CHINESE GEOGRAPHICAL SCIENCE
Volume 9, Number 4, pp. 289–296, 1999
Science Press, Beijing, China

PROGRESS IN STUDIES ON GEOGRAPHICAL ENVIRONMENTS OF THE QINGHAI-XIZANG PLATEAU[①]

Zheng Du(郑 度) Li Bingyuan(李炳元)
Institute of Geography, the Chinese Academy of Sciences, Beijing 100101, *P. R. China*

(Received 5 July 1999)

ABSTRACT: The Qinghai-Xizang (Tibet) Plateau area was subjected to twice uplift and planation in the Tertiary. Intenseuplifting of the plateau area has given rise to drastic changes and differentiation of physical environment on the plateau and the surrounding area since 3.4 Ma B. P. Significant environmental changes with dry tendency in interior of the plateau had occurred during the last 150 ka B. P. By comparative study on several mountains of the plateau, two systems of the structure-type of the altitudinal belt are identified and nine groups are subdivided . A distribution model with close relevance to highland uplift effect has been generalized. A number of striking geo-ecological phenomena and their spatial pattern such as moisture corridor, dry valleys, high-cold meadow zone, and high-cold arid core area are investigated and discussed. Based on the thermal conditions, moisture regimes and variation in landforms of the plateau is sequentially demarcated. A tentative scheme of 2 temperature belts, 10 natural zones and 28 physical districts has been proposed not including southern slopes of the East Himalayas. The Qinghai-Xizang Plateau is sensitive to "green house effect", showing close relation with global change. Characteristics of temperature and precipitation on the plateau during the last 2000 years, and response of glaciers, snow deposit and permafrost on the plateau to global change are dealt with in the present paper.

KEY WORDS: Qinghai-Xizang Plateau, geographical environment, palaeo-geographical evolution, environmental differentiation

The intense uplift of the Qinghai-Xizang (Tibet) Plateau in the last several million years has given rise to drastic changes of natural environment and distinct differentiation of the plateau proper and the neighbor regions. Recent progress in studies on palaeo-geographical evolution, differentiation of geographical environments, recent climatic and environmental changes are dealt with in the present paper.

1 PALAEO-GEOGRAPHICAL EVOLUTION

Tethys disappeared in the Qinghai-Xizang area due to the collision and combination of the Indian plate with the Eurasian plate at about 40 Ma B. P., then the Qinghai-Xizang Plateau area started stages of continental palaeo-geographical evolution. There were three uplift periods and two planation periods during the Cenozoic Era on the plateau deduced by the newly acquired proxy documents about planation surface, related sediments, palaeobiota, pollen, tectonic movements, magnetic movements, and so on (Wang *et al.*, 1996; Cui *et al.*, 1996; Li Jijun *et al.*, 1995, 1996, 1998; Raymo *et al.*, 1992; Zhang and Li, 1991). The three uplift periods occurred around 40 Ma, 22 Ma, and after 3.4 Ma B.P., respectively. The average height of the plateau was not more than

① Under the auspices of Chinese National Key Project for Basic Research (G1998040800) and CAS project on the Qinghai-Xizang Plateau (KZ951–A1–204, KZ95T–06)

2000 m a. s. l. in the two former periods, and probably not more than 1000 m by 3. 4 Ma B. P. after planation.

1.1 Twice Cycles of Uplift and Planation in the Tertiary

The first uplift of Qinghai-Xizang area occurred at the early stage of collision between plates around 40 Ma B. P., brought about uplift of the Gangdisê Range, deposited enormous Molasse with a thickness of 2000– 4000 m at its southern sides. After 38 Ma B. P. the earth surface was subjected to denudation and planation, the Qinghai-Xizang area was characterized by latitudinal zonation owing to predomination of the planetary wind systems (Shi *et al*., 1998a).

