Characteristics and planation surface formation environment of the red weathering crust in Hunan, Guangxi, Yunnan, Guizhou and Tibet

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Abstract The characteristics of red karst weathering crust in the research region can be divided into three subtypes. The first one includes the silicon to aluminum ratio, the composition of the clay minerals, etc., and reflects the weak action of de-silicon and aluminum enrichment. The second one, for example the granularity, shows that the viscous action is strong. The third one, such as the $CaCO_3$ content and pH value, has regional difference in a large scale, which is consistent with the condition of modern scenery, so it is not important as for the ancient environment.

Keywords: red karst weathering crust, planation surface, uplift of Tibetan Plateau.

Planation surface, a kind of large-scale geomorphologic scenery, is related to the long-time stable structural environment. The crust not only plays an important role in its formation, but also is a part of the planation surface. The research into the crust not only helps prove the existence of the planation surface, but also can extract the information of formation environment[1,2] in the planation surface. The rudimental red weathering crust in the Tibetan Plateau is mainly scattered sporadically in the limestone cranny. Therefore, it is hard to do detailed work and large-scale regional correlation. To the east of the Tibetan Plateau, the Yungui Plateau and Xianggui hills have been in the land environment since the Cenozoic era, so there the large area planation surface and the red weathering crust were developed[3]. To correlate the red karst weathering crust in these areas is an important way for solving the problems concerning the planation surface. The formation time, characteristics, environment and the large-scale comprehensive correlation of the planation surface have long been a tough task but a must in the research process of the Tibetan Plateau. After having researched many years into the relationship between the planation surface and the uplift of the Tibetan Plateau, we recognized the importance of the weathering crust, which belongs to the planation surface. Using the FT decomposition method to obtain twenty age data (7—19 MaBP), collected from the re-crystallization calcium that formed in the karst process in the Tibetan Plateau, we proved the planation surface formed in the middle of the Miocene[4]. It is very difficult to collect the re-crystallization calcium in the karst process to the east of the Tibetan Pla-

teau, such as the Yungui Plateau, because of the strong eluviation. However, if we can prove that there once existed one united planation surface with the same characteristics (from the Tibetan Plateau through Yungui to Xianggui) extending from the west to east by researching into the characteristics of weathering crust, we can conduct indirectly the time correlation of the planation surface to the east of the Tibetan Plateau, and find out the characteristics of the planation surface, the formative processes and features of the karst planation surface. This can develop the contents and methods of the basic theory on the planation surface, and can provide a good chance for developing the basic theory of geomorphology subject through Qinghai-Tibet Project research at the same time.

In recent years, the international geomorphologic circles have already tried many methods to solve the difficult problems on the planation surface. For example Theveniaut and Freyssinet researched into the age of the 40-m deep crusts using the ancient geomagnetism method in French Guyana[5]. Stern et al. researched into the ancient climate by analyzing the clay mineral of the Australian ancient crust[6], and Bind and Chivas used the clay mineral stable isotopes to analyze the Himalayan crust[7—9]. Vasconcelos used K-Ar method to do the dating research in regenerating mineral of the crust[10,11]. They all intended to use the weathering crust in their research, and to solve the issue on the planation surface and the age, characteristics, and environment of the weathering crust.

Laterite is the product under mild and hot climate. We can find it at high latitudes (Siberian[12]) in the world. The maturity of red lime-soil is not better than that of the laterite, but it is also considered as the product of the tropical and semi-tropical climate[13]. In such places as the Black Sea coast (under the dark calcium soil of the loess northern Waerna[14]), north Ireland (under the tertiary basalt)[15] and the main planation surface of the Tibetan Plateau hinterland, the lime-soil exists. This also proves that the red soil had a long history. Jenny considered it as the mild and hot climate products before the Quaternary[16]. Analyzing the rule of change in physical and chemical characteristics in the section and making a correlation in the region, we can obtain some new materials for the research on the environmental change in the formation process. Based on this thought, this paper correlates and researches into some large scale karst red weathering crust sections of the Tibetan Plateau, the Yungui Plateau, and the Xianggui hills (fig. 1), and correlates the non-karst red weathering crust, finally discusses the relationship between the red weathering crust and the double-planation surface geomorphology evolution in this region from the point of view of geochemistry and agrology.

1 Materials and methods

The red weathering crusts of the Tibetan Plateau are consistent with the main planation surface in the large geomorphologic range, and are distributed continually in local gentle hills or on the top. They appear in such areas as Dingri, Angren, Anduo and Biru. In general the thickness is less than 1 m, but it can reach 1.5 m in the margin of the east. The red weathering crusts on the

Yungui Plateau are more continual, and the depth is 3—5 m in general. They are mostly distributed in wide and flat surfaces on the top of hills in western Yunnan Province. The sections researched in central Yunnan and Guizhou lie on the plateau surface. The red weathering crusts in the hills in Hunan and Guizhou mostly lie in the karst plain, and the depth in northern Guangxi and central Hunan Province is greater than 5 m.

