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THE DISTRIBUTION REGULARITY OF HIGHER CATEGORIES IN CHINESE SOIL TAXONOMY①

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ABSTRACT: The regularity of the distribution of higher categories in Chinese Soil Taxonomy(CST) were studied through analyzing the diagnostic horizons and characteristics and the variation of soil forming factors in China. The results indicate that the distribution regularity of higher categories in CST is different from that in the past zonal classification, which is inferred on the basis of typical profiles and bioclimatic conditions. Among the 14 soil orders available in CST, 6 belong to the basic types, which show the regularly continuous distribution, and can be deduced into three larger groups: aridic, ustic and udic. The other 8 soil orders belong to the special types with the band-shaped, spot-shaped, chessboard-shaped, patch-shaped distributions and so on. Moreover, there is the regularity of vertical distribution in mountains.
KEY WORDS: Chinese Soil Taxonomy, The distribution regularity

Soil classification plays important roles in soil survey, soil mapping and agricultural technology transfer in the light of local conditions. It is also the medium of soil science communication among domestic and international scholars. Moreover, the survey and evaluation of agricultural natural resources are always based on the soil classification: firstly, the properties, types and distributions of soils must be surveyed; then the soil adaptation and production potential can be evaluated. This is one of the most important and basic work in the investigation of agricultural situation.

I. THE BACKGROUND OF THE OCCURRENCE OF CHINESE SOIL TAXONOMY AND ITS CHARACTERISTICS

The systems of soil classification in our country can generally be divided into two types: one is soil genetic classification (Xiong, 1987); and the other is soil taxonomy (Chinese Soil Taxonomy Research Group, 1991, 1995; Eswaran, 1991; Gong, 1986, 1987, 1988a,

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1988b, 1989a, 1989b, 1992, 1994; Xiong, 1987). Starting from soil forming conditions, the former judges soil types according to soil profiles and bioclimatic conditions; the latter, however, is the quantitative classification on the basis of the diagnostic horizons and characteristics.

The modern soil classification in China began in the 1930s. C. F. Marburt' soil classification theory was basically accepted at that time. After the People's Republic of China was established, the great progress in the soil classification had been made. The soil classification system used in our country since then was soil geographical genetic classification. The system played an important role in the history. But it failed to be compatible with the trend of the development of the modern science because of its lack of quantitative criteria. Therefore, starting from the 1950s, having absorbed the wisdom of soil scientists all over the world, spent ten years and revised the proposal for seven times, the soil scientists in America proposed the Soil Taxonomy on the basis of the diagnostic horizons and characteristics. The theory of the soil taxonomy developed very quickly over the world in the 1970s. However, no progress had been made in soil classification during that ten years in China, and it became difficult for us to communicate with the colleagues at home and abroad. Therefore, starting from 1984, funded by the National Natural Science Foundation of China and the Chinese Academy of Sciences, cooperating with more than 30 universities and research institutes, we proposed"Chinese Soil Taxonomy" (CST) (first proposal, 1991) and "Chinese Soil Taxonomy" (revised proposal, 1995).

Compared with the other soil classification in the world at present, CST has the following four characteristics: firstly, the classification is based on the diagnostic horizons and characteristics. So-called diagnostic horizon is the horizon with a series of quantative definition. The diagnostic horizons and characteristics are the cores of modern soil classification. Secondly, it is directed by soil genetic principle, and both the relative stable historic genesis and the morphology easily distinguished in the field are considered. Thirdly, it is compatible with the international soil classification systems. The mature international diagnostic horizons and characteristics have been accepted as possible as we can. If new diagnostic horizons and characteristics can be established, they are also based on the same principle and method. Fourthly, it has Chinese characteristics. Because of the vast territory and long history of agriculture, our country is abundant in soil resource, especially soils such as the anthropic soil, monsoonal tropical and subtropical soils, aridic soil, high mountain soil are rare in other places of the world. The types of those soils are not perfectly solved in any diagnostic classification in the world. According to the practice in our country, we have proposed a series of new diagnostic anthropic epipedons such as siltigic epipedon, cumulic epipedon, fimic epipedon, athrostagnic epipedon, and established anthropogenic soil order, including siltigic soil, cumulic soil, fimic soil, athrostagnic soil, etc. .

