Quaternary Geology and Environment in China

Editor in Chief
Liu Tungsheng

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Preface

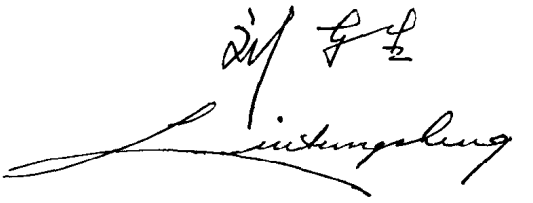
The XIII INQUA Congress will be held in Beijing from August 2 to August 8, 1991. The theme of the Congress is HUMANS AND GLOBAL CHANGES DURING THE QUATERNARY. We publish this volume to mark this history occasion and to welcome our colleagues and friends from all over the world.

The sixty years since the first INQUA Congress held in Moscow in 1932 has seen great changes in Quaternary research, of which the most remarkable character is that this science has been becoming increasingly inter disciplinary in nature and more global in scale. With the deepening of our understanding of the basic concepts in earth science, especially in geology, and of the evolution of the Earth and living organisms on it, Quaternary scientists are more aware of the theoretical and practical importance of our environment and its future developing trend and gradually focusing their research interests on this direction.

To anticipate or forecast environmental changes in the future requests a good grasp and understanding of the processes and mechanisms of past environmental changes, in both global and regional scales. Concrete and detailed regional or local paleoenvironmental data will certainly contribute greatly to our knowledge on the past, present and future of our planet. This volume presents results gained by Chinese Quaternary scientists in various aspects of Quaternary research in recent years. It is an up-to-date summary of present position of Chinese Quaternary research and also a comprehensive introduction to Chinese Quaternary for scientists all over the world.

For publication of this volume, besides efforts of all the authors, Professor An Zhisheng (Xi'an Laboratory of Loess and Quaternary Geology, Chinese Academy of Sciences), Wu Xihao (Institute of Geomechanics, Chinese Academy of Geological Sciences), Zhang Xuanyang (Chengdu Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences), Mr. Li Xuesong (Xi'an Laboratory of of Loess and Quaternary Geology, Chinese Academy of Sciences), Chen Xiqing (East China Normal University) and Ying Weide (Institute of Geomechanics, Chinese Academy of Geological Sciences) did much editorial work; staff members of Xi'an Laboratory of Loess and Quaternary Geology such as Mr. Sun Donghuai, Yan Yuansheng, Zhang Xiaoye, Xie Jun, Lin Benhai, Liu Hanqi, Jia Hongyu and Li Xiaoqiang, and Professor Lu Yanchou (Institute of Geology, State Seismological Bureau), Wei Lanying (Institute of Geology, Chinese Academy of Sciences) and Chen Yinshuo (Institute of Botany, Chinese Academy of Sciences) also devoted a lot of time and energies; Ms. Ma Jinlin (Institute of Geomechanics, Chinese Academy of Geological Sciences)

drew most of the graphic illustrations, and editors of the 3rd Editorial Division of Science Press paid great attention to it and behaved to be very cooperative and helpful. I am very grateful to them for their support and assistance.



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THE HUNTING FOR THE QUATERNARY VANISHED GLACIERS IN CHINA

Sun Dianqing

(Institute of Geomechanics, Chinese Academy of Geological Sciences)

The first report on Chinese Quaternary glacial vestige was published by Li Siguang (J.S.Lee) in 1922[1], who had discovered the moraines, erratics and striated boulders at the eastern foot of the Taihang range and in the Datong Basin in North China. On the Third Conference of Geological Society of China convened in May in the same year, he gave a talk on this discovery, though not being accepted by the experts attending the meeting. Nor the published report had received any response. Because many well-known foreign geologists and geographers had come to China and published a number of papers about their researches and investigations, yet not a word had said of the glacial vestige. The only record that has a bearing on the problem appeared in the classic work by James Geikie, *The Great Ice Age* published in the 17th century. From the tourists' report about the huge boudlers far away from the mountains in-between Xi'an and Tongguan and in north-eastern tip of Shandong, he inferred that the glacier might once existed in Northern China[2]. The account is, however, very brief, amounting to no more than a passing note.