After the second uplift of Qinghai-Xizang area appeared at about 22 Ma B. P., the plateau surface might raised up to 2000 m a. s. l. The coupling of ocean-continent evolution resulted in the occurrence of palaeo-Asian monsoon and changes of natural zonation, characterized by expansion of humid forest zone and retreat of arid region northwestwards. In the Miocene the natural zonation was complicated, the tropical and subtropical evergreen forest retreated southwards, the vegetation of southern sides of the Gangdisê Range reflected warm and humid environments (Shi *et al*., 1998a). Main period of denudation and planation occurred in 19 Ma– 7 Ma B. P. A number of lake basins formed on the northern sides of the Himalayas at about 7 Ma B. P., the strata of the late Miocene– Pliocene are mainly composed of lacustrine and fluvial-lucastrine deposits. Analyses of pollen and grain size of deposition shows that the studied area uplifted slowly with gentle relief and characterized by subtropical montane forest-steppe landscapes. The Qinghai-Xizang area was at about 1000 m a. s. l., with main vegetation of montane coniferous forest and needle broadleaved mixed forest (Shi *et al*., 1998b).

1.2 Strong Uplift of the Qinghai-Xizang Plateau since 3.4 Ma B. P.

The strong uplift of the whole plateau, periodically started in 3. 4 Ma B. P., is called the Qinghai-Xizang Movement. Then the Kunlun-Yellow River Movement and Gonghe Movement happened one after another, and the plateau uplifted continually. The Qinghai-Xizang Movement may be subdivided into 3 stages, i. e., 3. 4 Ma, 2. 5 Ma, and 1. 7 Ma B. P. The strong uplift of the area in 2. 5 Ma B. P. made the plateau surface raise up to 2000 m a. s. l., caused the formation of the plateau monsoon, and strengthened monsoon circulation, which intensified the winter monsoon and loess accumulation in the North China. Under influence of summer monsoon, the climate of Qinghai-Xizang Plateau was warm and humid, a lot of lakes developed (Li, 1995). Corresponding with the periodically uplift of the plateau in 1. 7 Ma B. P., the contemporary river valleys began to downcutting and a number of fluvial terraces to be formed. The average elevation of the plateau attained to 3000 – 3500 m a. s. l., mountains over 4000 m as a result of Kunlun-Yellow River Movement during 0. 8 Ma– 0. 5 Ma B. P. (Shi *et al*., 1999). The orbit pattern transformation of revolution in the Middle Pleistocene coupling with the global cooling caused the formation of the plateau cryosphere. Though the whole huge ice sheet didn't exist, glacier appeared in largest scale with an area of 0. 5 million km^2, accounting for 20% of the plateau (Li *et al*., 1991b; Shi *et al*., 1995). Owing to glaciers in large scale and stable snow deposit, the albedo increased, the Cold High of the plateau enhanced in winter season, and the plateau was colder than ever. Strong plateau monsoon blew to the Arabian Sea which made sea-surface temperatures low and summer monsoon weak (Emeis *et al*., 1995). While the interior plateau became more arid, and the drought of northwestern plateau was so serious that the Taklimakan Desert formed.