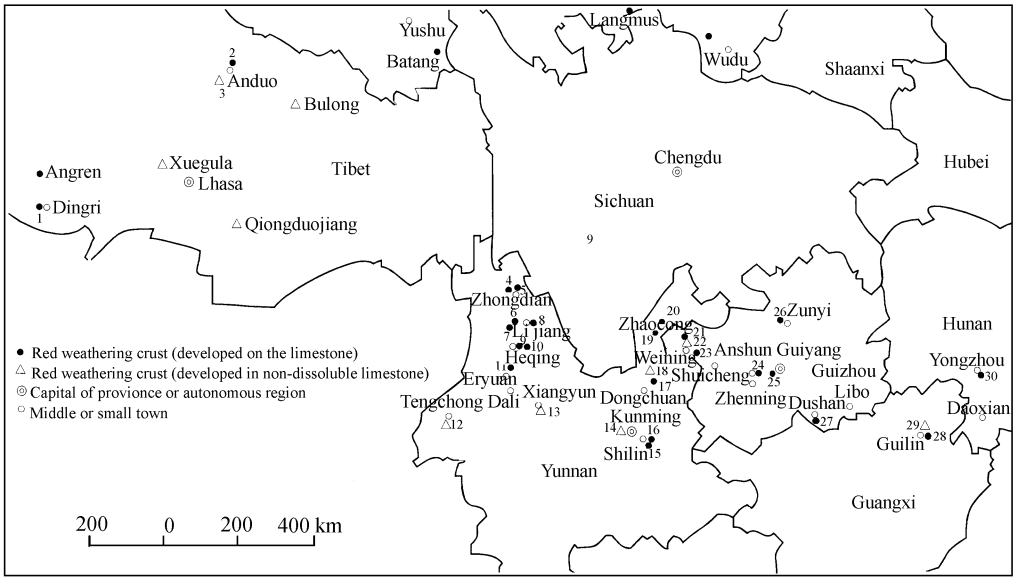

Fig. 1. Distribution of weathering crust in Hunan, Guangxi, Yunnan, Guizhou and Tibet. Explanation of the numbered sections (location/altitude (m)/depth (m)/number of sample): 1, Dingridongshan/4300/1/4; 2, Anduobeishan/5125/0.76/8; 3, Cuoe (buried weathering crust)/2/10; 4, Yirengang mountain pass/3550/1.5/4; 5, North of Napahai/3450/1.5/4; 6, Wuzhubi/3000/4/5; 7, Baihanchang/2500/2.5/3; 8, East of Lijiang/2600/4.5/7; 9, No. 1 of Shibaoshan Mountain/2250/2/4; 10, No. 2 of Shibaoshan Mountain/2500/4/5; 11, Dasongping/2800/4/5; 12, Laoxiangshan/1350/6/7; 13, Shuimushan Mountain/2600/4/5; 14, Xishan/2000/2.5/4; 15, Big stone forest/1900/2.5/3; 16, Naigu stone forest/1900/6/9; 17, Dahai/2800/6/7; 18, Tuobuka/2000/11/11; 19, Jiepu/2000/3.5/4; 20, Dalongdong/2100/11/12; 21, Zhuopu/2600/5/7; 22, Caohai/2500/5/6; 23, Meihuashan/2500/6/7; 24, Guihuang Road/ 1450/5/7; 25, Tianhetan/1250/8/9; 26, Maoshi/1400/3/4; 27, Mawei/900/3.5/5; 28, Nancun/150/5/7; 29, Naoshan/800/8/7; 30, Qingquanjing/150/8/8.

All the above-mentioned sections can be divided into three layers, upper, middle and lower. The upper layer in the Tibetan hinterland is dominated by rock debris. From Zhongdian to the eastern part, they are mainly the surface soil layers with high humus content, and interludes of some plant roots. The middle layers are red clay, and the texture is viscous and heavy. The layers in the Tibetan hinterland usually contain the gravel debris, and in the lower part we can see the $CaCO_3$ deposition sometimes. The lower layers in the central region are the un-weathered dissoluble rock, and the boundary with the above clay layer varies considerably.

The samples in this paper were collected mostly in the central red soil layer. There are 162 weathering crust soil samples (including 39 samples of the other lithologic weathering crust). The analysis of granularity includes the chemical composition of viscous grain, granularity analysis, physical and chemical analysis of soil (dissoluble rock, $CaCO_3$, pH, organism, CEC dating), XRD analysis. The base rock samples are also collected in most sections, for the mineral bulk-quantity

analysis, so that the relative leaching degree can be compared.

