Preliminary study on weathering and pedogenesis of carbonate rock*

WANG Shijie (王世杰), JI Hongbing (季宏兵), Ouyang Ziyuan (欧阳自远), ZHOU Dequan (周德全), ZHEN Leping (郑乐平) and LI Tingyu (黎廷宇)

(State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, China)

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Abstract South China is the largest continuous distribution area of carbonate rock in the world. The origin of the soils over the bedrock carbonate rock has long been a controversial topic. Here further exploration is made by taking five soil profiles as examples, which are developed over the bedrock dolomitite and limestone and morphologically located in upland in karst terrain in the central, west and north Guizhou as well as west Hunan, and proved to be the weathering profiles of carbonate rock by the research results of acid-dissolved extraction experiment of bedrock, mineralogy and trace element geochemistry. Field, mineralogical and trace element geochemical characteristics of weathering and pedogenesis for carbonate rock are discussed in detail. It is pointed out that weathering and pedogenesis of carbonate rock are important pedogenetic mechanisms for soil resources in karst area, providing a basis for further researches on the origin of soils widely overlying bedrock carbonate rocks in South China.

Keywords: **mineralogy, trace elements, acid-dissolved extraction experiment, weathering profile, carbonate rock, South China.**

Carbonate rock is an important type of rocks, covering about 25% of the land surface of the world. It is mainly distributed in the tropical and subtropical zones such as Southeast Asia, Mediterranean coast and Southeast of North America. Among them, South China is the largest continuous distribution in the world. Soils over carbonate rock distribution areas have different thickness. In the academic circles, the source of soil parent materials in Mediterranean coast and Southeast North America has long been a controversial topic. Some suggested that the parent materials of these soil were accumulation of insoluble residues from the underlying carbonate rock[1,2], and others considered that they were mainly derived from Sahara desert dust and carbonate rock weathering[3—5]. For lack of systematic researches on different geological evolution backgrounds and geographic environments, it is difficult to evaluate whether carbonate rock weathering and pedogenesis are important pedogenetic mechanisms in the distribution areas of carbonate rock[6]. Recently soils overlying the carbonate rock in South China have attracted the attention of some geologists. They put forward the concept of metasomatic pedogenesis of carbonate rock and suggested that the products of carbonate rock weathering and pedogenesis were the main source of soil parent materials[7—9]. However, their conclusion was unreliable because they did not provide enough evidence in proving that the studied soil profiles were the direct products of carbonate rock weathering and pedogenesis. In this paper, based on detailed

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five field investigation, typical soil profiles developed on the bedrock dolomitite and limestone and morphologically located in upland in karst terrain in the central, west and north Guizhou and west Hunan, are selected. Through acid-dissolved extraction experiment of bedrock carbonate rock, mineralogical and trace element geochemical researches, the source of the five soil profiles is proved to be residues of carbonate dissolution. Here carbonate rock weathering and pedogenesis in South China are discussed.

1 Experimental method

Put 2 kg powered carbonate rock samples in a 500 mL beaker, then add appropriate 1 mol/L HCl. Stir the beaker at a rate of 120 r/m to make carbonate rock dissolve faster. After 30 min, the acidity of the solution was measured. If neutral, after the upper clear leaching solution was discarded, 1 mol/L HCl was added to the beaker again to dissolve carbonate. The above procedure was repeated until the added acid no longer reacted with sample. The time for accomplishing this operation was about 24—30 h. The leached sample was washed repeatedly using distilled water until the washing solution became neutral, and then dried in an infrared lamp for analysis. X-ray diffraction were used to evaluate the effect of different concentrations of HCl on the change of mineral composition of dissolution residues of carbonate rock. Table 1 shows that there was no obvious difference in mineral composition of residue leached by 0.2, 1, 2, 5 mol/L HCl. However, minor difference still existed. Secondary shortite(d_{001} = 0.6 nm) appeared when leaching with 1, 2 and 5 mol/L HCl and minor secondary smectites(d_{001} = 1.52nm) appeared when leached with 2 and 5 mol/L HCl. Meanwhile, the peak height of main clay mineral of illite (d_{001} = 1.0 nm) decreased obviously when using 5 mol/L HCl leaching solution. Considering that when using HCl of lower concentration as leaching solution more time was required to dissolve carbonate completely, the effect of acid on the dissolution of clay minerals was obvious. For instance, the total amounts of illite and kaolinite were smaller when leaching with 0.2 mol/L HCl (table 1). So the use of 1 mol/L HCl in the extraction experiment was reasonable and did not significantly affect the mineral composition of residue.