1.3 Climatic and Environmental Changes on the Plateau since 150 ka B. P.

According to the comparison of continuous records in Guliya ice core with those in Vostok and Greenland, there are apparent regional characteristics about climatic and environmental changes on the plateau, which completely different from those in the Antarctic and Arctic over the past 150 ka. In the Last Glacier Maximum at 23 ka B. P., the temperature of Guliya ice core was lower than the present by 9℃, the glacier areas were 7.5 times than the present one. The last interglacier stage was extremely warm and humid, the record of Guliya ice core was warmer than the megathermal period in the Holocene by above 1℃(Yao *et al.*, 1996). In the great lake period during 40 ka– 25 ka B. P., the lake areas in the Karakorum Mountains and the West Kunlun Mountains were 3 times larger than the present one (Li *et al.*, 1991a). In the Late Pleistocene the dry tendency of the plateau interior gave rise to several lakes closed, and the exterior water system changed to the interior one, loess deposit extensively appeared on the northern flanks of the Kunlun mountains(Zhang *et al.*, 1994). The biggest episode was Younger Dryas (YD) temperature decline during the ice-melting age of the last glacial period. Based on the analysis of $\delta^{18}O$ in Guliya ice core within 5 ka– 20 ka B.P., there were three periods in the YD temperature decline on the plateau, which happened within 12.2 ka– 10.5 ka B. P.. Then the temperature increased radically and the value of $\delta^{18}O$ reached – 14‰ in 10.8 ka B.P. from – 21‰ in 10.9 ka B.P., which meant that the temperature increased by 11℃(Yao *et al.*, 1997). In addition, the contents of air dusts increased rapidly in the YD episode due to vegetation degradation and strong wind.

The Holocene may be subdivided into 3 periods (Li *et al.*, 1983; Yao *et al.*, 1992, 1995). In the Early Holocene temperature raised rapidly with increasing precipitation, which brought about the rise of lake surfaces, water desalination and luxuriant vegetation (Gasse *et al.*, 1996; Zhang *et al.*, 1994). The Period of 8.5ka– 7 ka B. P. in the Middle Holocene, with $\delta^{18}O$ up to – 12.5‰ and temperature higher than the present by some 1.5℃ (Yao *et al.*, 1997), was the optimum period in the Holocene. It was characterized by strong summer monsoon with plenty precipitation, forest vegetation expanded from southeast to proper of the plateau, several human activity relics of microlithic culture were found on the plateau (Li *et al.*, 1983). After 4 ka– 3 ka B. P., environment of the Late Holocene became worse, with temperature dropped and precipitation decreased, forest retreated to southeast periphery of the plateau, glaciers advanced and permafrost expanded in the New Ice Age. According to recent repeat measure of benchmark the mean uplift rate of the plateau is 5.8 mm/a (Zhang, Zhou *et al.*, 1991).

2 DIFFERENTIATION OF GEOGRAPHICAL ENVIRONMENT

Altitudinal variation and horizontal differentiation of physical environment on the plateau differ from the lowland region, showing three dimensional zonation with unique geo-ecological phenomena and their spatial pattern.

2.1 Altitudinal Belt System and Its Distribution Model

The structure type of the altitudinal belt (STAB) on the Qinghai-Xizang Plateau has long since drawn attention of geographers (Zhang Xinshi, 1994; Sun and Zheng, 1996, 1998b). The continental and monsoonal systems of structure-type can be identified based on spectrum-structure, base-belt, dominating belt, pattern of altitudinal belt and temperature-moisture regimes. They may be subdivided into high-cold semiarid, high-cold arid, high-cold super-arid, super-arid, arid, semiarid, subhumid, humid and high-cold subhumid structure-type groups (Zheng and Li, 1994; Sun and Zheng, 1996).

The distribution model of STAB shows that two spectral systems of the altitudinal belt form a striking contrast. From margin to interior of the plateau, in addition to the differences of base belt, the number of altitudinal belts decrease and the spectrum of the altitudinal belt simplifies. In eastern part of the plateau the upper forest limit of spruce (*Picea balfouriana*) is at 4400 m a. s. l. on the shady slopes, being the highest one on the earth. In addition to the location of subtropical zone (30°–31°N), its higher elevation may be probably resulted from the heating effect of vast mass of the plateau (Zheng and Li, 1994).

2.2 Spatial Pattern of Geo-ecological Phenomena

As concerns regional differentiation of Tibetan plateau, the moisture corridor, dry valleys, high-cold meadow zone and high-cold arid core area are striking geo-ecological phenomena, forming a unique spatial pattern of physical geography on the plateau (Sun and Zheng, 1996, 1998b).