2 Testing results and the property characteristics of the karst red weathering crust

2.1 Soil chemical property

2.1.1 The main chemical composition. Fig. 2(a) shows the main chemical composition of SiO_2, Fe_2O_3, Al_2O_3 in sample granularity analysis. We can see that: (i) The projection of the granule composition of the weathering crust in different regions is concentrated in one narrow area, which indicates the chemical composition has no obvious change. (ii) The projection area is obviously orientated and extends in the direction of Al_2O_3 / Fe_2O_3 =2 (the beeline in the figure), which indicates the existence of the action of de-silicon and enriched aluminum (the arrow direction indicates the strengthened action of de-silicon and aluminum enrichment). In addition it also indicates that the accumulation of Fe_2O_3 and Al_2O_3 are synchronous.

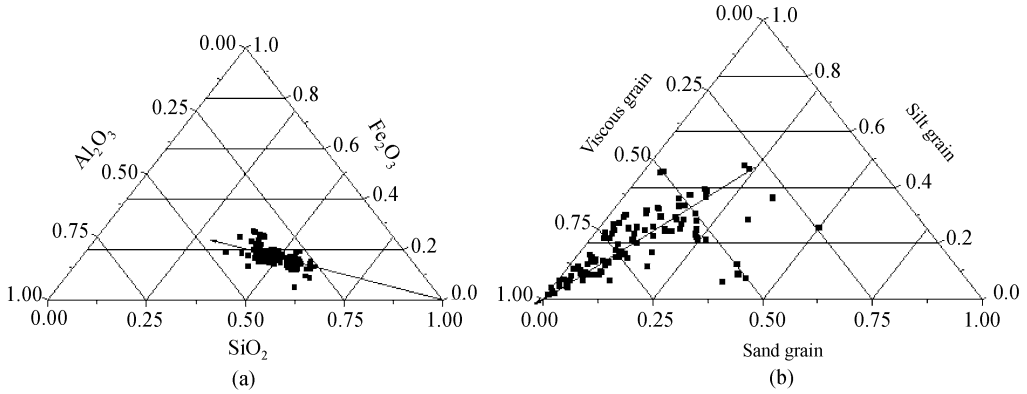

Fig. 2. The triangular table of main chemical composition (viscous grain) (a) and texture (b) of red karst weathering crust in the research region.

2.1.2 Silica-alumina rate (sa value) and salfemic rate (saf value). The sa value and saf value of viscous grains can be used as one of the indices of the weathering degree in weathering crust[16]. Kaolinite ($2SiO_2$ Al_2O_3) is considered as the silicate mineral that ranks the highest in the weathering sequence, and the most resistant to weathering. Its sa value is just equal to 2, so we usually use sa=2 as a criterion for the enrichment in aluminum (we say a mineral is obviously enriched in aluminum if its sa value is less than 2). The sa values for testing samples are mostly between 2 and 3, and the average is 2.63, and the saf value is between 1.12 and 3.03, and the average is 2.00. The sa value and saf value show that the karst red weathering crusts in the research region mostly belong to the sailic type, which did not experience obvious de-silicon and enriched aluminum-enrichment action, and only a few sections show weak aluminum-enrichment action.

2.1.3 Base leaching degree (ba). Base leaching degree (also called leaching rate) is usually expressed as the molecule ratio between oxide and alumina of the alkali metals of clay and the alkali metals. There are several ways to calculate ba as given below:

$$ba=(Na_2O+Ka_2O+Ca_2O+MgO)/Al_2O_3;$$

$$ba_0=(Na_2O+Ka_2O+Ca_2O)/Al_2O_3;$$

$$ba_1=(Na_2O+Ka_2O)/Al_2O_3.$$

The calculating results show that ba values are between 0.0925 and 0.57, 0.2507 on average; the ba_0 values are between 0.0192 and 0.242, averaging 0.11; the ba_1 values are between 0.0154 and 0.226, with an average of 0.0899. The results indicate that the base leaching variation is big, and the intensity is high.

2.1.4 The relative leaching rate. In order to correlate the weathering leaching degree of different sections, the authors also divided the soil weathering leaching coefficient in different sections with the ba value of the mother rock. Thus we can compare their relative value. We just denote them as re.ba_0, re.ba, re.ba_1, the last being the β value put forward by Jenny[17], and also called the soil weathering leaching index. The calculation formula is

$$re.ba_1=\beta=\text{leaching layer soil } ba_1/\text{parent material soil } ba_1$$

The calculation methods of the other two parameters are similar.

