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PALEOMAGNETIC CHRONOLOGY AND RECORD OF HIMALAYAN MOVEMENTS IN THE LONGGUGOU SECTION OF GYIRONG-OMA BASIN IN XIZANG (TIBET)

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Abstract The Neogene sedimentary environment in the Longgugou section of the Gyirong-Oma Basin as studied by means of paleomagnetic chronology. By correlation, the Cenozoic fault basin on the north slopes of Himalayas had been formed 7.2MaB.P. ago, and then shrank and died at 3.2MaB.P. It marked that the region around the Himalayas experienced strong uplift in the time span from 7.2 to 3.2MaB.P. The age of Hipparion fossil buried in the Longgugou section is about 7.0∼6.7MaB.P. In comparison with Hipparion fauna in North China, they should have similar geographic and climatic environment. Because of the continual movement of the Himalayas, the fault basin downwarped and attained the biggest area in the time span from 5.9 to 3.6MaB.P. With the uplift of the Tibetan Plateau and the subsidence of North China Plain, the terrain in western China became higher than that in eastern China, the climatic environment experienced strong differentiation between eastern and western China. Since 3.6MaB.P. rivers in the western part dissected the basins due to strong uplifting of Tibet, Gyirong-Oma lake basin shrank from 3.2MaB.P., died completely in 1.7MaB.P., and then stepped into the stage of erosion and dissection.

Key words Gyirong-Oma basin of Tibet, Paleomagnetic chronology, Hipparion fauna, Himalayas uplift.

1 INTRODUCTION

During the Cenozoic era, one of the most important geological events was the collision and compression between the Indian and Eurasian Plates. It resulted in the uplift of Tibetan Plateau and the formation of the Himalaya Mountain. The Indian Plate traveled northward to its collision with the Eurasian Plate, with closing of the new Tethys Ocean and uplifting of the Tibetan Plateau, new dividing range was formed, and the new rivers flowed from the summit, along the northern slopes of the Himalayas, to a series of fault basins (Gyirong-Oma Basin was one of them) while the older rivers which flowed into the Tethys Ocean died out. It recorded the environmental effect of the continental topography in China being transformed from higher in the east to higher in the west. The research of sedimentary features, paleontology record and time scale has a special meaning.

The Gyirong-Oma Basin situated at the northwestern slopes of the Himalayas (Fig. 1) with an altitude of 4100∼4400m, received a set of Neogene fluvial-lacustrine sediments. In the late 1970s, the expedition of CAS (Chinese Academy of Sciences) found Hipparion fauna in the Cenozoic sediments around the Oma village of

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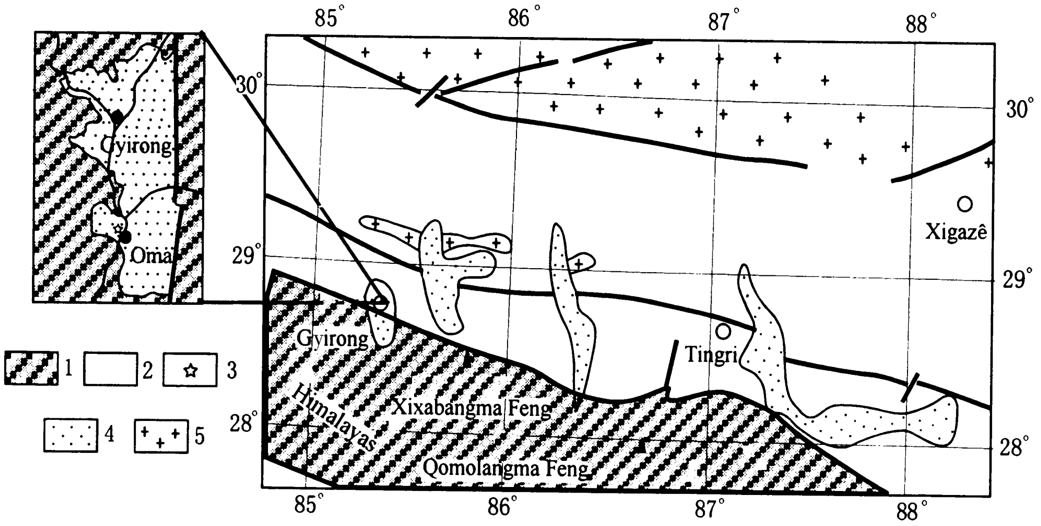
Gyirong-Oma Basin. By stratigraphic analysis, the section was divided into three sets of strata, i.e., upper, middle, and lower, and named as Oma Formation of middle and late Pliocene[1]. Tibet and North China had Hipparion fauna at the same time in the Neogene, which demonstrated that they had similar climatic environment at that time. But now there is great difference between these two areas in not only climatic environment but also geographic landscape. It had vital significance to date the fossil localities of Hipparion fauna (Gyirong-Oma Basin) in researching environmental changes of Tibetan Plateau.