Table 1 Half-quantitative estimate(%) of amount of dissolution residue of carbonate rock leaching with different concentrations of HCl

HCl	Illite	Quartz	Kaolinite	Anatase	Feldspar	Pyrite	Dolomite	Smectite	Shortite
0.2 mol/L	52.08	19.03	1.77	1.18	15.22	7.62	2.09		
1 mol/L	54.59	20.67	1.86	1.96	13.60	5.15	1.16		-
2 mol/L	58.41	14.60	1.06	1.51	15.97	5.59	1.86	+	-
5 mol/L	50.98	18.51	1.60	3.06	13.86	8.81	3.17	+	-

+, the product of reaction of feldspar with acid(d_{001} = 1.52nm); –, the secondary mineral appearing in the leaching process (d_{001} = 0.6 nm).

X-ray analysis was made on a dmax/2200 X-ray diffraction instrument at the Institute of Geochemistry, CAS. Samples for X-ray analysis were dried in air and ground in agate mortar (200 mesh). Trace element analysis was made on an Element ICP-MS at the Institute of Geochemistry, CAS. 0.1g sample, 1.5 mL HF and 1 mL HNO_3 were added into teflon melting pot to dissolve samples under closed condition. The sample pot was heated in a bake furnace at 140℃; after 48 h, it was placed on an electrothermal plate to cool down with 1 mL HNO_3 added. This procedure was repeated twice; then using 3 mL HNO_3 and 10 mL H_2O to dissolve the samples in a 100 mL plastic bottle to make ICP-MS measurement. Using neutron activation method, four standard samples (GSS-7, GSS-4, GSS-1, GSR-6) and two well measured samples (C4CH and T5CH) in different laboratories were used to evaluate the quality of the ICP-MS measured data. Except for sample T5CH with low concentrations of trace elements, the relative errors of measurement data of TiO_2, Rb, Nb, Pb, Th, U and REE were less than 10% (including a few exceptions, for example, Eu, Yb of GSR-6 and Eu, Ta, Lu of C4CH were less than 15%), Sr < 15%, Zr, Ta < 20%, as compared with the published data.

2 Characteristics of carbonate rock weathering profile

We discuss the carbonate rock weathering and pedogenesis in detail in the aspects of the field, mineralogical and geochemical characteristics.

2.1 Field investigation

Field investigation is the direct evidence to judge whether soil developed over carbonate rock is the weathering product of carbonate rock. In order to avoid the effect of talus material, the field investigation is focused on the soil profiles morphologically located in upland in karst terrain. Five most typical soil profiles developed well on the bedrock carbonate rock are selected: the Pingba farm profile in Pingba County in Central Guizhou, the Shuangshan profile in Dafang County in West Guizhou, the Zhongzhuang and Xinpu profiles in Zunyi City in north Guizhou and the Jishou profile in Jishou City in west Hunan (table 2). Compared with weathering profiles of other kinds of rocks, carbonate rock weathering profile has some special features: (i) the color of residual soil weathered by dolomitite is reddish and it is thicker than residual soil weathered by limestone, 3—10 m on average, the transition zone (zone BC in the Pingba and Xinpu profiles in table 2) is composed of crumble dolomitite sand and dark thin clay beds (10—50 cm) encircling the weathered bedrock, where the phenomenon of wrapping up each other of the weathered rock and soil can be seen sometimes; (ii) the color of residual soil weathered by limestone is yellowish and the soil is thinner generally, but the soil profile weathered by pure limestone is thinner than that by impure limestone. For example, the thin Dafang profile and the thick Zhongzhuang profile in tables 2; (iii) the bed structure of bedrock always remains at the lower part of soil profile weathered by muddy limestone, such as the Jishou profile in table 2; (iv) in the Chengxi residual soil profile weathered by chert-containing micritic limestone in the Dafang Town, Guizhou, the distribution feature of chert in soil is the same as that in the bedrock, i.e. the relative position and attitude of chert bullion or thin chert bed in the soil change little compared with those in the bedrock.