We can take re.ba value as an example. The base relative leaching rates are between $n\times10^{-1}$ and $n\times10^{-4}$, and one or two values are less than $n\times10^{-5}$, reflecting the base leaching degree is very high. In addition, the β, re.ba and re.Ba_0 values of the sample do not show obvious change with depth.

2.1.5 Soil weathering degree (μ value). Jenny[17] first put forward the μ value, which is the soil weathering degree. The calculation formula is

$$\mu=(\text{leaching layer } K_2O/Na_2O)/(\text{parent material layer } K_2O/Na_2O)$$

Because the colloid surface absorbs potassium preferably to sodium, the μ value is usually larger than 1. According to Jenny's research results[17], the μ value of the following soil types is in an ascending order: chernozem<podzolic soil<red and yellow podzolic soil<laterite soil. This indicates that the leaching degree and μ value are in positive correlation. The calculation results[1)] of the 16 sections in the research region show that the μ value varies greatly. The value[2)] is larger than 1 for most samples, and for some it can reach 10. This shows that the weathering degree in part of the sections is very high, but for different sections it shows great difference. The μ values also show that the leaching degree has a slight change in different sections.

2.1.6 MgO contents. The MgO contents of viscous grain can also be used as a criterion to classify the soil[16]. The boundary value of red earth and laterite is 0.65%. The boundary value of red earth and yellow-brown soil is 1.7%. Accordingly, most samples belong to red earth. Some belong to the yellow-brown soil with a value higher than 1.7%. A few samples are in the laterite upper limit, such as the Dalongdong of Zhaotong, Zhongdian of western and northern Yunnan

1) Na_2O in another seven sections cannot be checked and measured for lack of mother rock materials.
2) The μ value of part samples are less than 1. Maybe the collected samples lack the typical character.

Province.

2.2 Grain size characteristics

2.2.1 Viscous grain content and texture composition. The viscous grain contents of many samples from the research region are very high. For example, it can reach 98% in some sections in Dalongdong of Zhaotong. The lowest viscous grain contents are in Anduobeishan Mountains, only 64% (fine viscous grain being 58.6%). Compared with other soil in the south of the same region[18], the viscous grain contents of red karst weathering crust of the research region are 2 to 3 times higher. Therefore, the high viscous grain content is a common characteristic in the karst red weathering crust of research region.

Fig. 2(b) reflects the texture composition of all samples (granulite 1—0.02 mm, silt particle 0.02—0.002 mm, viscous grain<0.002 mm), and we can see that the sample points have the trend of concentrating on the viscous grain end. In addition, most samples concentrate on one beeline, reflecting the mechanic leaching phenomenon of viscous grain in the weathering crust sections (argillic action becomes stronger along the bias to the lower left), and the value of granulite particle/ silt particle is stable (about 1:2).

2.2.2 The ratio of silt particle and viscous grain. The weathering degree can also be reflected by the ratio of silt (2—20) and viscous grain (<2 m) contents in B layer because the silt particle groups can represent the original minerals preserved in fine soil particle which were not completely weathered during the geochemistry, organism and chemical weathering. However, the viscous grain represents the newly formed secondary mineral which underwent strong weathering. So, the smaller the ratio is, the higher the weathering degree of the weathering crust. After researching the ratio of B layer in 60 typical sections of Zhejiang, Li Renan (1986) (data provided by Dr. Zhang Jianlin) found the ratio values of B layer in red earth sub-type are all 0.75 (n=26), the sub-type of yellow-red earth are 1.15 (n=19), the sub-type red-yellow earth are 1.59 (n=19). Most ratios in this region are lower. According to the research results of Li Renan, most red karst weathering crust composition can come under the sequence of red earth. With the section of Huize in north-eastern Yunnan as an example, the ratio boundary is between 0.1 and 0.4.

2.3 Clay mineral combination

The XRD analysis results of all sections show that the clay mineral combination in karst red weathering crust section are mainly of 2:1 type, reflecting the weathering sequences of viscous grain minerals are not high as a whole (mainly montmorillonite, illite, in part sections such as Anduobeishan, Dalongdong of Zhaotong, the kaolinite content is high). The results basically accord with the information reflected by sa and saf values. The change in the clay mineral types and contents in one single section is much smaller than in the whole region. Clay mineral combination reflects that the weathering degree accords with the weathering degree reflected by the above-mentioned MgO, such as the sections of high kaolinite contents in Zhongdian of north-western

Yunnan in the central region and Dalongdong of north-eastern Yunnan, and the MgO contents in viscous grain parts of the samples are also low. Part of that belongs to the laterite region (<0.65%).