From 1933 to 1934, Li Siguang published two papers one following another[3,4], which made well-known to everyone a lot of evidences he had observed as glacial trace in the mountainous and piedmont areas along the lower reaches of the Yangtze River, and which arouse a heat controversy and an intensive opposition among the Chinese and foreign geologists and geographers. The opponents showing the strongest disagreement were the English professor G.B. Barbour and the French Prof. Teilhard de Chardin[5-8]. In 1934 when the debate was in its high heat, Li Siguang, Barbour, Teilhard de Chardin, Norin (Sweden geologist), and Yang Zhongjian went to Lushan, made a field observation, and exchanged opinions in face of the objective facts, and yet no agreement was achieved. The point is what Li Siguang took as glacier's moraines was viewed as solifluction or mudflow deposits by the opponents. To clear up their doubt, Li wrote in his book *Quaternary Glaciation in the Lushan Area, Central China* a special section "About the moraine" as a reply. Then in 1936, Li Siguang found the decisive arguments for the Quaternary glaciation in the Huangshan and Lushan. At the Banshanting in Huangshan, about 960 meters above sea-level, he found several large-scale striae on the granite composing one side wall of an U-shaped valley, the longest one being more than 6-7 meters long with 0.35 meter in width and the short one, 3-4 meters (photo 1 a,b). The striae coupled with the U valley invoke no interpretation else but the grinding of the glacier carried blocks. In Lushan, *i.e.* near Beishizui of Xingzi County, he found outcrops of a glacial pavement and a small roche Moutonnée with many striae on the basement rock of the

Middle Carboniferous limestone, on which covered a boulder clay layer. The discovery attracted the attention of the famous scholar H.V. Wissmann, a professor in the Department of Geography of Nanking Central University, who had long doubted about the Quaternary glacial vestige in China. After he went to Huangshan twice and to Lushan once, Wissmann reversed his point of view, cleared up his doubts, and published papers in foreign and Chinese journals to confirm the existence of the Quaternary glaciation in China.[11,12]

Afterwards, from the middle 1930s to the end of 1940s, widespread glacial vestiges were found in mountain and piedmont areas over the southwestern China and in western Hubei, Hunan, and Guangxi, and papers were published discussing about climate changes in Pleistocene in Asia[13-42].

After detailed work in Lushan, Li Siguang wrote a special issue about the glaciation in the Lushan area in 1937[42]. He recognized three glacial stages, namely the Poyang, the Dagu (which could be subdivided into two stages and one interstage), the Lushan stages, which, together with the Dali stage proposed by Wissmann occurred later in the western China, were then tentatively correlated with the four Europe glacial stages occurred in the Alps. This issue had been sent to press already but delayed due to the interruption of War of Resistance Against Japan until 1947 when it was lastly published.

After 1949, the establishment of New China, the geological and geographical work was extensively accelerated with more and more finds of Quaternary glacial vestige and correspondingly the papers related. For example, the papers published in the 1950s, though relatively less than later periods, are counted at about 20-30[41-66], mostly concerned with the eastern China. At the beginning of 1960s, a summary was made on the studies of the Quaternary glaciation in China[71].

In order to systematically survey Quaternary glacial vestige in China, a central liaison group of the study on Quaternary glacial vestige in China was set up with Li Siguang as the first director, and Zhu Xiaocheng, Hou Defeng, Yang Zhongjian and Sun Dianqing as vice directors; and a symposium was held with a field cooperative observation in Xiangshan near Beijing, which resulted in an article named *Quaternary glacial vestige in the Western Hills, Beijing and the glacial stages in China* written by Li Siguang and published under the name of the group[68]. The group members were universally agreed that the Quaternary glaciation in China were mainly mountain glaciers, but in some places, the glaciers did reach the piedmont or even the piedmont plain. Then on the basis of this common acknowledgement, problems were listed for the reference of the future work:

(1) The division of the Quaternary stratigraphy. Indeed, the glaciation is closely related to climate. The great change in climate bringing about the glacier can never be limited to local place, but covers a vast area and deeply influences the development of the Quaternary geology. So the Quaternary stratigraphy, its division must take the glacier prevailed in China into consideration.