CST is a multiple category classification including six categories, namely soil order, soil suborder, soil group, soil subgroup, soil genus and soil series. The former four are higher categories; the latter two are basic categories.

CST has been welcomed by the domestic and abroad since it was published. It has already been compiled into the university teaching books, and been applied to soil survey and mapping,

and agriculture production. Approved by Chinese Soil Society, it has already been regarded as the standard of Chinese soil classification and popularized.

II. THE REGULARITY OF DISTRIBUTION OF SOIL ORDERS IN CHINESE SOIL TAXONOMY

Because of vast territory, multiple topology and climate, strong human activities and long history, the soil distributions show the characteristics of regularly continuous distribution, regional discontinuous distribution and vertical distribution.

1. The Regularly Continuous Distribution

The regularly continuous distribution of soils is determined by the diagnostic horizons and characteristics, which are produced by dominant soil-forming conditions. In our country, there are many plateaus and mountains distributed in the western region, and hills and plains in the eastern region. The mountains distributed in length and breadth in our country affect the distribution of temperature and water. In the eastern region, the temperature gradually drops from the south to the north because of the variation of latitude. In the western region, however, because of complex topography, especially the uplifting of the Qinghai-Xizang(Tibet) Plateau, the horizontal variation of the temperature is disturbed, and the vertical variation was indicated instead. As a marked monsoon climate country, our country is controlled by northwest monsoon in winter, and affected by southeast and southwest monsoon in summer. The southeast monsoon not only affects the eastern region, but also arrives in the inland. The southwest monsoon mainly affects the regions of the Qinghai-Xizang Plateau and the South China Sea, resulting in a series of ustic soils from the northeast to the southeast in the central part of our country, the main part of which is Luvisol. It separates the soil regions of our country into two parts, namely southeast Udic series and northwest aridic series. Therefore, the characteristics of the horizontal distribution of soils can be summarized as three parts(Fig. 1).

1.1 Series of southeast udic soils

The vast region to the east of the Da Hinggan Mountains－Taihang Mountains－Qinghai-Xizang Plateau line is near to the ocean, where the climate is wet; aridity <11; the temperature decreases with the increase of latitude from south to north. Different kinds of forests develop there. The sequence of main soil association there is:

Udic Ferralisol－Udic Ferrisol
Udic Ferrisol－Udic Ferralisol
Udic Ferrisol－Perudic Cambisol
Udic Luvisol－Aquic Cambisol
Boric Luvisol－Udic Isohumisol
Orthic Spodosol－Cryic Cambisol