2.4 Physical and chemical characteristics

2.4.1 Cation exchange capability (CEC). CEC relies on the organic content, viscous grain content and the type of clay mineral. Most CEC values in the research region are between 20 and 40 mol kg^{-1}, and the organic contents are low, indicating that the clay minerals are mainly 2:1, which is in agreement with the XRD interpretative results and sa value. CEC does not have an obvious change rule at depths.

2.4.2 Organism, $CaCO_3$ contents and pH. The organism contents are much lower on the whole, and as a rule the organism contents decrease with the increasing depth[6]. $CaCO_3$ contents vary greatly, and one or two sections can reach above 90% (Lunan Stone), reflecting the lower section deposited severely, and the modern dissolving action is very weak. The change trends of pH and $CaCO_3$ contents are just the same.

2.5 The correlation to different lithological weathering crust

In order to compare the karst red weathering crust and the general red weathering crust, the authors collected seven red weathering crust samples in the region, which developed in non-dissolving rocks (fig. 1). Non-limestone weathering crusts have the full soil section texture. The leaching degree B layer is higher than limestone weathering crust. However, although the karst weathering crust and the non-karst weathering crust have different section textures (the former arrangement is not clear), the leaching action is also obvious. We can see from table 1 that the average values of the leaching index in two kinds of weathering crust of the full sections are just the same. So the red lime-earth can act as the representative index of formative environment[1)].

Table 1 Correlation of weathering and leaching characteristics of red weathering crust in Tibetan Plateau and eastern neighborhood

Weathcrust samples	Sa	Af	Saf	Ba	Ba_0	Ba_1
Limestone (113)	2.635	3.2892	2.0010	0.2507	0.1101	0.0894
Non-limestone (39)	2.5179	3.1410	1.8733	0.1938	0.0922	0.0868

3 Discussion of weathering crust formative environment

3.1 The regional change in the weathering crust characteristics

As the research region is nearly at the same latitude[2)] from east to west, the authors projected all kinds of the weathering indices to the longitude coordinate to correlate the change rule in the research region. The results indicate that sa (fig. 3(a)), saf, base leaching degree and relative

1) If we compared the B layer section, the leaching degree of non-karst weathering crust might be much stronger. So the limestone weathering crust zone is not clearer than the other lithology.

2) Only the north of Anduobeishan section inside the Tibetan Plateau, considering the region of the Tibetan Plateau moved north in large scale and the crust became shorter since the India-Asia plate collision, and the formative age latitude should be ear the south. So it is reasonable that we correlate it with the low.

leaching rate (fig. 3(b)), weathering degree (μ), MgO contents, viscous grain contents, the ratios of silt and viscous grain, clay mineral combination (kaolinite and montmorillonite contents, fig. 3(c)) and CEC are similar to each other from east to west. This accords with the information reflected by the main viscous grain chemical composition and texture triangle figure. But $CaCO_3$ contents decrease from west to east in longitude direction, at a rate of 1% $(^\circ E)^{-1}$. The pH change of weathering crust is mainly controlled by $CaCO_3$ contents, so the regional change trend of pH is just the same as the former, that is, decreasing at a rate higher than 0.1$(^\circ E)^{-1}$ from east to west.