2.2 Comparison of mineral compositions of dissolution residues of carbonate rock with those of soil profiles

Although the formation ages of the bedrock limestone in the Dafang, Zhongzhuang and Jishou profiles were different, the three soil profiles have the same mineralogical evolution trend (table 3). From zone C to the lower part of zone B, calcite (minor dolomite) decreased in amount, and even disappeared. Consequently the percentages of quartz and clay minerals increased abruptly; mineral composition of the dissolution residues of bedrock limestone was the same as those of soils basically, except that pyrite became iron oxide and hydroxide. For example, in the Jishou profile, they accord very well and are the same in the Dafang and Zhongzhuang profiles except for the appearance of secondary smectite in the upper part of zone B (Nos. 24 and 19 samples), which was formed during the weathering process of dissolution residue of limestone. As for the Pingba and Xinpu dolomitite weath-

Table 2 Geologic features of the five carbonate rock weathering soil profiles and the sampling sites

Bed	Pingba profile	H/cm	S.No.	Xinpu profile	H/cm	S. No.
A	grey-yellow overlying soil cover	15		black-grey overlying soil cover	30	
	brown-yellow soil with root of plants	40		deep grey soil	25	
B	brown-yellow soil	40	1	yellow-brown soil (left side)	20	8
	red soil with minor irony nodule	40	2	red soil (right side)	10	9
	purple-red irony crust	8		red soil	50	
	red-yellow soil	20		red soil	50	
	brown-yellow soil	25		red soil	100	10
	yellow soil	93	3	red soil	150	
	purple soil	2		red soil	150	
	yellow soil	235		yellow-brown soil	20	
	brown-yellow soil	26		yellow-brown, deep purple soil	30	11
BC				yellow laminated soil	6	12
	deep purple soil with lamination	30	4	light-yellow laminated soil	26	13,14
	the weathered rock	5—10	5	the weathered rock	2—6	15
C	the cracked rock	50		the cracked rock	30	16
	bedrock dolomitite(T_1a)		6, 7	bedrock dolomitite($\in_{2-3}ls$)		17
	Dafang profile			**Zhongzhuang profile**		
A	yellow-grey overlying soil cover	30		brown-grey overlying soil cover	45	
B	red-yellow soil	120	18	yellow soil	≫100	
	brown-yellow soil	25		yellow soil	100	
	light-yellow soil	15		yellow soil	50	22
	grey-yellow soil	3	19	yellow soil	50	
	light-yellow soil	5		grey-yellow soil	7	23
	grey-yellow soil	2		mottled soil	8	24
	light-yellow soil	4		light-yellow soil	6	25
BC	light-grey carbonate mud	2	20	blue-yellow carbonate mud	3	26
C	muddy limestone bedrock(T_2g)		21	Limestone bedrock(T_1^3m)		27
	Jishou profile					
A	overlying soil cover	≫100				
B	yellow soil	150	28			
	yellow soil with the bedding of bedrock	50	29			
	brown-yellow soil with the bedding of bedrock	90	30			
C	muddy limestone(O_1d)		31			

A, B, BC, C stand for overlying soil cover, soil and transition zone and bedrock, respectively; H, the thickness of sample.

ering soil profiles, evolution of mineral association for soil profile was similar to that of limestone weathering profile and mineral compositions of dissolution residues of dolomitite were consistent with those of soils (table 3). It was important to note that volcanic secondary minerals, glassy detrital matter and heavy minerals which usually existed in loess were not found in the samples, implying that there existed no eolian matter in soil profile. The fact that mineral composition of dissolution residue of bedrock carbonate rock was the same as those of soil was powerful evidence to prove that the soil is the weathering products of the underlying bedrock carbonate rock.