1 Himalaya mountains; 2 fault; 3 sampling locality; 4 Cenozoic Basin; 5 rock area.

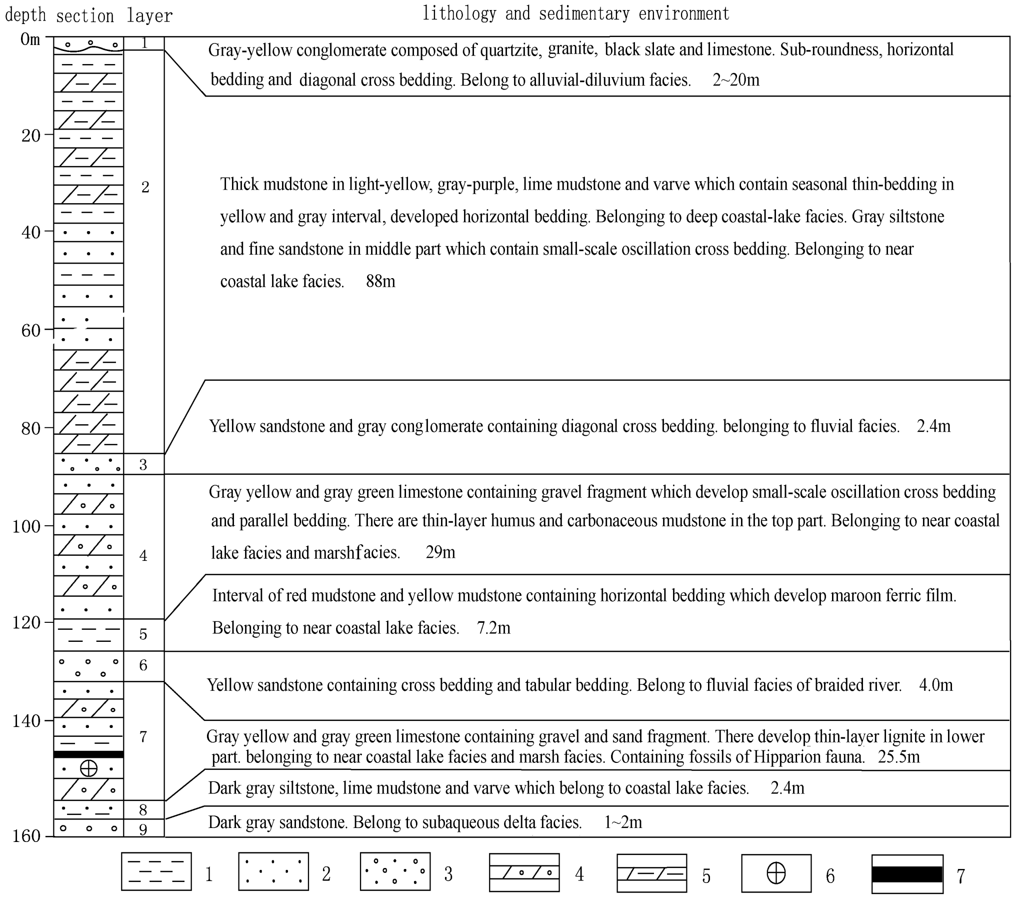
Fig. 1 Locality of Gyirong-Oma Basin of sampling section