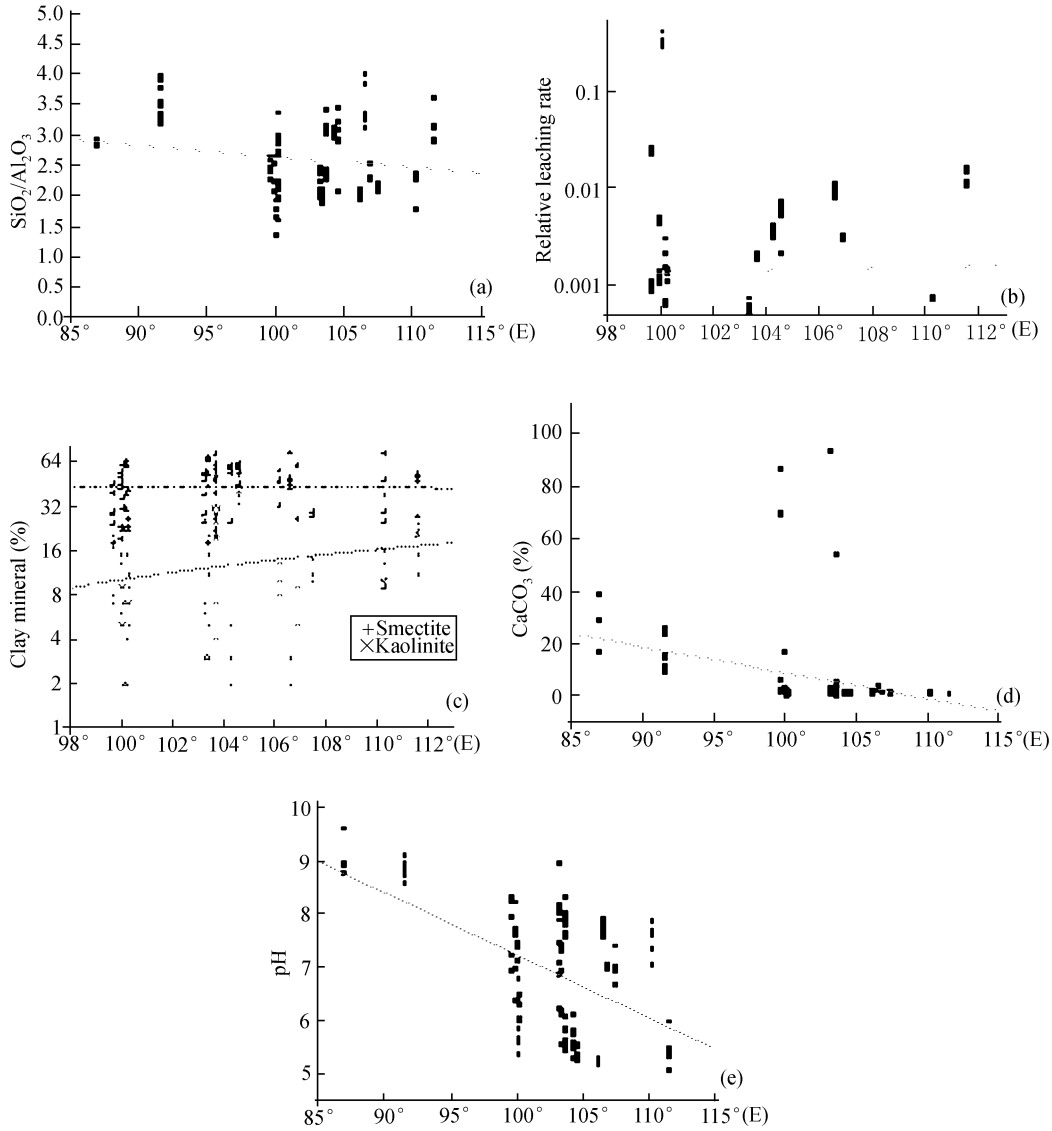

Fig. 3. The change trend of red karst weathering crust in the research region from east to west. *X* axis is longitude, *Y* axis is the qualities of weathering crust, and the lines and dashed lines are the results of linear fitting.

The increase rates with the altitude of $CaCO_3$ contents are about 5% km^{-1}, and pH correlation to altitude is positive, increasing at a rate of 0.4 km^{-1}.

The characteristics of karst red weathering crust in the research region show that all kinds of indices expressing the weathering and leaching degree and soil feature can be divided into two types. The first one can indicate the active characteristics of weathering crust under the modern environment, such as $CaCO_3$, pH, and organism contents. It can reflect the modern regional variation rules, so this characteristic of weathering crust is meaningless to ancient environment. This characteristic accords with the results of Jenny[6], Martin et al.[19] and Bronger[20]. The second one has the characteristic of no clear large scale regional variation, such as sa, ba, clay mineral combination, viscous grain contents, and the ratios of silt and viscous grain, indicating that the weathering crust formative environment has obvious similarity under the large scale condition. These two kinds of indices contrast clearly, reflecting the weathering crust does not form under the modern scenery condition, but acts as the composition of planation surface prominently. As a result the formative environment is similar. Although there is a height difference of hundreds of meters, we can prove that there exist one united planation surface from east to west in large degree. It is the main issue of this paper to reconstruct the planation surface and the development of weathering crust environment from those indices.

The second characteristic mentioned above can be summarized into three main points; that is, the aluminum-enrichment trend is not clear, base leaching rates are high and the viscous action is strong. Generally speaking, the viscous action and the aluminum-enrichment action are at the same time. That is to say, if the viscous grain contents are high, the aluminum-enrichment degree will be also high. This is inconsistent with the research results in the region. According to the regional geomorphology evolution history, the surface geochemistry and the analysis on the stable field of clay mineral, the authors consider that the characteristics of weathering crust in this region just reflect that the scenery condition and the developed environment of planation surface under the mild-hot condition are closely related.

