864 m) | Young stage (knick point 1100~1200 m) |
| 2.0 | | | | |
| Plio. | Third episode | Relative stable stage | Hill and wide valley (The second denudational surface) | Mature stage (Old Man Peak stage) (1200~1500 m a.s.l) |
| 7.0 | | | | |
| Mio. | Second episode | Uplifting stage | Lower mountain and V-shaped valleys | Young stage |
| 26.0 | | | | |
| Olig | | Relative stable stage | Lower hill and shallow deptression (The first denudational surface) | Late mature stage (Bright summit stage) |
| 37.0 | | | | |
| Eoc. | First episode | Uplifting stage | Middle mountain and canyon | Young stage Granitic mountain |
| 58.0 | | | | |

Notes: Himalayan Movement: First episode from Late Eocene to Early Oilgocene, about 45~35 Ma; Second episode from Early Miocene to Middle Miocene, about 26~15 Ma and Third episode from Late Pliocene to Early Pleistocene, about 4~2 Ma (After Huang et al., 1980).

## 3 Quaternary Rejuvenated Landscape

The Huangshan Granitic Pluton with its remnant Oligocene (the First) and Pliocene (the Second) Paleodenudational surfaces was uplifted greatly along the mountain-front fault zone, The Tangkou NE-SW fault, the Hot Spring NW-SE fault, and the near E-W faults of the intersecting granitic mountain in the Late Pliocene and Early Pleistocene by the Third Episode of the Himalayan Movement[12]. The First and Second Paleo-denudationaI surfaces have been eroded once again by streams to form deep canyons and middle mountains (Table 1). The knick points of present headward erosion are migrating back along the bottoms of the wide valleys of the second denudational surface. These knick points are at altitudes of 1,100-1,200 m above sea level. The knick point at Qingluan qiao (or Standing Horse Bridge) is 1,100 m above sea level[14]. Below the erosional knick point are deep V-shaped valleys that have been formed by fluvial erosion mostly along faults and joints.

A Landsat image showed that exposed Huangshan Granitic figure displays an elliptic shape with NE major-axis. This axial trend is consistent with the trend of the fold major-axis. The granite body is 20 km long, 14.4 km wide with an area 226.2 km$^2$ (Figure 2). A major fracture crosses into the middle part of Huangshan and cuts the mountain in half. The northwest part of the mountain is called Back Mountain. Valley development on Back Mountain is related to NNW and nearly S-N fractures, and tributary development of these valleys is reIated to nearly E-W fractures in the granite. The southeast part of the mountain is called Front Mountain. There valley trends relate to NE, nearly S-N and E-W fracture sets[15]. These valleys were formed by fluvial erosion along these verticaI or nearly vertical faults, fractures or joints to become straight line deep canyons. Both sides of these canyons have valley walls with very steep clifffs. Due to deep cutting, these canyons in the Huangshan region became a middle mountains with relief of 1,000 m or more.




**1—Scope of exposed Huangshan granite; 2—Scope of Shizilin granite; 3—Trajectory of linear structure**
**Figure 2 Linear structural feature map derived from analysis of Landsat image of the Huangshan region**

Pluvial fans were formed at the mouths of the valleys draining southeastern Huangshan. The largest pluvial fan is Baiting pluvial fan. It is 2.4 km long and 2 km wide, the top is at 360 m above sea level and the front margin is at 210 m above sea level. It consists of red boulder clay. The major-axes of boulders reach diameters of 1.5~2 m on the top part of the fan[16]. They have an imbricated arrangement and were infilled by gravel, sand and red clay in gaps. The gravel size decreases to 0.2 m in diameter in the distal part of the fan. The granitic boulders and gravels were weathered strongly and have a thick weathering crust. Based on the features of red vermiform clay and thick weathering crust, it is generally believed that the red boulder clay was formed in Middle Pleistocene.