In the past, Chinese scholars have carried out some investigation of the Hipparion fossils in Tibet[2]. In order to date the fossil localities of Hipparion fauna in Gyirong-Oma Basin, Shen et al.[3] had done the magnetostragraphic research in Longgugou section, but collected 32 specimens from the strata of Hipparion fauna fossil of 160m thick in the section. With a span of 4 million years in Cenozoic era and polarity reversed frequently, the number of samples is not enough to erect a precise time scale. The Gyirong-Oma Basin had recorded the information of Himalayan movements and evolution of fault basins of northern slope of Himalayas, so erecting a precise time scale is very important, as the base of researching evolution. To get high resolution magnetostratigraphic data, we have collected 348 magnetic specimens from the strata with Hipparion fauna fossil in the Longgugou section by means of paleomagnetic chronology, dated the time of stratigraphy, analyzed the sedimentary features, researched the environmental information of geology and climate from the record of the basin, and discussed the uplift of Himalayas.

2 MAIN STRATIGRAPHY

With the fast elevation and erosion of Himalayas, big amount of erosional sediments were deposited in two sides of the mountains, which are the early, middle Xiwalike group in the south slope and Zhada-Gyirong group in the north slope.

Previously, people had done some research in the stratigraphy of Gyirong-Oma Basin[3~5]. For analyzing sedimentary environment of the basin and dating the paleomagnetic time in different environment, the author described the stratigraphy from the sedimentology (Fig. 2).



Gray-yellow conglomerate composed of quartzite, granite, black slate and limestone. Sub-roundness, horizontal bedding and diagonal cross bedding. Belong to alluvial-diluvium facies. 2~20m

Thick mudstone in light-yellow, gray-purple, lime mudstone and varve which contain seasonal thin-bedding in yellow and gray interval, developed horizontal bedding. Belonging to deep coastal-lake facies. Gray siltstone and fine sandstone in middle part which contain small-scale oscillation cross bedding. Belonging to near coastal lake facies. 88m

Yellow sandstone and gray conglomerate containing diagonal cross bedding. belonging to fluvial facies. 2.4m

Gray yellow and gray green limestone containing gravel fragment which develop small-scale oscillation cross bedding and parallel bedding. There are thin-layer humus and carbonaceous mudstone in the top part. Belonging to near coastal lake facies and marshfacies. 29m

Interval of red mudstone and yellow mudstone containing horizontal bedding which develop maroon ferric film. Belonging to near coastal lake facies. 7.2m

Yellow sandstone containing cross bedding and tabular bedding. Belong to fluvial facies of braided river. 4.0m

Gray yellow and gray green limestone containing gravel and sand fragment. There develop thin-layer lignite in lower part. belonging to near coastal lake facies and marsh facies. Containing fossils of Hipparion fauna. 25.5m

Dark gray siltstone, lime mudstone and varve which belong to coastal lake facies. 2.4m

Dark gray sandstone. Belong to subaqueous delta facies. 1~2m

1 mudstone; 2 sandstone; 3 conglomerate; 4 limestone with conglomerate; 5 mud limestone; 6 fossils layer; 7 lignite layer.

Fig. 2 Column of lithology in Gyirong-Oma section

3 SAMPLE COLLECTING AND MEASUREMENT RESULTS

We collected 348 paleomagnetic samples from the Oma section of 160m thick. Sampling interval is about 0.5m, and every sample proceeded into two parallel groups (A, B) with totally 348×2 specimens. Group A was measured in the Key Laboratory for Continental Dynamics of Education Ministry of NWU, the samples were thermally demagnetized using TSM-2 thermal demagnetizer produced by the USA and measured in spinner magnetometer produced by MINISPING Company, the England. Group B was measured in the Paleomagnetic Laboratory of ETH, Switzerland. The samples were thermally demagnetized using TSM-2 thermal demagnetizer produced by the USA and measured in superconductive magnetometer produced by 2G Company, the USA. A part of the specimens were also studied for rock magnetism, to learn the carrier of remanent magnetism, choose the right way to demagnetize and analyze vector direction of characteristic RM. There were about 20 specimens damaged in the process.