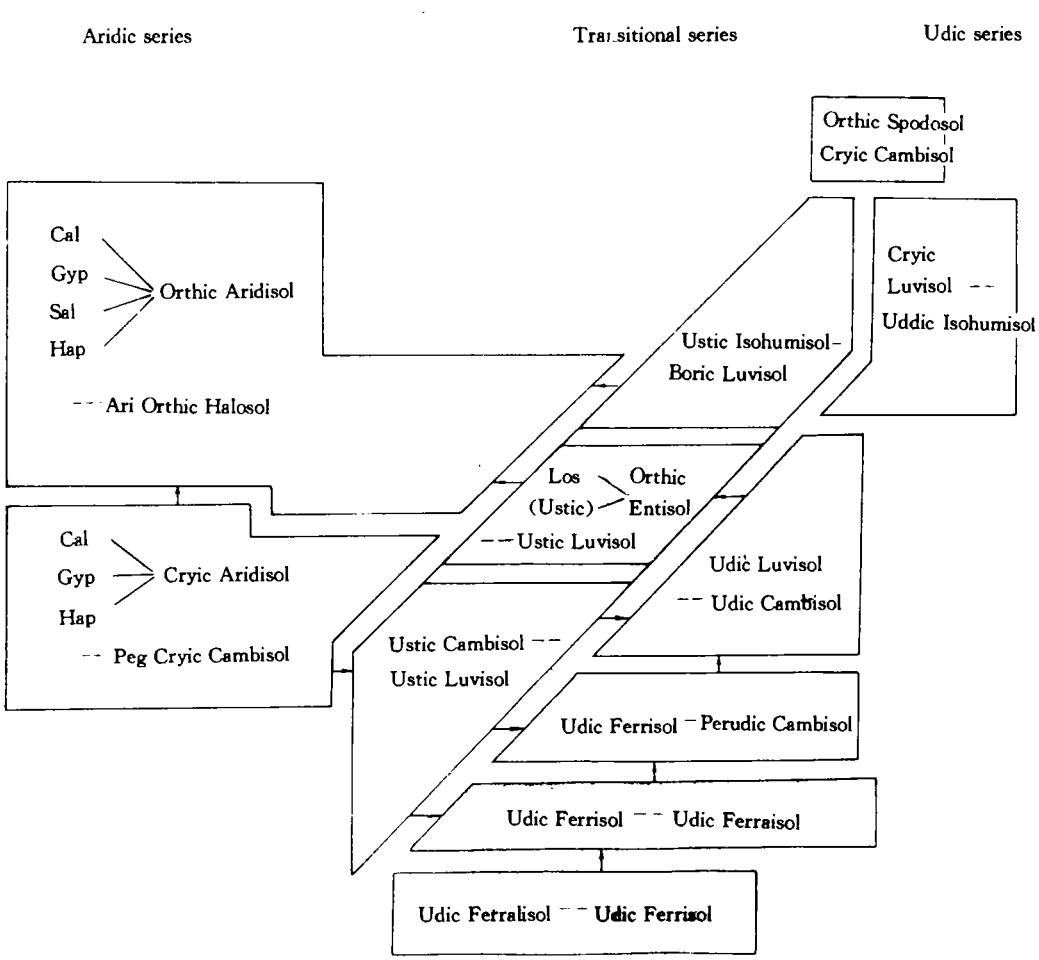

Fig. 1 The distribution pattern of main orders in CST

The region where the series of the soils are distributed is the essence of our country's agricultur. Paddy field is the basic pattern of the land-use and a set of agricultural production system dominated by the management of the paddy field has been formed there. It is also the main region of forests.

1.2 Series of northwest aridic soils

The soils are distributed in the vast region to the northwest of the line of west Inner Mongolia - Helan Mountain - Nyainqêntangla range, which is weakly affected by the ocean monsoon, and has arid climate. The aridity there is >11, and it gradually increases from east to west (on the Qinghai-Xizang Plateau, it gradually increases from southeast to northwest). The vegetation shows the horizontal variation from desert steppe, steppified desert to desert. A sequence of soils varying from south to north are :

Calcic
Gypsic Cryic Aridisol - Permagelic Cambisol
Haplic Cryic

Calcic
Gypsic Orthic Aridisol – Aridic Orthic Halosol
Salic
Haplic

Because of water shortage, the region has been developing "the oasis agriculture" mainly depending on the irrigation. The grassland, which has no conditions of irrigation, has been developing animal husbandry.

1.3 Series of ustic soils in the central part

It is distributed between the two former series of soils. The climate is subhumid or semiarid; the aridity is from 1 to 11; the main vegetation is steppe. The region spans 20 degree latitude from northeast to southwest. A sequence of soils, among which Ustic Luvisol is the centre, show as follows:

Ustic Luvisol – Ustic Cambisol
Loessal Orthic Entisol – Ustic Luvisol
Ustic
Ustic Isohumisol – Boric Luvisol