## 4 Quaternary Environment and Its Changes

Clay mineral analyses of the red boulder clay show that its main clay minerals are gibbsite and illite. The clay mineral assemblages correspond to a humid subtropical environment of red loam formation[16]. Sporo-pollen assemblages from these red boulder clays show that their main components are woody plants (*Pinus*–*Keteleeria*–*Querus* and *Rhus*), indicating a deciduous broad-leaved and broad-leaved evergreen mixed forest and coniferous broad-leaved mixed forest[17]. These assemblages correspond to the broad-leaved evergreen forest in the piedmont zone and the deciduous broad-leaved

forest at 1,100 m above sea level of Huangshan today. It can be seen that this region had a humid subtropical environment similar to the present during deposition of the red boulder clay. According to studies on the deposits from Peking Man Cave in Middle Pleistocene age, from Layer 13 to Layer 3, climatic changes of cold and warm periods were between the temperate and warm temperate zone from780 ka to 250 ka[18,19]. Studies on sporo-pollen assemblages of the Hexian-Man site, Anhui Province, on the north bank of the lower reaches of the Yangtze River indicate that during the middle period of the Middle Pleistocene, about 300~420 ka[20], a warm temperate zonal environment during cold periods and a subtropical zonal environment during warm periods were witnessed. Therefore, in the Huangshan region along 200 km south of the lower reaches of the Yangtze River, when the climate changed the amplitude of such a change should be smaller than the Hexian Man site (ranging between the north subtropical zone in the cold period and the middle subtropical zone in the warm period).

The coldest climate occurred in the last cold period of Late Pleistocene in China. This period is called the Dali glacial stage in West China. Based on sporo-pollen analyses, annual average temperatures of North China were 10°C lower than at present[21]. Annual average temperature of the lower reaches of the Yangtze River were 7°C lower than at present. Annual average temperature in the neighboring region of Huangshan was 5~6°C lower than at present based on the living conditions of the relic fossil Yangtze alligator in the coldest period of Last Pleistocene[23]. Assuming when annual average temperature at the Huangshan summit was 7°C lower than today, Beihai (the North Sea) (1,610 m above sea level) was 1.7°C (Table 2). Assuming the January average temperature was 10°C lower than today at top path, the North Sea was ~12.3°C. And the July average temperature at top was 5°C lower than at present, the North Sea was 14.1°C. Monthly temperature below zero occurred over four months. Using annual average temperature 7°C[24], we estinated the height of snow line was at 2,883 m above sea level in the coldest period of Last Pleistocene, 1,019 m higher than the highest peak – Lotus Flower peak (1,864 m above sea level). Therefore, the top part of the mountain could not have been glaciated in the Late Pleistocene when the summit was an environment of seasonal frozen layer.

**Table 2 Temperature of the coldest period in Last Pleistocene about 20 ka B.P.**

| Time (B.P.) | Location | Altitude (m, above sea level) | Annual average (°C) | Jan. average temperature (°C) | Jul. average temperature (°C) | Months of below zero | Altitude of snow line |
|---|---|---|---|---|---|---|---|
| 20 ka | North Sea | 1610 | 1.7 | -12.3 | 14.1 | 4 | 2883 m |
| | Hot Spring | 650 | 6.8 | -7.3 | 19.9 | 2 | (above sea |
| | Taiping | 193 | 8.5 | -5.1 | 22.5 | 2 | level) |
| Today | North Sea | 1610 | 8.7 | -2.3 | 19.1 | 2 | 3900 m |
| | Hot Spring | 650 | 13.8 | 1.7 | 24.9 | 0 | (above sea |
| | Taiping | 193 | 15.5 | 2.9 | 27.6 | 0 | level) |

## 5 Discussion on the Questionable "Pleistocene Glaciation" of Huangshan

Several of the geomorphic features described previously were thought by Lee (1936) to be of glacial origin (Figure 3): (1) The depressions on the First Paleo-denudational surface at top of the mountain, North Sea and Tian (Heavenly) Sea as they are called, were "cirque-like depression" "apparently formed vast snow fields in glacial time" and suggest that fairly large glaciers were sent from these places down to the northern side of the mountain." In fact, these depressions are much shallower and smaller than neve basins, their dimensions are only one hundred meter long and wide. The lower case "moraine deposit" and like "moraine deposit" never has been found at the northern side of the mountain. These depressions are truly confluence basins of headwaters on the First Paleo-denudational surface, not cirque basin[25]. (2) The wide valleys on the Pliocene (Second) denudational surface were called glacial U-shaped valleys by Lee (1936). But the valley heads of these valleys are very narrow,