Saturation curve of isothermal RM is one of the most common methods to identify magnetic minerals[6]. Under 300mT the specimens attain 80%~90% saturation intensity, showing the main carriers are magnetite and magnetic hematite (Fig. 3a). For some specimens (Fig. 3a) under 300mT the RM continue to increase, even under 2.5T, indicating the existence of magnetic minerals with high coercive force (such as red iron ore). According to the category of rock magnetism and previous experiences about demagnetization, thermal demagnetization should be the better method.

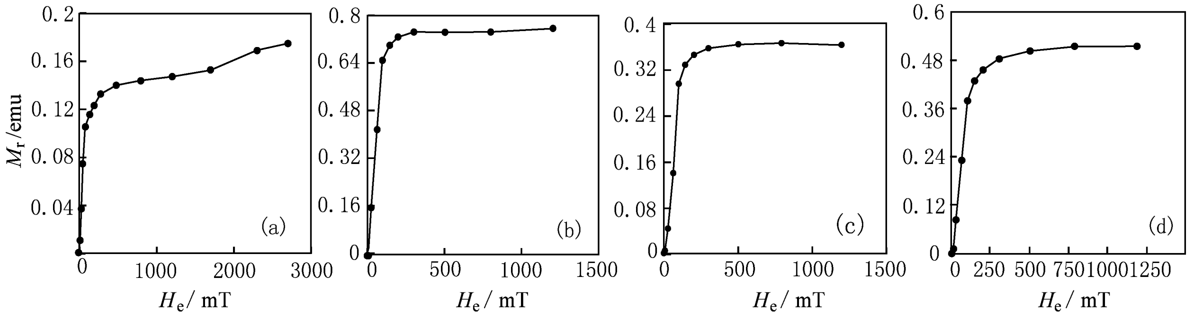


Fig. 3 Saturation curves of IRM of samples in Gyirong-Oma section

M_r represents isothermal remnant magnetization; H_e represents magnetic field.

