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RECENT DEVELOPMENT OF RESEARCH ON ENVIRONMENTAL EVOLUTION IN CHINA

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ABSTRACT: Recent achievements of the research on Chinese environmental evolution are briefly summarized in this paper. Following aspects are touched upon: relationship between Chinese environmental evolution and global change, the influence of the swift uplift of the Qinghai–Xizang Plateau, time sequence and the reconstruction of environment in characteristic stages, trend towards dryness in north and northwestern China, sea level change and regional studies.

KEY WORDS: environmental evolution, monsoon formation, uplifting of the Qinghai–Xizang Plateau

I. RECOGNITION OF THE RELATIONSHIP BETWEEN THE GLOBAL CHANGE AND THE EVOLUTION OF PHYSICAL ENVIRONMENT IN CHINA IN THE QUATERNARY

In his famous paper "The Ice Age in Lushan Mountain" in the 1930s,[1] Professor Li Siguang (J.S. Lee) believed that there are a lot of evidences about glacial activities of the Quaternary Ice Age in China. In recent years, a number of scientists have expressed doubt on the validity[2,3] of the "moraines" in these localities. But however, when he claimed: although there was no icecap on the continent of China, like that in Western Europe and North America, mountain glaciers were widespread in China during the Ice Age of the Quaternary, Prof. Li became the pioneer who recognized the relationship between China and the North Hemisphere on the Quaternary climatic vibration. Recent studies on the paleoglaciers in western China,[4] on the periglacial phenomena in northeast China and the Qinghai–Xizang Plateau,[5,6] the studies on pollen sequences,[7,8] on faunal group of mammal,[9] on the fluctuation of sea levels,[10] and especially from the results of the studies on loess profiles,[11,12] have proved this consistency.

Professor Chu Kochen, a famous geographer and climatologist, has published a series of papers about climatic fluctuation in China. In his paper "A Preliminary Study of the Climatic Fluctuations during the Last 5,000 Years in China"[13] published in the 1970s, based on the data from archaeology, historical and instrumental records, he compared the temperature fluctuation during the last 5,000 years in China with the variation of the snow line altitude in Norway; based on the data from phonology, compared the climatic fluctuation in China during recent 1,700 years with the climatic fluctuation in Greenland based on the data of oxygen isotope variation. It was found that the similarities between them were striking. As Professor Chu pointed out, the climatic fluctuation in China coincided with that of the world, although there were some differences in the time of the appearance of the coldest years and warmest years between China and other countries. His judgment has been evidenced by many later research works.

To prove that the climatic fluctuation in the global scale is the basic background of the physical environmental evolution of China, has laid down the foundation and guideline for the development of the research work on the environmental change in China.

II. PROGRESS IN RESEARCH ON THE UPLIFTING OF THE QINGHAI–XIZANG PLATEAU AND THE FORMATION AND EVOLUTION OF MONSOON

On the background of global change in general, there are regional characteristics in the environmental evolution of China in Cenozoic Era. The most outstanding among them are the swift uplifting of the Qinghai–Xizang Plateau and the formation and evolution of monsoon. Process of the upheaval of the plateau has long drawn the attention of Chinese and foreign scientists, because it influenced not only the environmental evolution on the plateau proper itself, but also the environmental evolution in the adjacent regions.

Based on geomorphological and sedimentary evidences, it is proved that the entire emergence of the plateau from the sea was in Late–Eocene, because the Mid–Eocene marine sedimentation is the latest marine layer in the Himalaya region.[12] The remnants of peneplains, 5,200–5,500 m a.s.l and 4,500–5,000 m a.s.l, and those great knick points on the Yarlung Zangbo River, manifested the alternation of strong uplifts–relative stable stages during the uplifting process.[14,15] Change of the phase in the thick piedmont sedimentation, from fine clay in the Upper Tertiary to coarse cobble in the Pleistocene, expressed that the uplifting accelerated since the beginning of the Pleistocene. By evidences of biology and geo–science, the height of the plateau remained generally at 1,000 m a.s.l or so at the end of the Pliocene with subtropical humid climate. The landschaft changed in accordance with the uplifting. On the background of global Cenozoic Decline, and chiefly, the rapid uplifting, the plateau assumed its present landscape finally. The uplift is still going on.[16]

It is the modern monsoon that controls the modern aerial differentiation pattern in China. That is the reason why the Chinese geo–scientists pay so much attention to the study of the formation and evolution process of East Asia monsoon.