Moisture corridor in the lower reaches of the Yarlung Zangbo River has played a significant role in carrying the moisture-laden air-masses from the Indian Ocean to the plateau proper (Yang *et al.*, 1987). As the most humid section of the Himalayas, it is one of the richest biota areas and an important center of speciation and variation. The tropical forest stretches along the river valley as far north as 29°N, much beyond the northern boundary of tropical zone in other continents of the world (Peng *et al.*, 1997).

In dry valleys, situated at the periphery of the plateau, a number of valley shrub landscapes occur extensively at bottom of deep gorges from the Hengduan Mountains in the east, middle and west Himalayas in the south to the Karakorum Mountains in the west (Zhang Rongzu, 1992; Zheng, 1999). Most of the dry valleys in the middle and northern sections of the Hengduan Mountains, pertaining to the semiarid category with specific landscapes, are predominated by meso-xeromorphic microphyllous thorny scrubs with sparse coverage. The montane drab soil in the valley is characterized by aridisol with weak eluviation, residual calcium carbonate and alkaline reaction (Zheng and Li, 1994).

High-cold meadow zone, characterized by highland subpolar humid/subhumid climate, is a transitional area from deep gorges to the plateau proper. The natural zone is unique in physical environment and natural ecosystem, and could not be found at the lowlands elsewhere on the earth. It is an important pasturelands of animal husbandry for Tibetan on the plateau. The boundary of the natural zone in southeast sides corresponds to the northwest limit of montane forest, depending on mean temperature of the warmest month and in keeping with boundaries between the plateau subpolar and the plateau temperate. In contrast, boundaries of the natural zone in the northwestern sides are correlated with the occurrence of alpine steppe or alpine meadow steppe, being in accord with the limit of moisture regimes from subhumid to semiarid (Zheng, 1996b).

A high-cold arid core area, located in the interior of the middle Kunlun Mountains in the northwestern subpolar desert and semidesert zone, presents a striking contrast to moisture corridor in the southeast of the plateau. This area is far off both tracks of moisture transportation from the Indian Ocean and the Arabian Sea (Lin and Wu, 1990). Evidences of the extremely aridity, such as high-cold super arid structure type group of STAB and the super-continental type of glaciers are found in the interior of middle Kunlun Mountains and its southern sides (Sun and Zheng, 1998b; Zheng, 1999).

2.3 Physico-geographical Regional System

As the main differential factor of latitudinal zonality, solar radiation presents its important influence: temperature decreases gradually from south to north, and so does the elevation of boundary limit of altitudinal belts. However, the circling distribution of radiation balance, temperature, and other factors centered in the northwestern plateau reflects the influence of altitude and topographical structure to much degree, which is in sharp contrast with the differentiation of latitudinal zonality.

Predominated by atmospheric circulation and topographical structure of the plateau, differentiation of regional combination of temperature and moisture presents as following: change from the southeastern warm-humid to the northwestern cold-arid; zoning alternation of montane forests-alpine meadow-alpine/montane steppe-alpine/montane desert. Compared with corresponding physico-geographic zone of the temperate belt in China, they are similar to each other in moisture regimes, while the plateau is characterized by relative low temperature (Sun and Zheng, 1998b).

Division of the physico-geographic regions complies with the bioclimatic principle, namely, the zonality principle. That is to say, the natural regions are divided according to temperature, moisture, and combination of topography in turn. According to the principle, method, and index of division of natural regions, the plateau is divided into 2 temperature belts, 10 natural zones with distinguishing features, and 28 physical districts except for south sides of the Himalayas. (Zheng, 1996a; Sun and Zheng, 1998b).

3 RECENT CLIMATIC AND ENVIRONMENTAL CHANGES

With vast area, high altitude, larger proportion of surface long wave radiation to radiation balance, drier surface and weaken impact of human activities on the nature, the Qinghai-Xizang Plateau is sensitive to "green house effect", showing close relation with global change. Recent climatic and environmental change of the plateau as well as their response are described below (Sun and Zheng, 1998a).