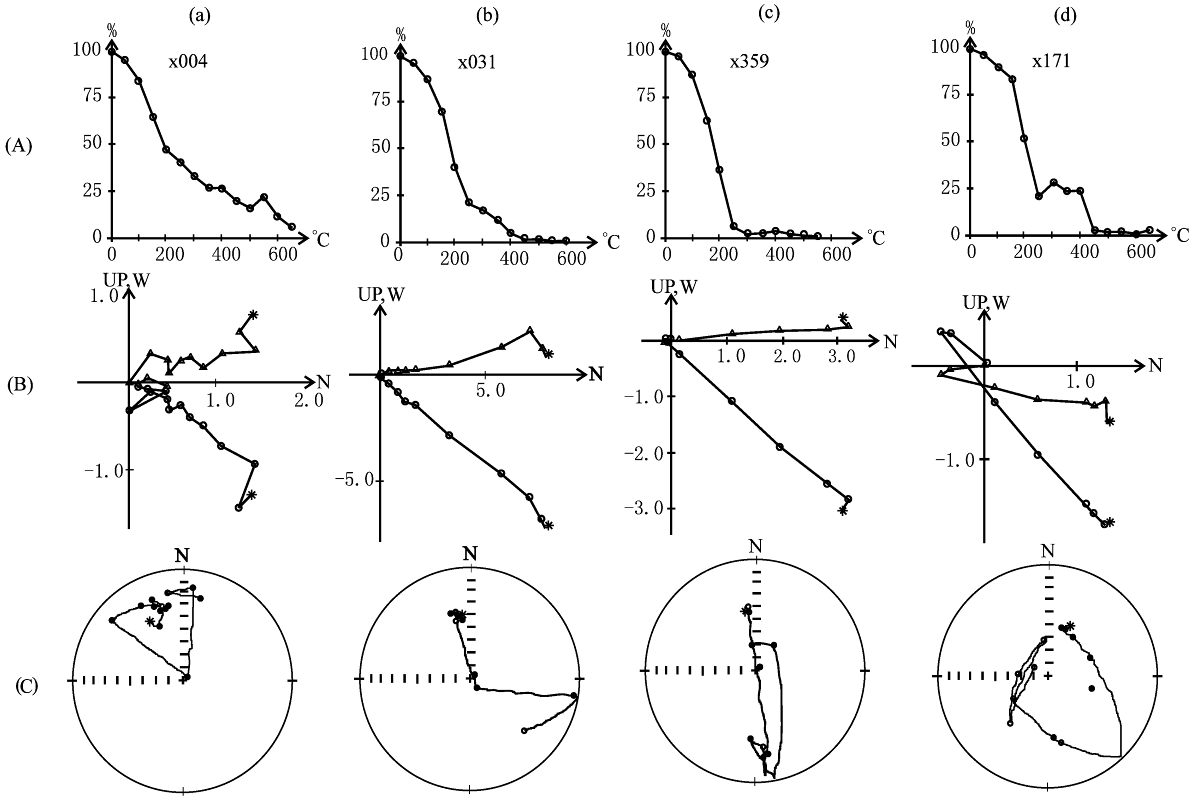


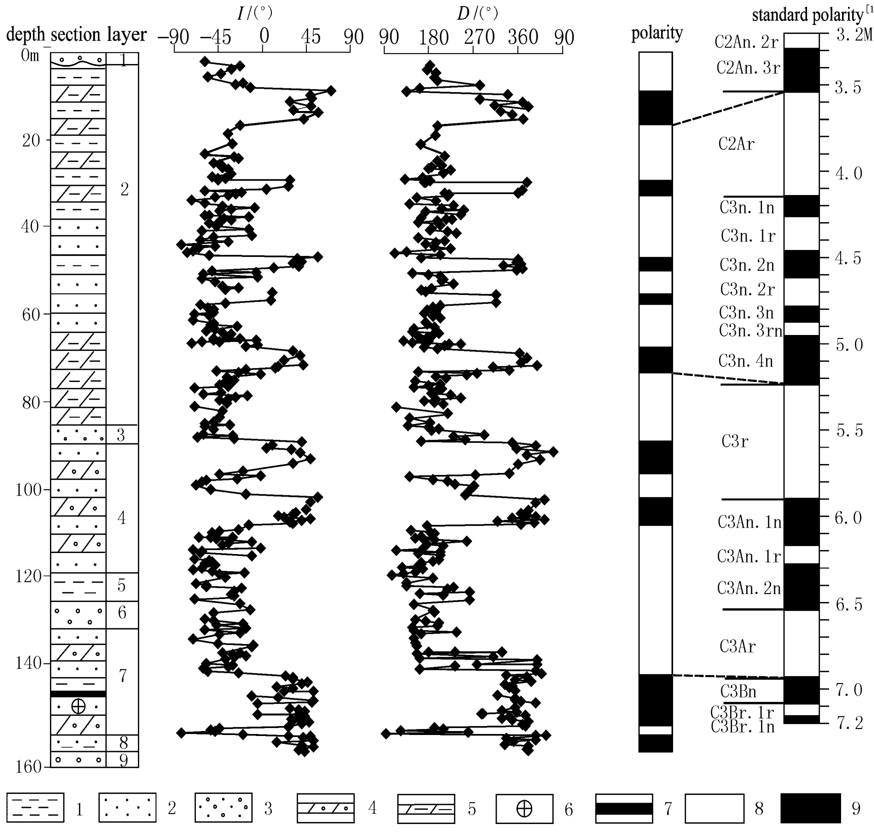
Fig. 4 Thermal demagnetization of sample in Gyirong-Oma section

(A) Zijdereld project; (B) Magnetic intensity; and (C) Normal project.

(a,b) Normal remnant magnetization; (c,d) Reversed remnant magnetization.