Recent achievements have proved that there is a close relationship between the formation of Asian monsoon and the uplift of the Qinghai–Xizang Plateau.[17] Manabe's experiments by mathematical simulation on the relationship between the monsoon and the plateau in the 1960s showed that if there were no the Qinghai–Xizang Plateau on the earth, there would be no anticyclone in Siberia in winter and the warm depression in India in summer. It meant that modern monsoon was inexistent in this area. When the Qinghai–Xizang Plateau introduced into the experiment, the distribution characteristics of the anticyclone and depression, both in space and time, are very close to the present.[18]

Most geo–scientists believe that modern monsoon could be formed only after the altitude of the Qinghai–Xizang Plateau was over 2,000 m above sea level, when it made a notable impact on the atmosphere both thermally and dynamically. As a barrier, the plateau protect the cold air on the Mongolia Plateau not to be disturbed by the warm current from south, so the cold anticyclone could form in Mongolia and Siberia in winter; similarly, the undisturbed warm depression could be maintained on Indian Subcontinent in summer.

The appearance of modern monsoon destroyed the planetary wind system on East Asia. A new pattern of heat–moisture balance and distribution was created, which induced the formation of the modern physical environment in China.

III. ESTABLISHMENT OF THE EVOLUTION SEQUENCE AND RECONSTRUCTION OF THE ENVIRONMENT IN CHARACTERISTIC STAGES

Many climatic or environmental evolution sequences, based on different kind of data or comprehensively, have been established in recent years. The longest covers the whole Cenozoic Era, the shortest covers the recent hundred years or decades, with different resolution. The area covered are from the whole country, eastern part of China, to a certain drainage or a province etc. "A Preliminary Study of the Climatic Fluctuation during the Last 5,000 Years in China" written by Professor Chu Kochen is one of the most famous papers.[13]

Reconstruction of the palaeoenvironment of different period showed that the Late Tertiary is the key stage for the formation of the present physical environment pattern in China.[19]

Palaeobotanists discovered that there was obvious differentiation of physical geographical zones in China as early as in the Late Paleozoic. There was clear difference in palaeoplants between south and north China during the Mesozoic too.[20] In the early Tertiary, a latitudinal differentiation was more clear than before. The physical geographical zonalities was controlled by the planetary wind system, the region in lower latitude with arid–semiarid landscape was under the subtropical high pressure zone. But the zones were not parallel to the present latitudinal circle. Due to the polar wandering since then, now the general trend of these zones is a little oblique to the present parallel, from northwest to southeast.[21]

Early Tertiary was quite warmer than present. In the Fushun Flora (northeast China, nearly 42° N) many typical subtropical broadleaf evergreen plants were present, and the fossils of metasequoia were abundant. Subtropical zone distributed 10° latitudes higher than present.[21]

There was a big adjustment of the distribution of physical geographical zones in China during the Tertiary. After this adjustment, in the Late Tertiary, the difference of physical regions of China became gradually similar to its present pattern.[19] The most prominent change was the disappearance of the subtropic arid zone in east China and the intensifying of the arid climate in northwest China due to the replacement of planetary wind system by monsoon system.