lack valley shoulders and faceted spours of glacial valleys. The V-shaped valley below Qingluan Qiao (1,100 m above sea level) has a nearly vertical wall with smooth surfaces on its eastern side. Lee (1936) noted that this surface has paralleI striae (960 m above sea level) along the lower part of the valley wall and said that this was the evidence supporting abrasion by glacial ice. However, the surface with striae is in a V-shaped valley, not U-shaped as would be expected if the valley had been abraded by glaciers. These striae have troughs 3~5 cm deep, 30-50 cm wide, and 100~940 cm long. The troughs are irregular in shape and do not have the wide heads and narrow down valley tails typicaI of glacial striae. Convex coarse porphyritic crystals of potassium feldspar are aligned in linear arrays along the troughs[25]. But, at present the origin of the striated troughs is still not known. The smooth valley wall is a result of exfoliation of granite and peeling at the mouths of granite slabs along joint planes. (3) Deposits of clay, sand, gravel and boulders which accumulated at the mouths of valleys on the piedmont (an altitude 360~250 m above sea Ievel) adjacent to Huangshan were interpreted as glacial moraine deposits by Lee (1936). He said that "if they had originated from glaciation, the glaciers must be of large size, and came down to an altitude no more than 300 m above sea level." Grain size analyses of the deposits show that the grain size distribution falls in the region of alluvial fans[26]. Clay mineral assemblages and sporopollen assemblages from the deposits indicate a subtropical humid climate and a mixed evergreen and deciduous forest of subtropical zone and not a cold glacial climate. SEM analyses show that surface textures of quartz sand grains from the deposits are alluvial/colluvial in origin[27] (Figure 3). The above facts show that these "glacial relics" were not formed by glaciation during the Pleistocene. Thus the idea "Pleistocene glaciation" at Huangshan is incorrect.

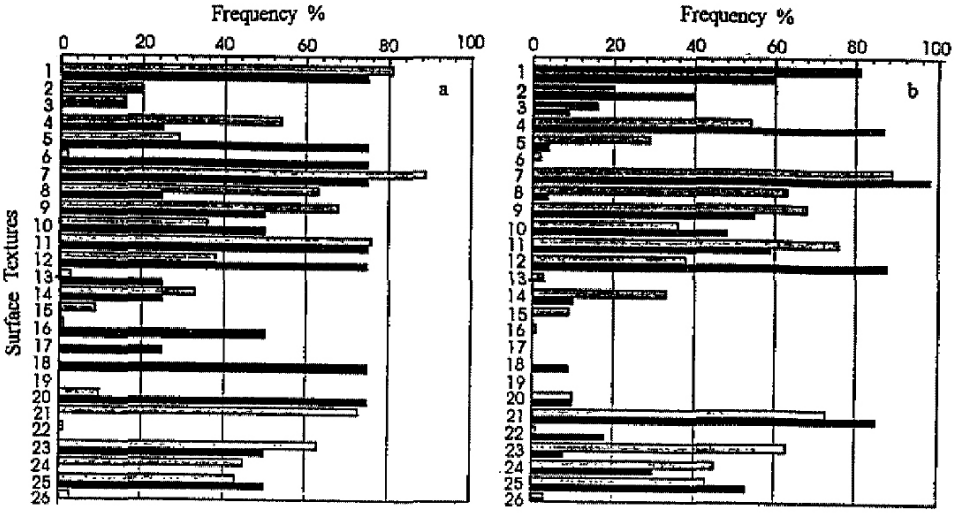



**Figure 3 Frequency graphs of grain surface texture by SEM analyses**

6 Formation of Beautiful Peaks and Fascinating Rocks

Some guidebooks and guide maps said that the origin of beautiful peaks and fascinating rocks are due to Quaternary glaciation. In fact, these granitic peaks and rocks had suffered strong frost weathering and not glaciation in the coldest period of Late Pleistocene[28]. They have undergone frost action along vertical, oblique and horizontal fractures, joints and cracks which produced landslides, mass movement and collapses along the margin of peaks and valley walls. Granitic peaks and huge rocks with vertical joints and fractures formed columnar peaks, such as Palm Peak and rock pillars. Peaks and rocks with oblique joints and fractures formed cone peaks, such as Lotus Flower Peak and cone

shape rocks, such as Peach Rock. Huge granitic rocks with vertical, oblique and horizontal joint formed various fascinating rocks, such as a rock monkey, rock cock and so on[29]. Therefore, dilatation and degradation of strong frost weathering in granite along joints and fractures are truly the formative origin oft hese beautiful peaks and fascinating rocks. From the viewpoint of geomorphology, the characters of glacial ground are smooth slopes and monotonous relief. The existence of various beautiful peaks and fascinating rocks can also confirm that the region has not developed mountain glaciers and piedmont glaciers and not suffered to glacial abrasion in the Quaternary.