Fig. 4 is the results of thermal demagnetization. Fig. 4(a,b) shows the demagnetization diagram of two normal polarity specimens. The temperature of sample in Fig. 4a goes up to 650°C, the RM vector trends to the origin, shows the RM characteristic of normal polarity sample. When the temperature of sample in Fig. 4b reaches 250°C, RM vector turns to be stable and trends to the origin, the curve shows the vector direction of PCRM (Primary Characteristic remanent magnetization). When the temperature gets 500°C, vector direction deviating for the RM intensity is too weak. Fig. 4(c,d) shows the demagnetization diagram of two reversed specimens. With the increase of temperature, sample polarity undergoes inversion gradually. The RM vector of sample in Fig. 4(c,d) gradually reversed during the procession of systematic demagnetization, when the temperature arrived at 300°C, the RM intensity became stable, the polarity turned to reverse, the curve shows the reversed vector direction of PCRM. When the temperature reaches 500°C, the vector direction deviating for the RM intensity is too weak. Synthetic vector direction in the range of 300 to 450°C represents the vector direction of PCRM. When comparing the thermal demagnetization with the alternating demagnetization, we thought thermal demagnetization result was better, all specimens were proceed to thermal demagnetization at 50°C, 100°C, 150°C, 200°C, 250°C, 300°C, 350°C, 400°C, 450°C, 500°C, 550°C, 600°C and 650°C. Most of samples acquired the PCRM, and 21 specimens having no obvious PCRM were excluded. Except these and 20 specimens damaged in process, there were 307 specimens used for magnetostragraphy. By analyzing the vector of PRM, we got the sequence of polarity in the section.

The measurement results are correlated to the GPTS (geomagnetic polarity time scale). It's better to have other substantial dating evidence, but the Tertiary in China, including the red-clay sediments in northern and northwestern China, and the fluvial-lacustrine sediments in northwestern China, rarely had dating data (such as volcano material). Paleomagnetic chron lacks isotopic age or other age evidence[7∼10]. Therefore, it's better to contrast the characteristic of polarity inversion to GPTS with some paleontology proofs (Fig. 5). Fortunately, Oma section had abundant mammalian fossils, most of them are the typical Baode stage fauna in North China such as *Hipparion gyirongensis* Hsu, *Chilotherium xizangensis* Huang, *Metacervulus capreolinus* Teilhard et Trassaet, *Palaeotragus micodon* Koken, *Gazella gaudryi* Schlosser, *Crocuta* sp and etc. The geological age of these fossils is late Miocene. Baode stage in China is about Turolian stage in Europe, corresponding to MN15∼MN12, i.e. 5.3∼8.0Ma. Considering the paleontologic factor, the characteristics of the polarity sequence in Longgugou section were contrasted with the GPTS of Cande-Kent95. The result shows that the records of Oma section can be correlated with 9 normal polarity zones and 9 reversed polarity zones in Cande-Kent95 GPTS, they are C3Br.1n, C3Br.1r, C3Bn, C3Ar, C3An.2n, C3An.1r, C3An.1n, C3r, C3n.4n, C3n.3r, C3n.3n, C3n.2r, C3n.2n, C3n.1r, C3n.1n, C3Ar, C2An.3n, C2An.2r. The 9th layer with 2m thick conglomerate was not



1 mudstone; 2 sandstone; 3 conglomerate; 4 limestone with conglomerate; 5 mud limestone; 6 fossils layer; 7 lignite layer; 8 reversed polarity; 9 normal polarity.

Fig. 5 The measurement result of paleomagnetism of Gyirong-Oma section sampled. The 8th recorded C3Br.1n. The bottom of the section is about 7.2MaB.P. The 7th layer with Hipparion fossil recorded C3Br.1r and C3Bn, the layer is about 7.0MaB.P. The top of the section is about 3.2MaB.P., corresponding to C2An.2r.