In the Pleistocene, the physical environment in China changed along with the alternating global cold–warm stages. Horizontal and vertical physical geographical zones moved forward and backward again and again.[22] Information from loess–paleosol series showed that at least 11 dry–cold periods and 11 wet–warm periods appeared alternately in the past 2.4 million years. Loess deposited in cold–dry period and soil profiles developed when climate became warm and wet. When loess deposition recurred, the soil profile was buried and transformed into paleosol. A polygenetic red paleosol horizon about 0.5 million yr. B.P. can be correlated with one of the cave deposit layers at Zhoukoudian in which the fossils of Beijing ape–man was discovered.[23]

Based on different kinds of proxy data, the distribution of temperature in the Last Ice Age in the Late Pleistocene has been reconstructed. The vibration of the temperature range was larger in higher latitude regions. The mean annual temperature was about 10–11 ℃ lower than the present in northeast China and to the north of the Tianshan Mountains; about 10 ℃ lower in north China; about 8 ℃ lower in the lower reaches of the Changjiang (Yangtze) River. In south China and on the Qinghai–Xizang Plateau, protected by the mountain barriers, mean annual temperature was only 6–7 ℃ lower than the present and in lower latitude regions to the south of the Tropic of Cancer, the decrease of temperature was no more than 5 ℃.[24]

It is much more difficult to reconstruct the distribution of precipitation than that of temperature, because most of the proxy data available for rainfall reconstruction lack strict quantitative significance. However, all the evidences now available proved that during the last glaciation, precipitation was less than the present all over China.

Comparing with the present, the southern boundary of the cold temperate zone moved southward about 10 degrees of latitude, making it occupy almost the whole area of northeast China. North China became the temperate zone from warm temperate zone. The lower reaches of the Changjiang River valley was covered by deciduous broadleaved forest with grassland of warm temperate zone. Subtropic zone retreated southward.

Northwest China, except the mountain ranges, was occupied by cool desert and semi–desert in glaciation.

The Qinghai–Xizang Plateau underwent a most striking physical change. During the early Pleistocene some alpine coniferous forests were spread on the Plateau, but by the last glaciation, few forests survived and were replaced by periglacial tundra.

Protected by the mountain barriers, many tropic and subtropic plants and animals survived in some suitable places in South China. After glaciation, they readvanced northward to the areas south of the Qinling.[25]

Multi–glaciations have been recognized in west China where alpine glaciers took place in the mountain regions and on the plateau. But recent investigations disproved the speculation that the Qinghai–Xizang Plateau had been covered by a great ice sheet in the Quaternary. Due to the monsoon circulation, both the dry winter and hot summer are unfavorable for the accumulation of snow.

After the last Ice Age, concordant with the global trend, temperature went up again, precipitation increased in China, and in the period of 5000–6000 yr. B.P. reached its climax, the warmest and wettest period in post Ice Age, the worldwide climatic optimum. Bamboo flourished in the middle and lower reaches of the Huanghe (Yellow) River, rhinoceros and wild elephants were wandering on the North China Plain. Then, the temperature was gradually lowering in vibration, reached the lowest point in 1500–1850 A.D., that is the worldwide "Little Ice Age". Canal on the Changjiang River Delta froze in winter, subtropical crops in south China were damaged seriously by cold waves. But however, the temperature fluctuation in the Holocene was not very large, the mean annual temperature was about 1–3 ℃ higher or lower then present.[13]

Main attention of the study of climatic fluctuation and environmental change in the Quaternary are paid to the period since 120,000 yr. B.P., especially to the last ice age and the post glacial climatic optimum, as they are very important "frames of reference" for the possible extremes in the future.

IV. DISCUSSION ON THE TREND TOWARDS DRYNESS IN NORTH AND WEST CHINA

Fluctuation of precipitation plays an important role in environmental change in China. In arid and semiarid regions, it is more important than temperature fluctuation. That is why so many scholars have focused their attention on the problem whether there is a trend towards dryness in north and western China.

Recent researches have provided so many evidences showing that there has been a trend towards dryness in these regions since the Middle Pleistocene.[26] The most convincing evidences are from the study of palaeohydrology of lakes in arid and semiarid regions.