(2) The identification of the Quaternary sedimentary facies. There is no doubt about the closeness of the relationship between the facies changes and distribution of the Quaternary deposits and the glacial activities. The current problem is how the distribution of the ground, lateral, terminal moraines be reflected in geomorphology. Does the loess in China, or at least part of the loess, belong to the frontal aprons?

So the subdivision of the loess sequence should not neglect the existence of the Quaternary glacial and interglacial stages.

(3) The relation between glacial activity and the physiographic cycle as well as the neotectonic movement. Previous division of the physiographic periods based on the heights of terrace and peneplain should be reconsidered if the glacial activity has been confirmed there. For example, the gravel layer on some mountain tops to the south of the Badong along the Yangtze River coupling with the hanging valley which has nothing to do with faulting activities should be considered as the vestige of the Quaternary glaciation.

(4) The distribution and the flourish and decline of the Quaternary biota. The possible relationship between the living condition of the apeman and the glacial activities. The climate changes between the glacial and interglacial were rather intensive, but under some conditions, the organism who accustomed to the warm climate, i.e. existed in interglacial, would not necessarily extinct completely during glacial. This demonstrated the phenomenon of the mixed biota of warm and cold species. Recently-discovered fossil *Coelodonta* in North China plain which lived under the cold climate condition is significant in the identification for the glacial stage.

(5) How to combine the Quaternary glacial studies with the production practice. In the Forty Items of the National Programme for Agriculture Development, there are at least 5 items such as the building of the water reservoirs, the development of the irrigation; the preventing of the flood and drought; cultivating of the deserted land so as to enlarge the crop's land; the improvement of the soil and water and soil preservation which can not belittle the influence of the glaciers. The concentration of the H^+ ions in the soil is influenced by the glacial activities. The glacial boulder clay is rather low in permeability and hence is a water-proof layer. If little attention is paid to the moraines and other sediments which are related with the current actions in building the water reservoirs, some disaster effect would result in great loss. Also, in the exploration of the mineral resources, especially in the prospecting engineering and drilling, the underestimating of the glacial action has caused loss in our work. There is no need to say the placer in the moraines, which should be explored using the glaciology.

In order to push the Quaternary glaciation studies in China, the group compiled, edited and published the book *Collection of the Graphs and Photos About the Glacial-eroded Landscape and Glacial Vestiges* in 1963[76]. This book collected almost all the important glacial vestiges found from 1922 to 1962 in eastern China. Then the group co-operated with the Committee of Quaternary Research of China compiled, edited and published the book *Collected works on Quaternary glacial vestiges in China*[77] in 1964. The book mainly collected the studies on the Quaternary glacial vestiges and related glacial subdivisions in northwestern margin of North China plain, along the east slope and the frontal zone of the south part of the Longmenshan in Sichuan, along the east slope of the Da Hinggan ridges, in the Dabieshan region, in the east part of the Qingling and along the east piedmont of the Taihang range, among which the most detailed is the observation made by Prof. Li Chengsan in Longmenshan area. In the 1960s and 1970s, there were also many other articles about the Quaternary glacial vestiges published[67-108] covering mainly eastern China and also parts of the mo-

untain areas of the western China. The articles published in the 1980s were even more[109-194].

Among the evidences obtained in the recent 20 odd years about the Quaternary glacial vestiges in mountain areas and piedmont plains in China, there are quite a few decisive arguments for the glacial activities. These include: 1) glacial erratic boulders; 2) glacial-ground gravels and striated pebbles; 3) glacial pavements due to the grinding of the glacier-carried gravels and sands; 4) moraines including ground, lateral, and terminal ones, and related glacial-outwash; 5) glacio-structures due to the pushing and pressing of the glacial movements; 6) glacial landscape such as the cirque, corrie and U-shaped valley though partly destructed by later erosion during the interglacial; 7) the bodies and trace of the animals and plants which lived under the glacial climate, that is the evidence which should have existed but would not be found everywhere. If the above-mentioned glacial vestiges are combined together from the mountain to the piedmont and even to the plain, one can see the glacial routes, *i.e.* the growth, movement, and the disappearance of the glacier. According to the data available of the glacial-eroded landscape, the geomorphic features and distribution of the glacial deposits, most of the Quaternary glaciers in China belong to the valley glaciers and piedmont glaciers except for those on the Qinghai-Xizang Plateau and in the Da and Xiao Hinggan range areas. This is different from the continental glaciers in Europe or America.