4 SEDIMENTARY EVOLUTION OF GYIRONG-OMA BASIN IN NEOGENE

Gyirong-Oma Basin was formed in 7.2~3.2MaB.P., the evolution experienced stages of origin-expand-contract, expand-contract, and expand-contract-consume. Corresponding sedimentary environments are submerged delta facies- deep lake offshore facies- nearshore facies and swamp subfacies, fluvial facies-nearshore facies and swamp subfacies, and fluvial facies -nearshore facies and offshore facies-alluvial-pluvial facies, three main cycles. The features of sedimentary assemblage reflected tectonic evolution, climatic change, paleogeomorphology and material supply mode, in certain degree recorded the characteristic of environmental evolution in the northern slope of Himalaya shan. According to the variety of the sedimentary facies in the section, the sedimentary context was divided into three combinations of cyclic deposition.

First cycle: It contained 9th, 8th and 7th layers and covered the time span of 7.2~6.7MaB.P. With the closure of Tethys Ocean and uplift of Tibetan Plateau, along the northern slope of the Himalayas formed a series of fault basins. In the early period, the edge of fault basins was characterized by steep slopes. Large numbers of coarse alluvium and proluvium sediments flowed into lake-basin, formed coarse-grained delta-fan sediment (in 9th layer). This stage formed in 7.2MaB.P., which might record an obvious uplift of Himayalan-Tibetan Plateau. Since then, the basin continued to sink and the lake continued to deepen. A set of deep-lake-offshore-facies sediment such as deep-grey siltstone, grey fine sandstone, mud limestone and varved clay (in 8th layer) were deposited. Tectonic movement tended to slow down at 7~6.7MaB.P., the basin became stable or lifted very slowly and the lake became shallow, a set of nearshore shallow-lake and swamp sediments were deposited (in 7th layer). Happarion fauna fossils were found under the lignite layer, especially some forest steppe type such as *Hipparion chilongenis*, *Chilotherrum* sp., *Palaeoteragus microdon* Koken and etc.[1]. Affiliated with extensive distributation of Hipparion fauna in red-clay in North China[7], it showed the similar climatic environment between the fault basins in northern Himalayas and red-clay in North China.

Second cycle: It contained 6th, 5th and 4th layers and covered the time span of 6.7~5.9MaB.P. The basin descended again and flood flowed into it. Coarse-grained alluvium and proluvium sediments were deposited again on the top of the first cycle. As the basin continued to sink and the lake continued to deepen, a set of nearshore facies such as calcarenite, siltstone, red mudstone and humulith were deposited.

Third cycle: It contained 3rd and 2nd layers and covered the time span of 5.9~3.2MaB.P. Coarse-grained alluvium and proluvium sediments deposited again in lake-basin. A set of obliquely beded yellow, gray sandstone and gray conglomerate were deposited. Since then, the basin continued to sink and a set of deep-lake-offshore facies including thick wheat mudstone, gray purple mudstone, mud limestone and varved clay were deposited with 88m thick. During the course, the basin was lifted a little again for a short time, deposited a little nearshore sand-beach sedimentation such as gray siltstone and fine sandstone. Since 3.2MaB.P., Tibet was lifted fast, fault basins contracted quickly and the Oma basin was consumed. The research by Wang[5] indicates Gyirong Lake-basin died out in 1.7MaB.P. A set of Quaternary fluvial sediments were deposited on the top of those lacustrine sediments. It marked that fault lake-basins in northern slope of Himalayas ended the history of development and stepped into the stage of erosion and dissection.

5 HIMALAYAN MOVEMENT AND THE TOPOGRAPHIC TRANSFORMATION OF EASTERN AND WESTERN CHINA IN CENOZOIC ERA

With Himalayan movement and uplift of Tibetan Plateau, the Chinese topography Changed very much. Scientists researched in many fields[12~16]. Since the Indian Plate collided with Eurasian Plate, there took place uplift many times. The two continents first collided and joined together in 60MaB.P.[15], the Gangdisi Mountain uplifted at that time. Since 23MaB.P., with intensive secondary Himalayan Movement, the Himalayas grew up. Li[16] researched the overlying basalt on the planation surface in dividing range of Mangkang (eastern Tibetan Plateau), dated the K-Ar age (3.4MaB.P. and 3.8MaB.P.), thought the basalt along the cranny erupt in the planation surface as the first uplift of Tibetan Plateau (3.6MaB.P.). He also researched the planation surface around the Kunlun Mountain, where the latest K-Ar age of main planation was 7.0 MaB.P., thought Tibet was once elevated at 7MaB.P. and formed the main planation surface in middle and late Miocene, but the surface of middle Miocene was leveled off, the latest uplift of Tibetan Plateau was in 3.6MaB.P[16].