More than one thousand lakes scatter on the Qinghai–Xizang Plateau, most of them are salty and inland ones at present. Terraces and lacustrine deposition around these lakes indicate that in the period of the Middle Pleistocene Inter–Ice Age, there was a moist stage on the plateau. The palaeoshorelines were more than 20 and even 100 m higher than that of the present.[27,28]

A lot of salty and semi–salty lakes are dispersed over the belt that is along the southeastern border of the Inner Mongolia Plateau from Hulun Buir to Ordos and Alxa. Study of the lacustrine sediments showed that the lakes were residuals of ancient bigger lakes, and there was a lake zone in this regions too, in the Middle Pleistocene. The highest palaeoshoreline of Daihai Lake is 40–45 m higher than that of the present.[29]

Around the lakes in Xinjiang and in Gansu Province, relics of high palaeolacustrine terraces also could be found. The lacustrine sediments of the Early and Middle Pleistocene distributed around Lake Lop Nor in Tarim Basin, is known as the famous "Great Ear" on the landsat image.

The drying of lakes might be caused by such factors as the change of the upper or lower river systems, or tectonic effects on lake basins, not climate. However, if the shrinking processes of a variety of lakes in a vast area happens simultaneously, it is undoubtedly due to climatic factors.

The size of the continental mountain glaciers in the western part of China was not dependent on temperature but on precipitation. Comparing size of mountain glaciers in different periods, it is found that after the Middle Pleistocene, the size of glaciers in later glacial period was smaller than that developed in the preceding period. That means that the precipitation of the later glacial period was fewer than that of the former glacial period.

Research on the formation and development of the deserts in China has arrived the conclusion that most deserts came into being after Middle Pleistocene and from then their trend of expansion is clear.[30]

Historical records of northwestern provinces: Shaanxi, Gansu, Ningxia showed that the percentage of drought year in per century is steady increasing. In and before the 9th century it was less than 17%, from the 10th to 14th centuries increased up to 27%, from the 15th to 17th centuries 43%, the 18th century 46%, after the 1830s it was over 51%.[31]

By historical records, in eastern China, there were 650 wet years and 350 drought years in the area south of 40° N, before 1000 A.D. In the period after 1000 A.D., only 320 years were wet, drought years increased to 850.[32] The flood–drought records of Beijing showed that there were six wet–drought cycles in recent 500 years, the wavelength is about 80 years. But the wave is asymmetrical: drought part is longer than wet part, and the wet part shortened again and again with the passage of time.[33]

It is an objective fact, that there is a trend toward dryness in north and western China since the Middle Pleistocene in general. What extremely concerned now is whether this trend will be enhanced under the prospect of global warming by the increasing of CO_2 in the atmosphere.

V. PROGRESS IN THE STUDY ON SEA LEVEL CHANGES

There was very little attention paying to the sea level changes in China before the 1950s.

Thanks to the great amount of surveying and drilling works on the coastal plain and the continental shelf, a vast amount of scientific data were collected, including sediments, fossils, especially spore—pollen and foraminifera and topographical features. After these proxy data were tested and dated reliably, the process of sea level changing along the Chinese coast during the Quaternary revealed its outline.[34–38]

The transgression before the Late Pleistocene was determined by the marine deposition with the paleontological evidences. It was found that there were foraminiferal fossils 428.6 m beneath the Beijing Plain, in the bottom of the Quaternary sediments. It is about 2.26 million yr. B.P., dated by palaeomagnetic technique. That is the famous "Beijing Transgression". It is surprising that the foraminifera fossils at the same age were found in the Sangganhe River basin and some basins in Fenwei Graben which are located in the west of the Taihang Mountain. According to the present relief, we couldn't make any satisfactory explanation for this phenomenon, instead, they might be the evidences for the neotectonic movements in the Quaternary.