The major advances in the study of Quaternary glaciology in China in the last twenty odd years are presented as follows:

(1) Recognition and study of the early glacial stage. Before the middle of the 1960s, the Quaternary glacial was divided mostly according to the subdivisions made by Li Siguang, the earliest being the Poyang stage and the youngest being the Dali glacial stage. The work in southwestern China and in the Qinghai-Xizang Plateau and the further work in northern China and in Lushan revealed two earlier glacial stages. In the Qinghai-Xizang Plateau and in southwestern China, there are six glacial stages, namely, the Jingxian, the Shizishan, the Wangkun, the Nachitai, the Xidatang, and the Bentoushan stages for the former and the Longchuan, the Yuarmou, the Matoushan, the Zhongshan, the Dongshan, and the Dali stages for the latter. The two early stages in both areas predated the four discovered by Li Siguang, the vestiges of which have been also found in the Western Hills of Beijing and in Nihewan in northern China. But in Lushan, only one early glacial stage can be identified, called the Dabai glacial stage.

(2) Recognition of the Dali glaciation in eastern China. In addition to the glaciated landforms preserved in the high mountains in eastern China, there also the periglacial phenomenon occurred at Jiezicun, Weinan of Shaanxi, in Tianmushan of Zhejiang, in northeastern China, and near Beijing. A lot of glacial sediments contain the fossil plants and sporepollen assemblage indicating a cold climate. The ^{14}C datings suggest that the Dali stage started at 30 000 a BP., and ended at 10 000 a BP., which can be further subdivided into two stages and one interstages with the coldest climate, and hence the largest glacial scale being at about 18 000 a BP.

(3) The series of the Quaternary glacial stages in China and their geological ages (Fig. 1). According to the Quaternary sedimentary types, the characters of the glacial terraces, the Quaternary magneto-stratigraphy and the ^{14}C chronology, the Quaternary glaciation in China can be divided into six stages, the ages of which are preliminarily