3.1 Characteristic of Temperature and Precipitation During the Past 2000 Years

There are plenty of proxy data about climatic and environmental changes on the plateau over the last 2000 years, such as ice core, tree-ring records and historical documents, etc. (Sun and Zheng, 1998a).

The records of temperature changes during the past 2000 years show that the beginning of the Christian era was cold; in 100–200 A.D. it was 1℃ warmer than today; temperature was low during 200–400 A.D., from 500 A.D. it became warmer, marked warming to the 1050 A.D.; maximum range of temperature decline occurred in the end of the 11th century, followed by the warm period during 1200–1400 A.D. Afterwards, the climate changed to be cold dramatically and entered into the modern Little Ice Age which can be divided into three apparently cold periods in 1500, 1630, 1830 A.D. or so, respectively. Among the three periods, it was the first period that temperature declined with the maximum range, and the third period that lasted longest. Then, the climate became marked warm. The warming trend continues to now (Wu *et al.*, 1981; Kang, 1997; Yao, 1997; Yao *et al.*, 1996).

The monthly mean minimum temperature of winter in western Sichuan are reconstructed during 1650–1994 based on ring-widths of spruce. There were several obvious periods of cold winter and warm winter. Among them, the coldest winter occurred in 1954–1979, even colder than one of cold periods in the Little Ice Age; the warmest winter occurred in 1712–1734 (Shao *et al.*, 1999).

Based on the accumulation amount of ice core in Guliya, precipitation was high in 200 A.D., then was low from 400–1400 A.D., increased obviously from 1500–1700 A.D., reduced again in 1800 and then increased in the 20th century. The maximum of accumulation amount reached 400 mm/a, while the minimum only 150 mm/a in the same period (Yao, 1997; Yao *et al.*, 1996).

According to the study on water logging, drought, and snow hazard in southern Xizang based on the historical documents of the Qing Dynasty Government, and climatic records after 1951 in Xizang, there were three periods with much rain and three dry periods over the last 100 years. In addition, the dry periods tend to prolongation (Lin *et al.*, 1986).

3.2 Recent Temporal and Spatial Variation of Temperature and Precipitation

Analysis indicates that the atmospheric temperature commonly tends to increase with positive gradient from the 1950s to the early 1990s on the plateau excluding the eastern fringe. Among the 40 years, the 1980s was warm period. Regions with atmospheric temperature of the 1980s higher than that of the 1950s are distributed mainly in the plateau proper, and temperature increased with gradient ranging from 0.10 to 0.30 ℃/10a in the plateau. Temperature still rises in the majority of the plateau and the rising range is bigger in the western plateau during the 1990s. The recent warm period begins obviously differently in each part of the plateau: the southeast earlier, then the Yarlung Zangbo River Valley, the northeast and southwest one after another, and last the western arid area of the plateau. The increase of atmospheric temperature occurred mainly in winter seasons. In summer seasons, temperature increases with small range and sometimes even decreases (Lin *et al.*, 1996).

Over the period of records, the mean annual precipitation reduces in the plateau. The regions with precipitation decline are mainly the Yarlung Zangbo River Valley, eastern Xizang, western Sichuan, southern Qinghai, and Qaidam Basin, etc. In these regions, the precipitation gradient is 10–40 mm/10a and precipitation reduces radically in summer seasons. But precipitation increases in the southeast, south, and north of Xizang with higher elevation and the northern Qinghai. In a word, the Qinghai-Xizang Plateau is characterized by temperature increase and humidity reduction from the 1950s to the early 1990s (Lin *et al.*, 1996).