Previously, people researched in terms of uplift and planation of mountain and plateau, discussed Basin Tectonic System, orogeny and crust deformation. Basic conclusion was that Himalayas grew up in 23MaB.P., Tibet Plateau uplifted and leveled off many times. The consideration of Li was representative[16], namely Tibet Plateau had intensive uplift since 7.0MaB.P. and experienced latest uplift in 3.6MaB.P. The author thought that the records of Himalayas in Gyirong-Oma Basin are in accord with the research of Li[16].

According to the result of this paper, the Himalayas were uplifted intensively in 7.2MaB.P., many fault basins were developed in the north slope. Gyirong-Oma Basin was formed and extended gradually. The Happarion fauna fossils of forest steppe type were found in the strata of 7.0∼6.7MaB.P. in Gyirong-Oma basin. In comparison with Hipparion fauna distributed extensively in North China, they should have had similar geographic, climatic environment and even altitude. After 6.7MaB.P., Hipparion fauna dispeared in Gyirong-Oma Basin, indicating that they couldn't conform to the changing ecologic environment and altitude. The Happarion fauna still lived in North China at that time. Obviously, since then the topography in the west became higher than that in the east. The uplifting of Tibetan Plateau, changing of air circulation and forming of monsoon had great influence on the environment of eastern and western China. By analyzing the uplifting record of sedimentary environment in Gyirong-Oma basin, the Himalayas continued to rise during the time from 5.9 to 3.2MaB.P., fault basins subsided and extended to deep lake. For the intensive uplift in 3.2MaB.P., rivers cut down older lake basins, Gyirong-Oma lake basin contracted and then stepped into the stage of erosion and dissection. By researching the dust deposited in the north of China, An et al.[7] thought East Asian winter monsoon was formed in 7.2MaB.P., and enhanced in 3.6MaB.P. owing to intensive uplifting of Tibetan plateau. There are several reports about dust deposit research, most of them support that there were two obvious climatic changes caused by the uplifting of Tibetan plateau and enhancing of East Asian monsoon. The similar record are got from the Gyirong-Oma basin that the fault basins on the north slopes of Himalayas were formed in 7.2MaB.P. and contracted in 3.2MaB.P.

6 CONCLUSIONS AND DISCUSSION

The paleomagnetic result shows that the whole section have recorded 9 normal and 9 reversed polarity zones. Compared with the Cande-Kent95 GPTS, they correspond to C3Br.1n, C3Br.1r, C3Bn, C3Ar, C3An.2n, C3An.1r, C3An.1n, C3r, C3n.4n, C3n.3r, C3n.3n, C3n.2r, C3n.2n, C3n.1r, C3n.1n, C3Ar, C2An.3n, C2An.2r. The 8th recorded C3Br.1n, the bottom of the section is about 7.2MaB.P. The 7th layer with Hipparion fossils recorded C3Br.1r and C3Bn, the fossil layer is about 7.0MaB.P. The top of the section is about 3.2MaB.P., corresponding to C2An.2r. They showed that the basin was formed in 7.2MaB.P. and died in 3.2MaB.P. Their timing and character are related to the uplift of Tibetan plateau which had experienced two intensive uplifts in 7.0MaB.P. and 3.6MaB.P. The Happarion fauna fossils of forest steppe type were found in Gyirong-Oma Basin during the time 7.0∼6.7MaB.P. In comparison with Hipparion fauna distributed extensively in North China, they should have had similar geographic and climatic environment and even the same altitude. Then Hipparion fauna disappeared in Gyirong-Oma Basin indicating that the topography in China had transformed greatly since middle middle Cenozoic (7.0MaB.P.), Tibet became higher than North China.

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