Table 3 The distribution features of minerals in carbonate rock weathering soil profiles

Sample No.	Dolomite	Calcite	Quartz	Illite	Kaolinite	Chlorite	Smectite	Feldspar	Anatase	Pyrite	Hematite	Limonite	Amorphous mineral
						Pingba profile							
1	+	–	+	+	–	+	–	+	+	–	+	–	+
2	–	–	+	+	+	+	–	+	+	–	+	–	+
3	+	–	–	+	+	+	–	+	+	–	+	–	+
a	–	–	+	+	+	–	+	+	+	+	–	–	–
4	+	+	+	+	+	+	+	+	+	–	+	+	+
5	+	–	+	–	–	–	–	+	–	–	–	–	–
6	+	–	–	–	–	–	–	–	–	–	–	–	–
7	+	+	–	–	–	–	–	–	–	–	–	–	–
						Xinpu profile							
10	–	–	+	+	+	–	–	–	+	–	+	–	–
11	–	–	+	+	+	–	+	+	–	–	–	–	–
12	–	–	+	+	+	–	+	+	–	+	–	+	–
15	+	–	+	+	+	–	–	+	–	–	–	–	–
b	–	–	+	+	+	–	–	+	–	–	–	–	–
16	+	–	+	–	–	–	–	–	–	–	–	–	–
17	+	–	+	–	–	–	–	–	–	–	–	–	–
						Dafang profile							
18	–	–	+	+	–	+	+	+	–	–	–	+	–
19	–	–	+	+	–	+	–	+	+	–	–	+	–
20	–	–	+	+	+	+	–	+	–	–	–	+	–
c	–	–	+	+	+	+	–	+	+	+	–	–	–
21	+	+	+	+	+	–	–	+	–	–	–	–	–
						Zhongzhuang profile							
22	+	+	+	+	–	+	–	+	+	–	–	–	–
23	+	+	+	+	+	–	–	+	+	–	–	–	–
24	–	–	+	+	–	+	+	+	+	+	–	–	–
25	+	+	+	+	–	+	–	+	+	–	+	–	–
26	+	+	+	+	–	+	–	+	+	–	+	–	–
d	+	+	+	+	+	+	–	+	+	+	–	–	–
27	–	+	+	–	–	–	–	–	–	–	–	–	–
						Jishou profile							
28	–	–	+	+	–	–	–	+	–	–	–	+	–
29	–	–	+	+	–	–	–	+	–	–	–	+	–
30	–	–	+	+	–	–	–	+	–	–	–	+	–
31	–	+	+	+	–	+	–	+	–	–	–	–	–

For sample number see table 1. a, b, c, d stand for dissolution residue of Nos. 7, 17, 21, 27 sample respectively; + for presence of mineral in sample; – for absence of mineral in sample.

2.3 Distribution patterns of rare earth elements (REE) and trace element ratios in soil profiles

In fig. 1, the concentrations of REE for samples from the bedrock limestone to the soil in the Dafang, Zhongzhuang and Jishou soil profiles were different; however, the distribution patterns of REE for samples were similar, showing that the evolution characteristics of REE in soil have an obvious inheritage to the parent rock limestone (fig. 1 (a)—(c)). In the Pingba and Xinpu soil profiles, REE were differentiated clearly from the bedrock dolomite to the upper part of soil, but from the bedrock to the zone BC (Nos. 7,6,5,4,17,16,15,14,13 samples in table 2) the distribution patterns of rare earth elements were similar, in which the four separate smooth curves (La-Ce-Pr-Nd, Pm-Sm-Eu-Gd, Gd-Tb-Dy-Ho, Er-Tm-Yb-Lu), i.e. "M type" tetrad effect existed (fig. 1 (d)), corresponding to those observed in marine carbonate and its products of water-rock interaction[12]. All the above features demonstrated that the studied profiles were *in-situ* weathering profile of dolomitite. The REE distribution patterns for samples in the upper part of the soil profile similar to those for upper continental crust (UCC) were distinguished from these for samples in the lower part and bedrock of the soil profile (fig. 1 (f)). This could be related to the intensity of chemical weathering of soil profile, and is yet to be further researched.