3.3 Response of Glaciers, Snow Deposit and Permafrost on the Plateau to Climate Change

The value of material balance of glaciers is negative, terminus of glaciers is shrinking, depth of glaciers becomes thinner, scale and speed of glacier shrinking tend to decrease gradually from the temperate glacier of maritime type on the southeastern margin to the frigid glacier of continental type in the interior of the plateau in recent decades. The response of glaciers to climatic change on century scale delays approximately 10–20 years. Much regional difference exists in respect to response of glaciers, for example, glaciers of maritime type change more forceful than the continental ones. Over the past 100 years, global glaciers have shrunk commonly with three periods of glacier advance during the 1880s–1890s, the 1920s–1930s, and the 1960s–1970s, respectively. The period with relative low temperature appeared before each advance of glacier.

There are two snow deposit centers on the plateau, one center is located in the eastern part of the plateau and the southeast Xizang; another center is situated in western part of the plateau including Kashimir and Pamir bounded by 84°–86°E. In addition, snow deposit occurred in fringes and the interior mountains of the plateau; while vast expanse of the interior plateau had little or without snow. The area and depth of snow deposit on the plateau tends to reduce from fringes to hinterlands of the plateau. Analysis shows that area of winter snow deposit on the plateau tends to increase in recent years especially in January (Tang *et al.*, 1998).

Permafrost area on the plateau amounts to 1.5 million km^2. Observation of ground temperature of drilling hole in the northern mouth of Jingxian Valley and on the south slopes of Tanggula Range indicates that: ground temperature of 15–20 m increased by 0.6–0.8℃ and 0.3–0.5℃ respectively during 1975–1994, which means the permafrost has nearly melted completely during the last 20 years (Tang *et al.*, 1998). In the coming 50 years, under the background of further warming of plateau climate, assuming the atmospheric temperature rises linearly with 0.4℃/10a, permafrost area on the plateau will reduce 3%. The reduced area may not be over 30% of the total area of permafrost on the plateau, if the area of detachment of frozen ground is included in the reduced area (Li, Cheng and Guo, 1996).

REFERENCES

Cui Zhijiu, Gao Quanzhou, Liu Gengnian *et al.*, 1996. Planation surfaces, palaeokarst and uplift of Xizang (Tibet) Plateau. *Science in China (Series D)*, 39(4): 391–400.

Emeis K. C., D. M. Anderson, H. Dooser *et al.*, 1995. Surface temperatures and the history of monsoon upwelling in the Northwest Arabian Sea during the last 500 000 years. *Quaternary Research*, 43

(2): 355– 361.

Gasse F., Fontes J. CH., Campo E. Yan *et al.*, 1996. Holocene environmental changes in Bangong Co Basin (Western Tibet). *Paleogeography Paleoclimatology Paleoecology*, 120: 79– 92.

Kang Xingcheng, L. J. Graumlich, P. Sheppard, 1997. The last 1835 years climatic change inferred from tree ring records in Dulan region. *Quaternary Sciences*, (1): 70– 75(in Chinese)

Li Bingyuan, 1995. Evolution of the lake in the North Qiangtang Plateau. In: *Studies on Formation and Evolution, Environmental Changes and Ecosystem of the Tibetan Plateau*. Beijing: Science Press, 261– 266. (in Chinese)

Li Bingyuan, Wang Fubao, Zhang Qingsong, 1983. *Quaternary Geology in Xizang*. Beijing: Science Press. (in Chinese)

Li Bingyuan, Zhang Qingsong, Wang Fubao, 1991a. Evolution of the lakes in the Karakorum-West Kunlun Mountains. *Quaternary Sciences*, (1): 64– 70. (in Chinese)

Li Bingyuan, Li Jijun *et al.*, 1991b. *Quaternary Glaciation Distribution Map of the Qinghai-Xizang (Tibet) Plateau*. Beijing: Science Press.

Li Jijun *et al.*, 1995. *Uplift of Qinghai-Xizang (Tibet) Plateau and Global Change*. Lanzhou: Lanzhou University Press.