3.2 The formative environment of red karst weathering crust

The viscous grain contents and the climate are closely related. Jenny[14] has once conducted quantitative research of their relationship. The relationship is linear from Maine to Alabama of the USA, within 1-m-deep soil of 21 places (the basement rocks are gabbro and diorite):

$$\text{Viscous grain (\%)} = 4.97T - 3.74 \ (r = 0.814)$$

As to the distribution of the seven kinds of rocks, r=0.49—0.86. Regression analysis indicates the viscous grain contents will decrease with the increasing yearly average climate or the decreasing latitude (45—30° N). As to the soil above the basic rock, the relationship is

$$\text{Log viscous grain (\%)} = 0.10 + 0.47T \ (r = 0.918).$$

This shows that the viscous grain contents are positively correlated to the formative soil environment. Precipitation can control the viscous grain contents because it can increase the humidity of

the heart soil, which is beneficial to the viscous action. Therefore, the viscous grain contents reflect the condition of formative soil environment to some degree. On the other hand, geomorphology affects not only the movement and accumulation of viscous grain, but also the soil layer humidity by influencing the hydro-geological texture of the surface and underground water. So geomorphology and its derivative hydro-condition are also important factors that affect the viscous grain contents. The viscous grain contents of weathering crust in the research region are very high, and some can reach above 90% (fig. 2(b)). The authors consider that this characteristic not only reflects the mild-hot climate condition and the long time viscous action, but also is related to the special geomorphology hydrologic condition. That is to say, there must be the combinative effect of the geomorphology wave, which ensures continual viscous action of the soil layer and prevent it from being eroded, and the scenery condition of shallow underground water etc.

The research region is at low latitudes. The climate should have been hot and moist under the condition of low elevation before the uplift of the Tibetan Plateau. But the main chemical composition, mineral combination, sa and saf values of the weathering viscous grain part in the research region do not reflect typical intense aluminum enrichment, a characteristic only of the soil in moist-hot zone. The authors believe that this just reflects the special geomorphology and hydrologic condition in the planation surface. Because the planation surface is near the base level of erosion, and is relatively even, and the underground water is shallow, the surface water is not drained well, the underground water is stagnant, which will affect the leaching action (even restricting effective leaching of the whole soil layer completely). Therefore, in the soil layer, the indices expressing leaching action such as the viscous grain contents, sa, saf values are high. Jenny once pointed that in the over-wet zone, because the permanent expansion results in the poor inside drainage, in the viscous grain-rich soil not only the decomposition is restricted, but also the gibbsite may change into kaolinite, which results in a large amount of silicate viscous grains[14]. In addition, the research results of surface geochemistry show that clay mineral combination of the weathering crust mainly relies on the current velocity inside the crust[21]. Mineralogy research indicates that the type of clay mineral under the surface environment mainly depends on the water/rock ratio of the reactive system[22]. The two results are the same in nature. The high current velocity or the water/rock ratio mean that inside the system silicon activity is low, so de-silicon and aluminum-enrichment action can easily proceed, and kaolinite and diaspore clay minerals can easily form. The low current velocity or water/rock ratio mean that the silicon cannot be easily moved inside the system, and the results are that only the clay mineral whose combination is mainly montmorillonite can form. Sherman and Ikawa[23] show that the low elevation and high precipitation can mainly form the kaolinite, but if the drainage is not good, the kaolinite contents will be the highest in the yearly precipitation of 900 mm, and will disappear in 1000—1100 mm. This explains why the clay mineral combination cannot simply indicate the formative climate condition all the time. The authors consider that the clay mineral combination of the research region which are mainly montmorillonite reflects that it is the stagnant environment, and the latter just derives

from the even geomorphology planation surface.

Considering all kinds of characteristics of the red karst weathering crust in the research region, we can see that the formative scenery condition is one kind of environment, which benefits the viscous grain action, but is not good for the leaching. On a large scale, we consider this scenery condition can only lie in the low elevation planation surface under the low latitude, where the climate is moist and hot.