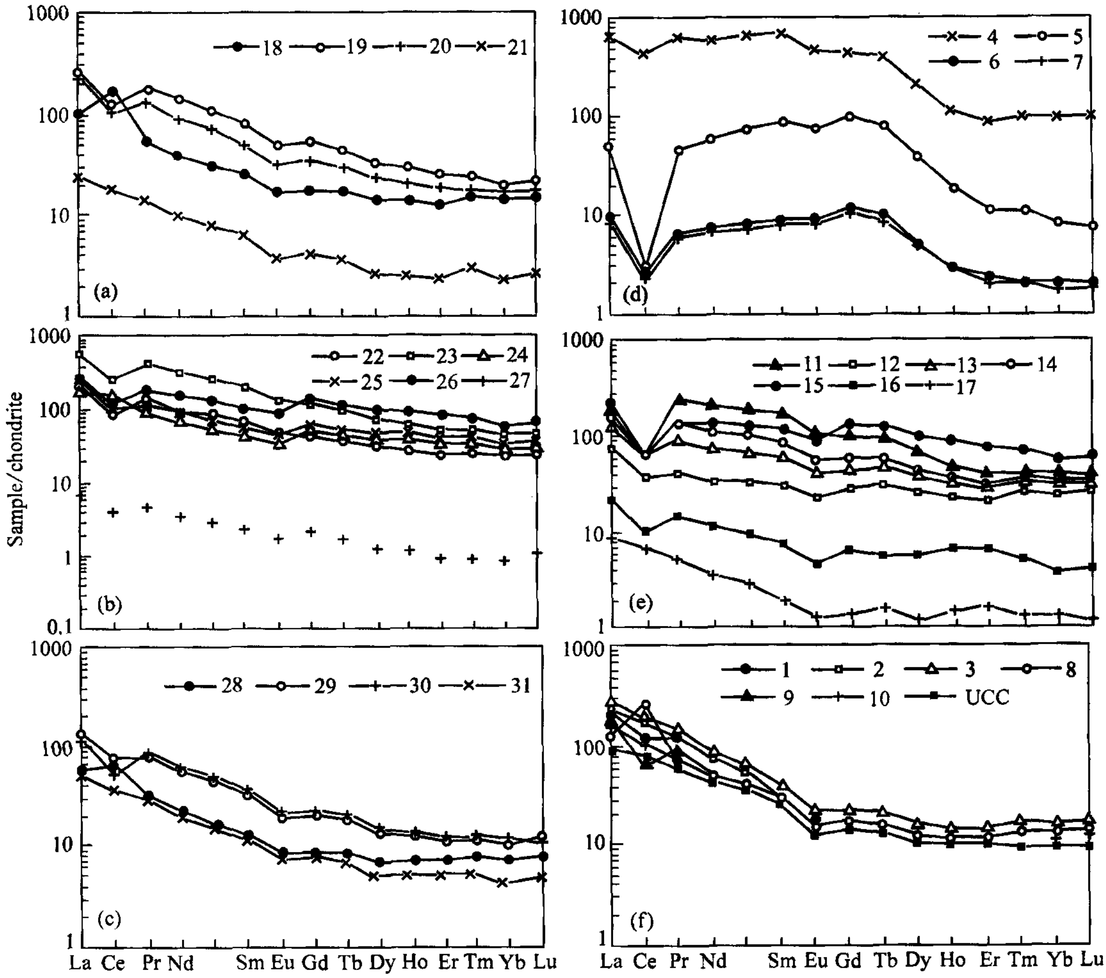

Fig. 1. Chondrite-normalized REE distribution patterns for samples of soil profile. (a) the Dafang profile; (b) the Zhongzhuang profile; (c) the Jishou profile; (d) samples from zone C to zone BC in the Pingba profile; (e) samples from the zone C to zone BC in the Xinpu profile; (f) samples from the middle-uper parts of zone B in the Pingba and Xinpu profiles, UCC for average upper crust composition[10] (for the sample number see table 2); REE values of chondrite are cited from Boynton (1984)[11]. The above two standard values were not explained in tables and figures.

REE geochemical behavior of carbonate rock weathering and pedogenesis has features anologous to other rock weathering and pedogenesis[13—16]. In fig. 1 the total amounts of rare earth elements varied greatly from the bedrock samples to soil samples, especially in zone BC; the REE amounts of most soil samples exceeded UCC; the distribution patterns of rare earth elements were rich in light REE and relatively flat in the parts of heavy rare earth elements; $(La/Yb)_N$ was in the range of 3—18 and increased from zone C to zone BC to zone B; δEu had relatively constant negative anomaly from 0.63 to 0.85, and δEu for zone B became larger than that for zone C and zone BC; the negative δCe was the largest in the boundary between rock and soil, but from the lower to upper part of soil profile the value decreased slowly, sometimes became positive.