In this region, the dryland is the basic pattern of the land-use. A set of water-saving agricultural production system have been developed. Because only the area with the condition of irrigation can produce the paddy, the paddy field shows the patch-shaped distribution. In addition, a series of particular island soils were formed in the southern coastal islands in our country. The soils in the islands are sequentially distributed as Udic Ferralsol, Udic Ferrisol, Perudic Luvisol from the low to the high. The kind of distributed model totally shows in Hainan Island. The other smaller islands, however, may fail to experience each stage of the model mentioned above because of their positions and altitudes. Some islands formed late even remain at the stage of Entisol. For example, the Fos Lithomorphic Isohumisol formed by the coral fragment and guano accumulation is distributed in the islands of the South China Sea.

2. The Regional Discontinued Distribution

The soils with the regional discontinued distribution are inlaid in those regions with regularly continuous distribution. The effects of topography, parent material, hydrographical condition, time and human activities cause the variation of soils in the region of regularly continuous distribution. The varied soils are separated into smaller or bigger areas, which is the reason why the soils of regional discontinued distribution are inlaid in those of regularly continuous distribution, resulting in the abundant types of vegetation and soils(Fig.2).

2.1 A band-shaped pattern

A series of alluvial-lacustrine plains are distributed from south to north in the southeast re gion of the country , and many basins and lakes in the northwest inland . The Gleysol was formed there due to their aquic soil moisture regimes and Gleyic characteristics . The soil