## 7 Conclusion

From the foregoing the following conclusions have been reached:

(1) The major part of Huangshan consists of the Cretaceous Huangshan Granite which formed about 125 Ma ago. It is a granitic batholith with two stocks. Its exposed area is 226 $km^2$.

(2) Intrusion of the Huangshan Granite and its cover strata folding are related to subduction of Paleo-Pacific Plate beneath the southeastern margin of Asian Plate.

(3) Landsat image analysis shows that valley trends are related to NNW and near S-N trending fractures in the northwestern mountain (Back Mountain) and valley trends are related to NE, NNW and near EW trending fractures in the southeastern mountain (Front Mountain).

(4) The altitude of the First Paleo-denudational (gradational) surface at summit today is 1,600~1,800 m above sea level. It formed in the Oligocene about 30 Ma after the first episode of the Himalayan Movement. The altitude of the Second Paleo-denudational surface at present is 1,200~1,500 m above sea level. It formed in the Pliocene about 5 Ma after the second episode of the Himalayan Movement. The two Paleo-denudational surfaces were uplifted more than 1,000 m (based on the altitude of the knick point 1,100~1,200 m above sea level) during the Quaternary and the streams eroded deep canyons and mid-mountains since that time.

(5) The formative origin of beautiful peaks and fascinating rocks is strong frost weathering of granite in the last coldest period of the Late Pleistocene and is not related to glaciation.

(6) The above noted facts show that Lee's (1936) proposal of “Pleistocene glaciation” at Huangshan is incorrect.

Through on-going research published since the 1960s, the mountain evolution process and environmental changes of the Huangshan region have been understood. We believe that the idea of “Pleistocene glaciation” at Huangshan and Lushan will be put to rest by the earth science world in the near future.

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## References

[1] LEE J S. Confirmatory evidence of Pleistocene glaciation from Huangshan, southern Anhui [J]. *Bull. of Geol. Soc. of China*, 1936, 15(3): 279-290.

[2] HUANG Pei-hua. Research on Quaternary climatic changes in China [J]. *Chinese Science Bulletin*, 1963a, (1): 34-39. (In Chinese)

[3] HUANG Pei-hua. The problem of glacial relics at south of the Yangtze River [J]. *Chinese Science Bulletin*, 1963b,