After Beijing Transgression there were many times of transgressions in different scales on the coastal plain of East and southeast China.

The traces of sea level changes since the Late Pleistocene are preserved much better. In general, three transgressions and two regressions could be identified during the last 120,000 years. By the family name of foraminifera,[37] they are:

Asterorotalia Transgression started 110,000 yr. B.P. up to its climax in 70,000 yr. B.P., when the sea level was 5—7 m higher than the present. And then the regression came into being. The regression lasted 25,000 years, arrived its lowest position in 40,000 yr. B.P., when the sea level was more than 70 m lower than the present.

Pseudorotelia Transgression started 40,000 yr. B.P., in 25,000 yr. B.P. at its climax, when the sea level was nearly at the present position, and then succeeded by the regression. In 15,000 yr. B.P. it reached the lowest level, it was more than 150 m lower than the present. It is the lowest sea level known up to now. At that time, the coastal line was located on the edge of the continental shelf of the East China Sea, it was retreated to the east side if Taiwan Island and to the south of Hainan were connected with the continent. The South China Sea became a closed basin, Mammals on Asia continent could moved southward passing Malay Peninsula to Sunda Islands, and eastward passing Taiwan, Philippine Islands, to Sulawesi Islands.

Ammonia Transgression started 17,000—16,000 yr. B.P. when sea level was 3—5 m higher than the present, and then the sea level retreated gradually to the present position.

During these transgressions and regressions, there were usually some stagnancies or even reversals, and their relics are found in many places.

Temperature curve of surface sea water in the East China Sea for the Quaternary, compiled on the basis of the habits of marine fauna, agrees with the temperature curve compiled on the basis from the proxy data on China continent. Fauna fossil assemblages showed that during transgressions, cold—water fauna gradually replaced by the warm—water fauna; during the periods of regression, warm—water fauna gradually replaced by the cold—water fauna. Woolly rhinoceros moved northward and were wandering on the continental shelf where now is the Bohai Sea, when the sea level was on its lowest. It is evident that the main marine transgression—regression cycles in China in the Quaternary were coincident with and controlled by interglaciation—glaciation cycles of climatic fluctuations. In fact, the Late Quaternary sea level changes of China seas are one part of the global sea level change. The first transgression and the third transgression coincide with the pre—wurm and post Wurm interglacial periods, the second transgression coincides with the interstadial between Wurm I and Wurm II, and two regressions between them coincide with the glacial Wurm I and Wurm II.

VI. REGIONAL STUDY AND THE IMPACTS OF HUMAN ACTIVITIES ON ENVIRONMENTAL EVOLUTION

Multiple proxy data and techniques have been used for the comprehensive research on regional environmental evolution. Most of the results are from the Qinghai—Xizang Plateau, the Loess Plateau, around the desertland in northwest China, the farming—pastoral belt along the southeastern border of the Inner Mongolia Plateau, the East China Plain and the borsea. These regions are "sensitive" area, where a sharp, long process of environmental change have undergone, and a wealth of proxy data had been accumulated in which environmental evolution information could be abstracted.

A number of recent research have delt with the human—environment relationships in China. Neolithic relics found in such area on Xizang Plateau where the natural conditions today are unable to be endured by human beings, the ruins of ancient villages even large cities such as Lou Lan State near Lop Nor dried lake, Tong Wan City in Ordos desertland,[39] are the evidences showing that human society might be influence by environmental change. But it is proved that the acute problems such as desertification in border region of arid area in North and northwestern China, serious soil erosion and land deterioration of the Loess Plateau, degradation of the grassland in Inner Mongolia, the shrank or even disappearance of lakes on the East China Plain, etc., are mainly caused by human activities, by the unreasonable land use, the over cultivation and deforestation.[40] Besides violent neotectonics, unstability of monsoon circulation, the long history of human activities and heavy population is one of the three dominating factors for the environmental change in China.

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