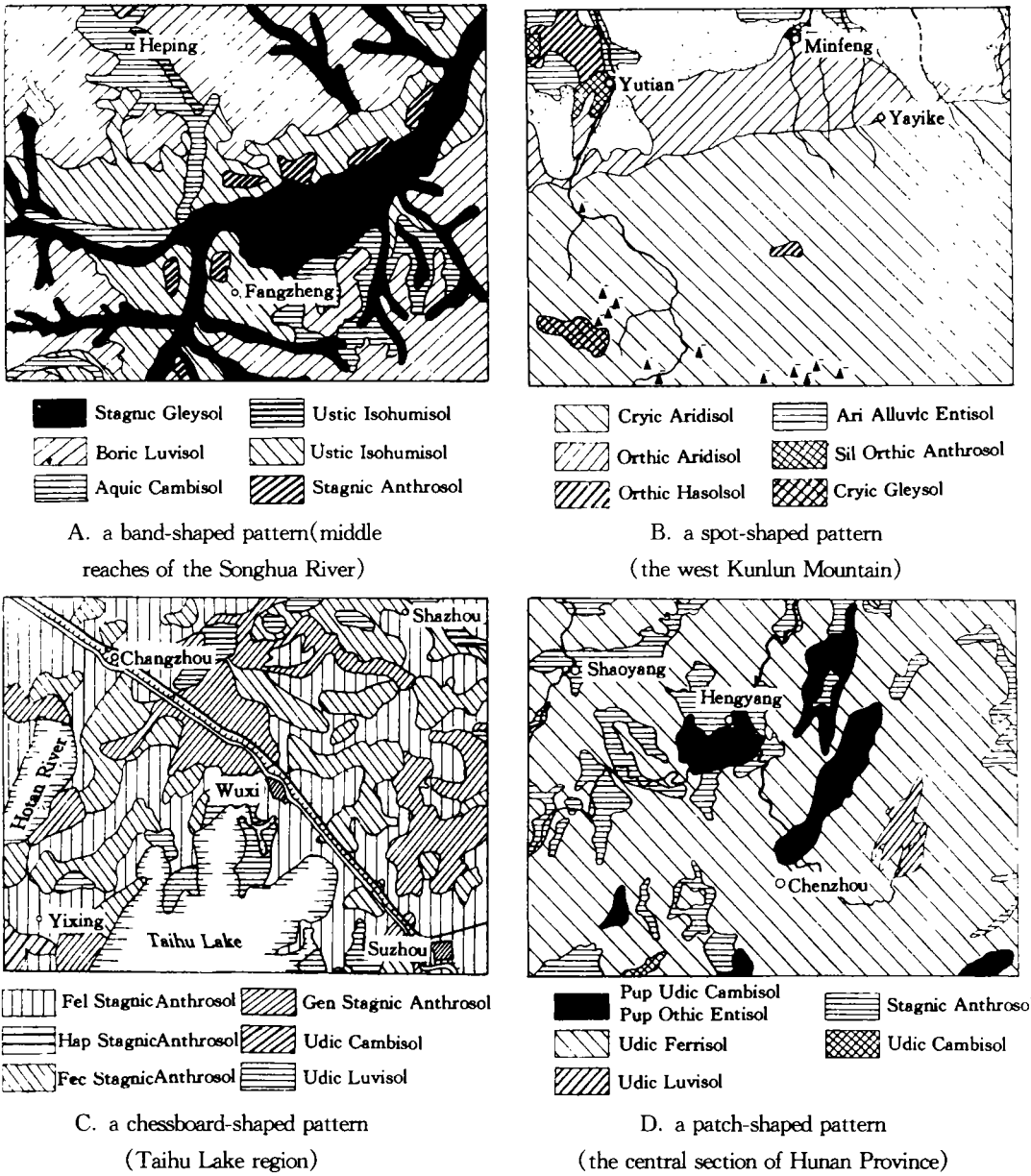

Fig. 2 The patterns of soil regional discontinued distribution

stretches along the river valley and shoaly land of lake, showing a band-shaped pattern (Fig. 2A). The Gleyic process controlled by underground water is different from that controlled by stagnant water. The processes are also affected by the subordinary elements such as soil temperature regime, resulting in different types of Gleysol. In general, stagnant Gleysol has been formed in the Sanjiang Plain of the northeast region and Songpan grassland of northwest Sichuan Province; Orthic Gleysol in the Bohai Gulf and the Lixia River of Jiangsu Province; Cryic Gleysol in the Altay mountainous region.

2.2 A spot-shaped-pattern

In the Huaibei Plain of Anhui and Henan provinces, Jiaolai Plain of Shandong Province, Yishuhe Plain, Xuhuai Plain of Jiangsu Province, Nanyang Basin of Henan Province, Zaoyang of Hubei Province etc., the most of soil-forming parent materials are river or lake sentiments, and the lever of underground water is about 2 metres, which led to the formation of Aquic Vertisol whose main clay constituent is montmorrillonite. Besides, Udic Vertisol was formed on the basalt parent material in Zhangpu of Fujian Province and Shangsi and Ningming of Guangxi Province; Ustic Vertisol was formed on the calcareous parent material in Tiandong of Baise Basin of Guangdong and Yuanmou and Yuanjiang valley basins of Yunnan Province. The soils mentioned above are dotted in the background soils like stars in the sky, so they are called the soils with a spot-shaped pattern. Andisol formed by volcanic accumulation in the modern volcanic regions in the northeast, Yunnan, Taiwan, Xingjiang, Qinghai of our country also shows spot-shaped pattern. (Fig.2B).

2.3 A chessboard-shaped pattern

As a result of a long history of utilization and reconstruction, Anthrosol is extensively distributed in our country except few regions, which are high and cold, or the arid regions with water shortage. Stagnic Anthrosol is mainly concentrated in the river alluvial plain, terrace and lake shoaly plain located to the south of the Qingling -- Huaihe line, the dams and intermountainous basins of the Yunnan-Guizhou Plateau, and other hills and low mountainous regions. Orthic Anthrosol is mainly distributed in the regions to the north of the Qinling－Huaihe line. The land has gradually become square and specified in the plain after the basic construction of agricultural fields, such as digging the ditches for irrigation and leveling the land. In the lake mash regions, the special anthropogenic topography called as " mulberry dyke－fish pond" and piling field has been created as a result of digging the low and piling the high. In the hill regions, the terrace field has been created from the normal sloping field in order to prevent the loss of water and soil. Looking from the plane figure, we can find that they are always located near the populous towns and villages with the square fields lined with trees and netted with ditches and roads. So it is called the chessboard-shaped pattern(Fig.2C).