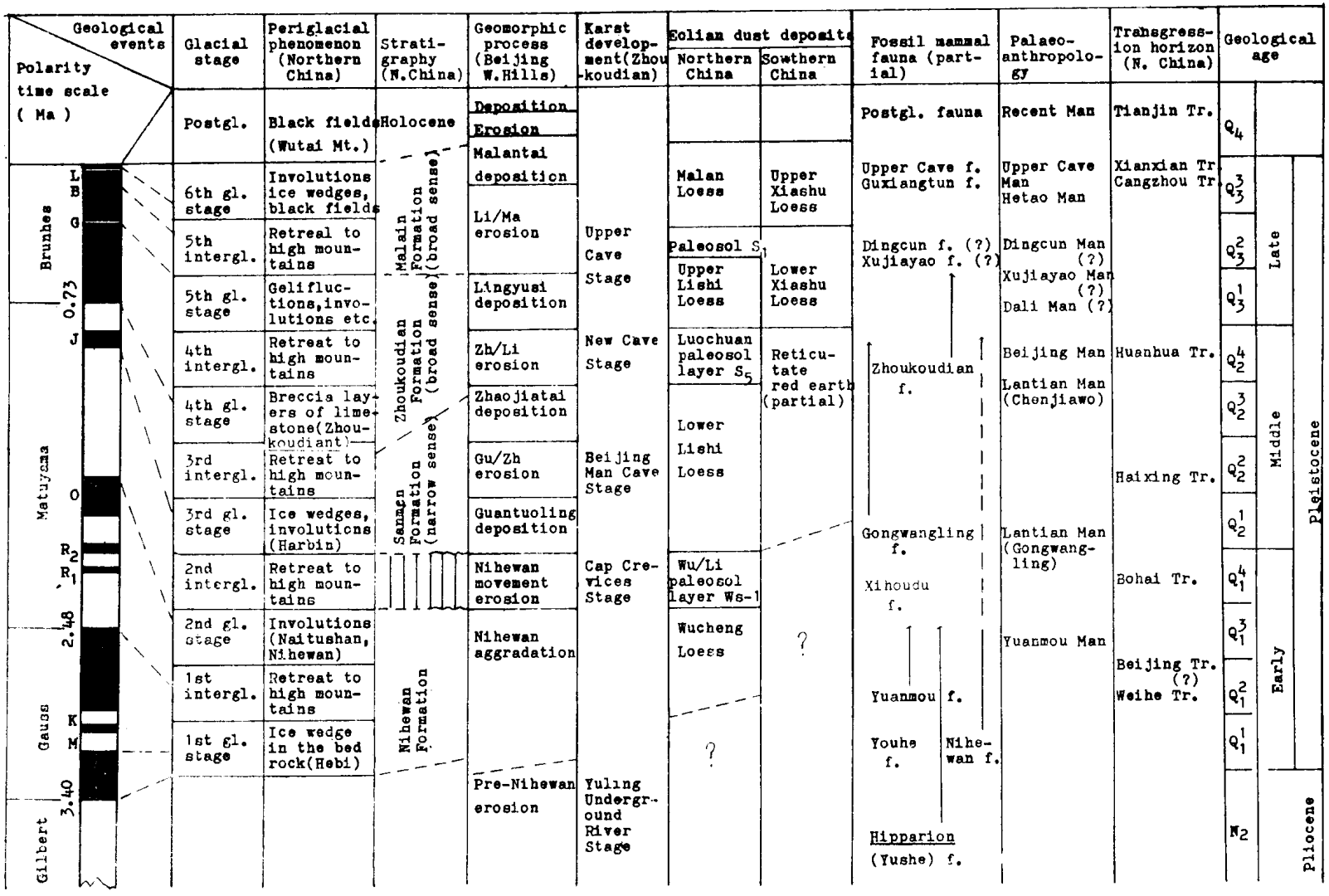

Fig. 1 Tentative correlation of Quaternary glacial stages and their related geological events

defined mainly in accordance with the paleomagnetism series as follows:

1) the first glaciation, i.e. the earliest glaciation commenced near the boundary between the Gilbert and Gauss Chrons (3.4 Ma BP) and ended at 2.7 Ma BP. The coldest stage occurred between the Mammoth and the Kaena Subchrons.

2) The 2nd glaciation continued from 2.0 to 1.5 Ma BP, during the Olduvai Subchron (1.87-1.67 Ma BP.) of the Matuyama Chron. Because the first interglacial was colder than present and oscillated many times between warm and cold, so the climate boundary between the 1st and 2nd glaciations is rather ambiguous, especially where the sediments profile is continuity.

3) The 3rd one occurred during 1.2 to 0.9 Ma BP. The Jaramillo Subchron of the Matuyama Chron might appear in the late stage of this glaciation. During the 2nd interglacial from 1.5 to 1.2 Ma BP, there occurred an intensive and extensive tectonic movement, the vestige of which is usually served as an marker for differentiating the 2nd and 3rd glaciations.

4) The 4th one spanned a period from 0.8 to 0.6 Ma BP. The M/B boundary (0.73 Ma BP) is recorded in the moraines of this glaciation. A series of terraces formed by the river's downcutting during the 3rd interglacial can be often found between the platforms covered by the 3rd and 4th glacial deposits.

5) The 5th one is tentatively set at 0.4 to 0.2 Ma BP. It is separated from the 4th interglacial by the Gimanka Subchron of the Brunhes Chron. The 4th interglacial is rather long.

6) The 6th one, *i.e.* the final glaciation, commenced about 70 000 a BP, possibly even as early as 100 000 a BP when the Blake Subchron occurred, and ended at 13 000-10 000 a BP. The Laschamp Subchron occurred in the late stage of this glaciation. In the postglacial after this 6th glaciation there were also neoglaciation and small glaciation, which have been studied in detail by the researchers on modern glaciation and on Holocene.