Li Jijun, Fang Xiaomin, Ma Haizhou *et al.*, 1996. Geomorphological and environmental evolution in the upper reaches of the Yellow River during the late Cenozoic. *Science in China (Series D)*, 39(4): 381 – 390.

Li Jijun, Fang Xiaomin, 1998. Studies on the uplift of Tibetan Plateau and environmental changes. *Science Bulletin*, 43 (15): 1569 – 1574. (in Chinese)

Li Shuxun, Cheng Guodong, Guo Dongxin, 1996. The future thermal regime of numerical simulating permafrost on Qinghai-Xizang (Tibet) Plateau, China, under climate warming. *Science in China (Series D)*, 39(4): 434– 441.

Lin Zhenyao, Wu Xiangding, 1986. A preliminary analysis of the regularity in flood, drought and snowstorm in Xizang Plateau during historical times. *Acta Meteorologica Sinica*, 44(3): 257– 264. (in Chinese)

Lin Zhenyao, Wu Xiangding, 1990. A preliminary analysis of moisture transportation pathways on the Qinghai-Tibetan Plateau. *Geographical Research*, 9(3): 33– 40. (in Chinese)

Lin Zhenyao, Zhao Xinyi, 1996. Spatial characteristics of changes in temperature and precipitation of the Qinghai-Xizang (Tibet) Plateau. *Science in China (Series D)*, 39(4): 442– 448.

Peng Buzhuo, Pu Lijie, Bao Haosheng *et al.*, 1997. Vertical zonation of landscape characteristics in the Namjagbarwa massif of Tibet, China. *Mountain Research and Development*, 17 (1): 43– 48.

Raymo M., W. Ruddimen, 1992. Tectonic forcing of late Cenozoic climate. *Nature*, 359: 117– 122.

Shao Xuemei, Fan Jinmei, 1999. Past climate on West Sichuan plateau as reconstruction from ring-widths of dragon spruce. *Quaternary Sciences*, (1): 81– 89. (in Chinese)

Shi Yafeng, Zheng Benxing, Li Shijie *et al.*, 1995. Era, elevation and environmental changes of the Maximum Ice Age on the mid-eastern Qinghai-Xizang (Tibet) Plateau. *Journal of Glaciology and Geocryology*, 17(2): 97– 112. (in Chinese)

Shi Yafeng, Tao Maocang, Ma Yuzhen, 1998a. The relation of the second rising in Qinghai-Xizang Plateau and the Asia Monsoon. *Science in China (Series D)*, 28(3): 263– 271.

Shi Yafeng, Li Jijun, Li Bingyuan (eds.), 1998b. *Uplift and Environmental Changes of Qinghai-Xizang (Tibet) Plateau in the Late Cenozoic*. Guangzhou: Guangdong Science and Technology Press. (in Chinese)

Shi Yafeng, Li Jijun, Li Bingyuan *et al.*, 1999. Uplift of the Qinghai-Xizang (Tibet) Plateau and East Asia environmental change during Late Cenozoic. *Acta Geographica Sinica*, 54(1): 10– 21. (in Chinese)

Sun Honglie, Zheng Du (eds.), 1996. *Formation and Evolution of the Tibetan Plateau*. Shanghai: Shanghai Science and Technology Press. (in Chinese)

Sun Honglie, Zheng Du, 1998a. Studies on Qinghai-Xizang Plateau. In: *Advances in Global Change Studies of China*. Beijing: China Ocean Press. 60– 57.

Sun Honglie, Zheng Du (eds.), 1998b. *Formation, Evolution and Development of Qinghai-Xizang (Tibet) Plateau*. Guangzhou: Guangdong Science and Technology Press. (in Chinese)

Tan Maocang, Cheng Guodong, Lin Zhenyao (eds.), 1998. *Contemporary Climatic Variation over Qinghai-Xizang (Tibet) Plateau and Their Influences on Environments*. Guangzhou: Guangdong Science and Technology Press. (in Chinese)

Wang Fubao, Li Shengfeng, Shen Xuhui *et al.*, 1996. Formation, evolution, and environmental changes of the Gyirong Basin and uplift of Himalaya. *Science in China (Series D)*, 39(4): 401– 409.