2.4 A patch-shaped pattern

The rapid increasing population has led to the excessive cultivation and utilization of the land in many parts of the country, which results in strong soil and water erosion and severe silting of rivers and lakes. Therefore, on the new land surface caused by severe erosion, Entisol without any important soil-forming process and any other secondary characteristics and Cambisol with only cambic horizons or variant and accumulated horizons (they have no other accumulation of transport materials except for calcic horizon, hypercalcic horizon, calcipan, gypsic horizon and hypergypsic horizon in the range from surface to 100 cm) were formed. The two types of soils have the characteristics of popular and extensive spatial distribution. Besides the anthropogenic factor, the lithological and time factors also control the soil-forming process of Entisol; the factors of time and climate control the Cambisol forming process. Therefore, the

two types of soils show relatively concentrated distribution and connect with different types of soils. In the plane figure, they show the patches with different sizes, and are called as the patch-shaped pattern(Fig. 2D).

3. The Vertical Distribution of Soils

The soil distribution shows the vertical zonation due to high topography, variation of bioclimatic conditions and soil properties. The structure of the vertical spectrum varies regularly with the mountainous position and altitude and slope direction. Comparing the different kinds of the vertical spectrums in mountainous regions, we can find that in the Ferralsol region, only a vertical spectrum of udic soils occurs. In the regions of Ferrisol, Luvisol and Isohumisol, however, the vertical spectrums become complete and complex (in the Ferrisol region, three vertical spectrums occur, the bottom soils of which are ustic, perudic and udic Ferrisols respectively; in the Luvisol region, four vertical spectrums occur, the bottom soils of which are boric, ustic, perudic, and udic Luvisols respectively; in the Isohumisol region, three vertical spectrums occur, the bottom soils of which are lithomorphic, ustic and udic Isohumisols respectively). In the regions of Aridisol and Spodosol, the soil vertical spectrums become simple again (in the Aridisol region, only two vertical spectrums occur with Cryic and Orthic Aridisols as bottom soils respectively; in the Spodosol region, another two vertical spectrums occur, with humic and orthic spodosols as bottom soils respectively). It can be found that the regular occurrence of soil vertical zonation is caused by the variation of bioclimatic conditions in mountainous regions, which results in the variant main soil forming process and soil properties.

The higher the mountains and relative altitude, the more complete the soil vertical spectrums. In those regions, the conditions of synthetic utilization are more advantageous. The Mount Qomolangma is the No. 1 peak in the world, and the soil vertical spectrum in that mountainous region is the most complete. In the southern side of the mountain, a sequence of soils : Udic Ferrisol – Udic Luvisol – Orthic Spodosol – Perudic Cambisol – Cryic Cambisol – Orthic Entisol occurs from the foot to the peak within a distance as short as several ten kilometres. In the general middle and high mountainous regions, the altitudes are not high enough to form complete soil vertical spectrums. For example, in the Lushan Mountain, only udic Ferrisol – Perudic Ferrisol – Udic Luvisol – Perudic Cambisol shows sequentially from the bottom to the upper (Fig. 3).

The slope direction has a marked effect on the soil vertical spectrum. The best illustration is the Qinling – Taibai mountain which spans the north subtropical zone and warm – temperate zone and strikes from east to west. The bottom soils in the southern side are Arp – Udic Luvisol and Fer Udic Luvisol; those in the northern side are Haplic Ustic Luvisol and Eum Orthic Anthrosol. Besides different kinds of bottom soils in the north and south, the low limitation of soils of main vertical spectrum seems obviously distinctive though the ranges of their zonations differ to less extent. The low limitation altitude of Hap Udic Luvisol in the southern side is

1300 m; that in the northern side is 1500 m. Boric Luvisol and Perudic Cambisol above the former show the same characteristics.