(4) Going on a multi-disciplinary way. Simultaneously with the study on the Quaternary glacial vestiges, the studies on other aspects of Quaternary have made encouraging progresses, such as those on Quaternary palaeontology, Quaternary stratigraphy especially climatostratigraphy and marine stratigraphy, on the eolian dust accumulation and red soil, especially the loess, on sea-level changes and transgression and regression, on Quaternary tectonics, on the basic character of the climate evolution in Quaternary, the condition for the development of Quaternary glaciation in China, and Quaternary tectono-climatological cycles, and on the lower boundary of Quaternary All these lines of the studies have shown that there is a close interaction among the above-mentioned aspects, which integrate them as a whole. In particular, when considering Quaternary geological development and the environmental evolution of Quaternary, the climate change is an important factor which cannot be neglected. This remind us what the late famous palaeontologist and Cenozoic geologist, Yang Zhongjian said in his late years, i.e. "as for Quaternary geology in China, the glaciation is a key for the entrance, without which the door cannot be opened, not to say to pass through the hall into the inner chambers". This has been accepted by most researchers.

All the work on the Quaternary glaciation, on the regional geology and on the hydro-geology and engineering geology for the recent 20 or more years have provided sufficient evidence to confirm the glaciation prevailing once and again in China, espe-

cially in the eastern China. Most of the geologists and geographers are positive in acknowledging them, yet a few others are negative in showing some doubts. The opponents maintain that except for the high mountainous region more than 3 000 meters above sea level, there is no Quaternary glacial vestiges in eastern China, and the boulder clay layers are some melange or oliotostrome produced by the mudflows or rockflows. The mountains such as Huangshan, Lushan along the lower reaches of the Yangtze River, and the Taihangshan and Xishan mountain of Beijing in northern China are all less than 2 500 meters above sea level, and hence there is no vestige of the Quaternary glaciation whatever to be mentioned.

But the glacial boulder clay, the glacial pavements, the glacial striated pebbles, and the cold-enduring huge animal fossils such as the *Mammuthus*, *Coelodonta* and the spore-pollen assemblages reflecting a cold climate occurred commonly in these areas. How to explain all these facts if there was no glacial climate and no glacial activities. Take the example near Beijing, the glacial pavement at Longensi temple in the Western Hills, the large glacial-striated blocks at Liuchu (one of the 8 Temples of the Western Hills, Beijing, means the 6th Temple) and the huge erratic boulders in the valley of the Miyun County are all there for observation and study. The author believes that they are the reliable witness of the Quaternary glaciation.

As for Lushan, it is a place where Li Siguang identified the earliest evidence for Quaternary glaciation in China. He made a survey of the Quaternary glaciation there intermittently spanning six years. He firstly studied the regional geology and mapped a regional geological map, and repeatedly investigated the geomorphy and deposits up and down the mountain, including the erosional and depositional geomorphic features and the boulder-clay layers and other glacial deposits. In 1937, he wrote the book *Quaternary Glaciation in Lushan Area, Central China* (in Chinese and English).

Since the 1950s, there were many geologists and geographers, both at home and abroad, coming to Lushan to investigate the glacial vestiges, including some famous scholars the Polish Professor S. Kozarisk, the America Professor Miller, and the Secretariat of the INQUA Dr. Ch. Schluchter *et al.*, they all confirmed the glacial vestiges in Lushan. In 1978, sponsored by the Institute of Geomechanics of Chinese Academy of Geological Sciences, a national conference on the Quaternary glaciology and Quaternary geology was convened in Lushan with about 200 attendants including many famous geologists, geographers and palaeontologists, such as Prof. Yang Zhongjian, Xu Jie, Jia Lanpo, Xu Ren, Wu Lubo, Zhou Mingzheng, and Yang Huairen. The conference arranged two days for geological tours to observe the main glacial traces in the Lushan area. The conference unanimously confirmed the existence of the glaciation in Lushan, and no one definitely argued against. The conference also proposed to set up a special committee of the Quaternary glaciology and Quaternary geology, which was then formally established in 1979, in another science meeting in Urümqi, Xinjiang.

From 1986, the Institute of Geomechanics, cooperated with the Hydrological Team of Jiangxi, surveyed the Lushan area and its peripheral areas once again, and drilled on the covering area for two years, obtained more detailed data and further subdivided the glacial stages, including one earlier than the Poyang stage.

It appears now that the key point for the Quaternary geology and environment in

eastern China or even in whole China is to enhance the surveying and the detailed subdivision of the glacial stages, to go deeper in studying the division of the loess sequence and red soil accumulation, the Quaternary sea-level changes and transgression and regression, the basic condition of climate evolution, the Quaternary stratification and to synthesize the above-mentioned disciplines to find the interaction between each other.

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