(10): 29-33. (in Chinese)
[4] HUANG Pei-hua. Quaternary climatic changes in China and problem of Lushan glaciation remnants [J]. *Glaciology and Cryopedology*, 1982, 4(4): 1-14. (In Chinese)
[5] HUANG Pei-hua. Research and contention on Quaternary glaciation problem of East China during 50 years [J]. *Glaciology and Cryopedology*, 1983, 5(2): 1-8. (In Chinese)
[6] DERBYSHIRE E. A history of glacial stratigraphy in China [J]. *Quaternary Science Reviews*, 1987, 6: 301-314.
[7] CHEN Jiang-feng, ZHOU Tai-xi, XING Feng-ming et al. A discussion on Mesozoic overthrust in South China [J]. *J. of China University of Science and Technology*, 1991, 21(3): 30-36. (In Chinese)
[8] XING Feng-ming, XU Qiang, CHEN Jiang-feng et al. The Late Proterozoic continental acceationary history of the southern margin of the Yangtze platform [J]. *Acta Geol. Sinica*, 1992, 66(1): 59-72. (In Chinese)
[9] HUANG Pei-hua. Evolutional process of geomorphology at Huangshan [J]. *J. of China University of Science and Technology*, 1995a, 25(2): 160-165. (In Chinese)
[10] WANG Chang-rong. Research on the geology of Huangshan [J]. *J. of Anhui Normal University*, 1989, 12(4): 35-40. (In Chinese)
[11] ZHOU Tai-xi, CHEN Jiang-feng, LI Xue-ming. Has Indo-Sinian magmatism occurred in Anhui Province [J]? *Acta Petrologica Sinica*, 1988, 3(1): 46-53. (In Chinese)
[12] HUANG Ji-qing (Direction). The Geotectonic Evolution of China [M]. Beijing: Science Press. 1980. (In Chinese)
[13] HUANG Pei-hua. Quaternary geomorphological development and environmental evolution of Lushan and Huangshan [A]. BAO Hao-sheng. Professor REN Mei-e 80 years Memorial Volume [C]. Nanjing: Nanjing University Press, 1993a. 114-120. (In Chinese)
[14] HUANG P H, DIFFENDAL Jr. R F, YANG M Q. Geomorphological evolution of Huangshan in China [A]. Geological Society of America, *Abstracts with Programs*, 1995a, 27(6), 377.
[15] DIFFENDAL, Jr. R F, HUANG P H. Weathering and structural features of Huangshan, China [A]. Geological Society of America, North-central section, *Abstracts with Programs*, 1996, 28(6), 36.
[16] XIE You-yu, CUI Zhi-jiu, ZHU Jin-hu et al. On the characteristics of Proceedings of the National Conference on Quaternary Glacier and Periglacier (Selection) [C]. Beijing: Science Press, 1985. 71-78. (In Chinese)
[17] HUANG Pei-hua, REN Zheng-ji, LU Zhong-jia. Evolution of Quaternary natural environments in eastern China and natural environments of "Quaternary glaciation" at Mount Lushan [J]. *Acta Geographica Sinica*, 1987, 42(4): 289-298. (In Chinese)
[18] HUANG Pei-hua. Depositional cycles of Peking Man cave and their comparison with the loess depositional cycles and climatic cycles of deep sea cores [J]. *Scientia Geologica Sinica*, 1993c, 28(4): 305-311. (In Chinese)
[19] HUANG Pei-hua. Evolutional process and depositional cycles of Peking Man cave in relation to living environments of Peking Man [J]. *Acta Anthropologica Sinica*, 1995b, 14(2): 101-109. (In Chinese)
[20] HUANG Pei-hua, LIANG Ren-you, ZHENG Li-zhen et al. Preliminary study on ESR dating of Hexian Man and its fauna [J]. *Nuclear Techniques*, 1995b, 18(8): 494-497. (In Chinese)
[21] KONGZhao-chen, DU Nai-qiu, WU Yu-shu et al. Vegetational and climatic changes since Paleogene at Zhoukoudian [M]. Beijing: Science Press, 1985. 119-154. (In Chinese)
[22] LI Wen-yi. Vegetation and environment of East China in Quaternary cold stages [J]. *Acta Geographica Sinica*, 1987, 42(4): 299-307. (In Chinese)
[23] ZHOU Bing-gen. How living was Alligator in glacial period [J]. *J. of Central China Normal University (Natural Science)*, 1994, (2): 260-262. (In Chinese)
[24] SHI Ya-feng, CUI Zhi-jiu, LI Ji-jun. Problem of Quaternary Glaciers and Environments in Eastern China [M]. Beijing: Science Press, 1989. 363-374. (In Chinese)
[25] HUANG Pei-hua, LU Zhong-jia, NING Yuan-ming. Put questions to Pleistocene glaciation in Huangshan region [A]. Proceedings of the National Conference on Quaternary Glacier and Periglacier, Selection [C]. Beijing: Science Press, 1985. 38-40. (In Chinese)
[26] HUANG Pei-hua. A study on the sedimentation mechanism and environments of Quaternary boulder clay deposits at piedmont in mountain Huangshan, Anhui Province [J]. *Scientia Geographica Sinica*, 1994, 14(3): 211-216. (In Chinese)
[27] HELLAND P E, HUANG PH, DIFFENDAL Jr. RF, SEM analysis of quartz sand grain surface textures indicates alluvial/colluvial origin of Quaternary "glacial" boulder clays at Huangshan, East-China [J]. *Quaternary Research*, 1977, 48: 177-186.

[28] SUN Yu-feng. Some views on glacial geomorphology of Huangshan [A]. Proceedings of the National Conference on Quaternary Glacier and Periglacier (Selection) [C]. Beijing: Science Press, 1985. 34-37. (In Chinese)

Biographies

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