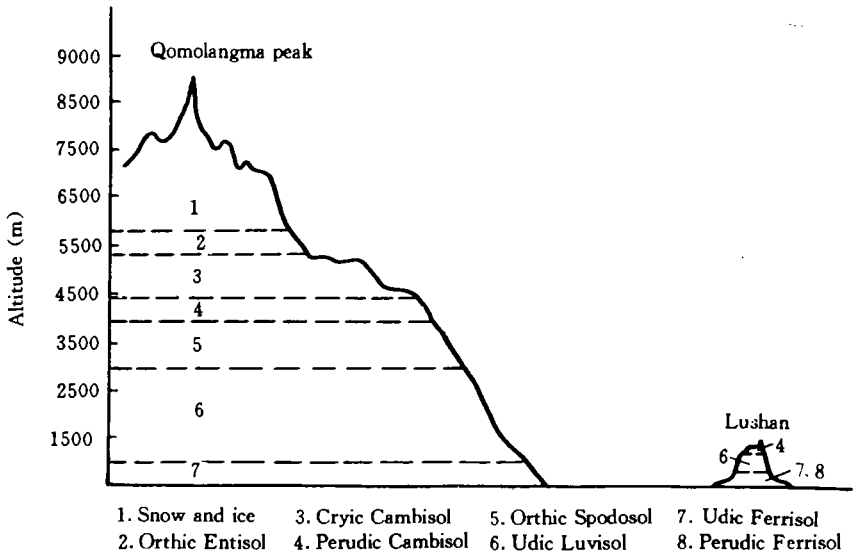

Fig. 3 The vertical zonation of soils in Mount Qomolangma and Lushan Mountain

III. THE CHARACTERISTICS OF THE DISTRIBUTION OF HIGHER CATEGORIES IN CHINESE SOIL TAXONOMY

The distribution of higher categories in Chinese Soil Taxonomy is different from that in geographical genetic classification published before.

(1) Corresponding to the bioclimatic conditions, the distribution of higher categories in the geographical genetic classification show "three direction" (latitude, longitude and vertical direction) according to the theory of zonality. That in Chinese Soil Taxonomy, however, shows the characteristics of zonal spanning and soil combination. For example, Luvisols span several bioclimatic zones stretching from the Da Hinggan Mountains of Northeast China to the southeastern part of the Qinghai-Xizang (Tibet) Plateau. Ferralsols are mainly distributed in the low hills of tropical zone, which are composed of basalt, shallow sea sediment and old weathering materials of granite, however, in the range of south subtropical zone, they can still be seen in the low hills composed of shallow sediments and other old weathering materials of base rock. Ferrisols are popularly distributed in the hills and low mountains (altitude below 800 m) of the south subtropical and tropical zones, however, in the eastern part of central subtropical zone (including Nanling mountainous region), they are only distributed in the low hills composed of Quaternary red earth and weathering materials of red sandy rock etc. of Tertiary, and rarely seen in other high hills and low mountains.

(2) The spatial variation of soils in the warm temperate and temperate zones of the central part of the country is very complex. In the viewpoint of soil taxonomy, Ustic Luvisol is the

main type of soil in the region. However, Ustic Isohumisol occurs in the northern part of the region due to the organic material accumulation. Los Entisol occurs in the central part due to the loess parent material. Ustic Cambisol occurs in the northern part due to the soil erosion.

(3) In the western region, the arid northwest inland region and Qinghai-Xizang Plateau were regarded as two independent soil zones in the past. The former was divided into temperate and warm temperate soil zones; the latter was divided into several soil zones with the characteristics of horizontal and vertical distribution. In Chinese Soil Taxonomy, however, we classify the whole western region as two series of soils: Orthic Aridisol – Ari Orthic Halosol and Cryic Aridisol – Peg Cryic Cambisol.

(4) The soils in the coastal islands have unique characteristics, however, their distribution regularity and positions in the soil classification have not been explained in detail in the past. In Chinese Soil Taxonomy, they are regarded as an independent series of soils.

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