Wu Xiangding, Lin Zhenyao, 1981. A preliminary study on climatic evolution on Qinghai-Xizang (Tibet) Plateau during the last 2000 a. *Proceedings of Climatic Changes in China*. Beijing: Science Press. 18– 25. (in Chinese)

Yang Yichou, Gao Dengyi, Li Bosheng, 1987. A preliminary study on the vapour channel in the lower reaches of the Yarlung Zangbo River. *Scientia Sinica (Series B)*, (8): 893– 902. (in Chinese)

Yao Tandong, 1997. Climatic and environmental record in the past about 2000 years from the Guliya Ice Core. *Quaternary Sciences*, (1): 52– 61. (in Chinese)

Yao Tandong, Shi Yafeng, 1992. Climatic changes of Holocene reflected in the ice core from Dunde. In: *The Climates and Environments of Holocene Megathermal in China*. Beijing: China Ocean Press, 206 – 211. (in Chinese)

Yao Tandong, Jiao Keqin, Tian Lide *et al.*, 1995. Climatic and environmental records in Guliya Ice Cap, *Science in China (Series B)*, 38(2): 228– 237.

Yao Tandong, L. G. Thompson, Qin Dahe *et al.*, 1996. Variations in temperature and precipitation in the past 2000 years on the Xizang (Tibet) Plateau-Guliya Ice Core Record. *Science in China (Series D)*, 39(4): 425– 433.

Yao Tandong, L. G. Thompson, Shi Yafeng *et al.*, 1997. Climatic variation since the Last Interglaciation recorded in the Guliya ice core. *Science in China (Series D)*, 40(6): 662- 668.

Zhang Pengxi, Zhang Baozhen, Qian Guimin *et al.*, 1994. The study of paleoclimatic parameter of Qinghai Lake since Holocene. *Quaternary Sciences*, (3): 225- 236. (in Chinese)

Zhang Qingsong, Li Bingyuan, 1991. The Uplift of the Karakorum-Kunlun Mountains and its impact on environmental changes. *Journal of Chinese Geography*, 2(1): 14- 28.

Zhang Qingsong, Li Bingyuan, Zhu Liping, 1994. New recognitions of Quaternary environment in the northwest Tibetan Plateau. *Acta Geographica Sinica*, 49(4): 289- 296. (in Chinese)

Zhang Qingsong, Zhou Yaozheng, Lu Xiangshun *et al.*, 1991. On the present uplift speed of Qinghai-Xizang Plateau. *Science Bulletin*, 36 (21): 1820- 1824. (in Chinese)

Zhang Rongzu (ed.), 1992. *Dry Valleys in the Hengduan Mts Region*. Beijing: Science Press. (in Chinese)

Zhang Xinshi, 1994. The principal eco-geographic types of mountain vertical vegetation belt systems in China. In: *Researches on vegetation Ecology*. Beijing: Science Press, 77- 92. (in Chinese)

Zheng Du, Li Bingyuan, 1994. Evolution and Differentiation of the Physico-Geographical Environment of the Qinghai-Xizang (Tibet) Plateau. *The Journal of Chinese Geography*, 4(1/2): 34- 47.

Zheng Du, 1996a. The system of physico-geographical regions of the Qinghai-Xizang (Tibet) Plateau. *Science in China (Series D)*, 39 (4): 410- 417.

Zheng Du, 1996b. A preliminary study on the zone of alpine shrub and meadow of Qinghai-Xizang (Tibet) plateau. *The Journal of Chinese Geography*, 6(3): 28- 38

Zheng Du (ed.), 1999. *Physical Geography of the Karakorum-Kunlun Mts Region*. Beijing: Science Press. (in Chinese)