The bulk of limestone changed very much in the course of weathering crust forming (most base may run away in this process). Supposing that the titanium does not move and based on the research of red calcareous soil in southwestern region of Guangxi, Wei[24] et al. calculated the formative soil rudimental quantity to be 0.15%. That is, one-meter-deep weathering crust needs 627-m-deep basis rock weathering crust. So it is impossible that the deep layer weathering crust can form in the limestone without long time weathering of the huge thick layer under the moist and hot condition. But long time karst action and disappearance of the deep rock layer must cause the geomorphology to develop toward the peneplain, and form the topography undulating meek planation surface. The latter does not benefit the weathering crust leaching action. Wang Shijie did the geochemistry research of the carbonate red weathering crust in Hunan and Guizhou, and obtained the results that the development degree of the carbonate weathering crust is not high[25] in the whole field. The research results of other scholars[26—28] on the carbonate weathering crust also indicate that the de-silicon and aluminum-enrichment action of this kind of weathering crust is low. For example, the authors found this phenomenon near the airport of Qifengzhen in Guilin. In the hole left by the manual work after picking the soil, the color of the main body of the weathering crust is gray except for the red thin soil layer in the upper. This reflects the characteristic of forming crust action in karst planation surface on one hand. That is, the de-silicon and aluminum- enrichment action is restricted, but it is beneficial to the viscous grain formation. According to the research results of Curtis et al.[29], Trudgill[30] on the development of karst weathering crust and the preserving condition, the authors consider that the red karst weathering crust in the research region mostly develop in planation surface in karst region. So the time of soil action is very long, but it is still very difficult to reach the high soil stage. Ref. [2] pointed out that the red weathering crust is not the typical characteristic of original planation surface, but rather the result[2] of the leaching condition getting better caused by the slow tectonic uplift. Although the leaching condition gets better after the fast tectonic uplift in the middle and western region (Tibetan Plateau, Yungui Plateau), it is very hard for the soil viscous and heavy karst weathering crust to reach the high aluminum-enriched stage. At the same time, it can be carried away due to the quick erosion.

From the places where karst red weathering crust is distributed (the even summit or karst plain), such as Anduobeishan, Tai'an of Lijiang, Stone Forest of central Yunnan, Tianhetan of Guiyang, Daloushan of north Guizhou, Guilin of Guangxi and Yongzhou of south Hunan, we can see that red karst weathering crust and planation surface are closely related. The weathering crust of this region is mainly connected with the open and smooth geomorphology surface. On the other

hand, continual weathering and soil action was also the main content of planation and the premise of the planation surface formation. The common active results lead to the united planation surface formation of the research region.

4 Discussion and results

In order to solve the Tibetan Plateau uplift issue, using planation surface to estimate the original height[4,31] before the uplift is one research direction where a breakthrough is expected. Using weathering crust to recognize and reconstruct the united planation surface is one of the most important taches. On the other hand, since the late 1980s, many methods such as ancient geomagnetism[5], stable isotope analysis of clay mineral[6—9], surface mineral dating[10,11], have been widely used so that using the weathering crust for dating and to reconstruct ancient environment have a bright prospect. So the research on weathering crust not only can help solve the Tibetan Plateau uplift age, range, and speed, but also can obtain the information of environment change, and serve for the reconstruction of the time and space coordinate of Tibetan Plateau uplift.

We need to point out that, because of the diversity of the soil action factors and the difference of its sensitive degree to environment change, and the difference of the research weathering crust in depth, geomorphology place, collecting sample depth, space in between, and quantity distribution, the projections of all kinds of indices appear slightly dispersed. But the change trend in space is clear.

We mainly obtain the following conclusions:

1) Regional correlation results show that the characteristics of chemical composition, mineral combination and granularity composition of viscous grain part in red karst weathering crust do not show obvious regional difference from east to west. The authors consider this may show that the scenery conditions are similar to the united planation surface formed at the same latitude. This proves that using weathering crust to research and solve the planation surface correlation in a large region is reasonable.

2) All kinds of weathering leaching indices of red karst weathering crust in the research region indicate the weathering crust developing stages are not the same. Viscous grain part index, such as silicon and aluminum ratio and silicon, aluminum and iron (high), CEC and clay mineral combination (the XRD analysis results show the clay minerals are mainly 2:1 type), indicate that the development degree of weathering crust is low (de-silicon and aluminum-enrichment action being weak). However, the base leaching degree and relative leaching rate (small), soil weathering degree (large), MgO contents (low), viscous grain contents (high), silt/viscous grain (large) reflect the development stage of weathering is high (alkali metals and alkali metals element leaching and running out are very serious). This disagreement just relies on the special geomorphology and hydrologic condition of planation surface under the moist and hot climate.

3) Because the meek geomorphology wave does not benefit the surface water drainage and restrict the weathering crust leaching effectively, it results in the de-silicon and aluminum-en-

richment action of weathering crust to be pervasively weak. This causes the silicon and aluminum rate to become higher. This also proves there exists one united planation surface; this opens up the geochemistry characteristics of weathering crust in planation surface.

4) The planation surface scenery has the pervasive characteristics of poor drainage and shallow underground water under the moist and hot condition. This is favorable to the formation of clay, but the long stagnant water environment restricted the movement of silicon. The results in clay mineral combination is mainly 2:1 type, which also opens up the clay mineral combination characteristics of weathering crust in planation surface.

5) $CaCO_3$ contents and pH in weathering crust has obvious difference from east to west, reflecting the modern environmental condition in the research region from east to west. So this kind of index does not have the ancient environment meaning.

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