Table 4 shows that ΔNb and ΔZr of soil samples in each profile were constant, especially the former, and the change in Nb/Ta for soil profile kept relatively stable. These are consistent with the known fact that Nb, Ta, Zr and Ti, etc. were conservative elements during the process of weathering and pedogenesis. The ratios between these elements can provide information about the soil parent materials during the process of isovolumic weathering[17]. However, the same situation did not exist in the process of non-isovolumic weathering[18]; for instance, ΔNb and ΔZr differ greatly between the bedrock and soil samples because of large volume change during the process of carbonate rock weathering (table 4). This is a unique feature of carbonate rock weathering and pedogenesis. In Nb vs. TiO_2 and Zr vs. TiO_2 diagrams, the samples of each profile had a good linear relation, the correlation coefficient being 0.969—0.998 (fig. 2 (a), (b)), demonstrating that the soils were *in-situ weath-*

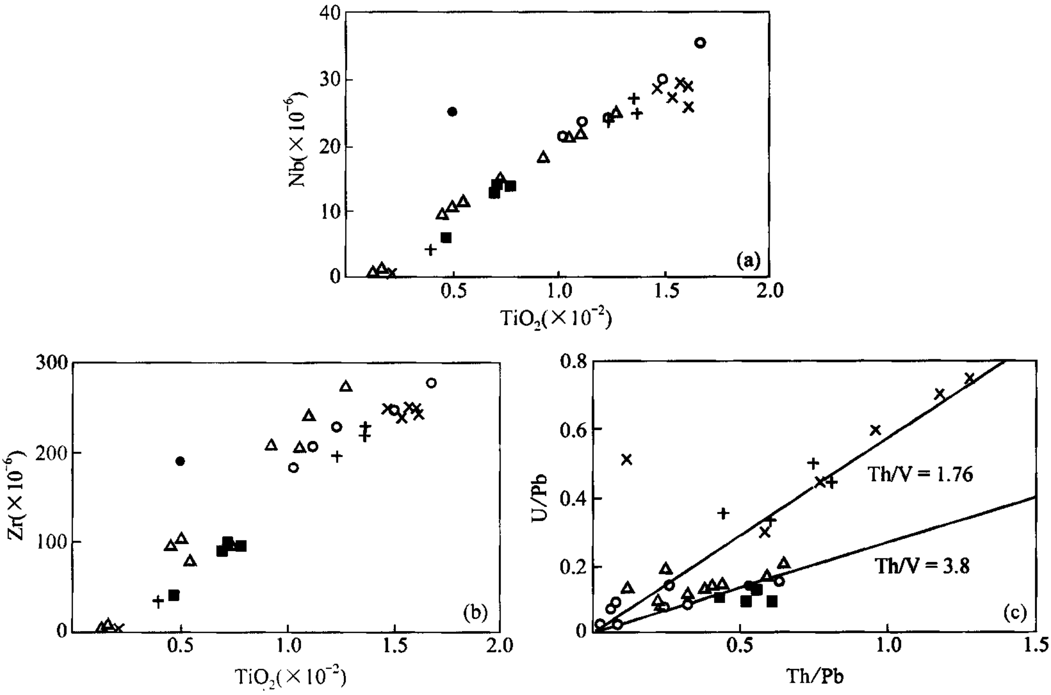

Fig. 2. (a) TiO_2 vs. Nb, (b) TiO_2 vs. Zr, (c)Th/Pb vs. U/Pb diagram for samples in the five weathering profiles. PB, the Pingba profile; JS, the Jishou profile; XP, the Xinpu profile; ZZ, the Zhongzhuang profile; DF, the Dafang profile; UCC, average composition of upper crust composition; line Th/U = 3.8 defined by UCC; line Th/U = 1.76 simulated from data of the Dafang and Zhongzhuang profiles.

ered products of underlying bedrock carbonate rock. Rb/Sr increased slowly from the lower to upper part of soil profiles (table 4), which might be related to the upward increase in weathering intensity[19]. In U/Pb vs. Th/Pb diagram (fig. 2(c)), the ratios between U/Pb and Th/Pb of each soil profile had an increasing trend, and those of parent rock and the weathered rock were concentrated in the left lower parts. When the weathering process went downward, feldspar in the upper soil would decompose continuously, and Pb in feldspar, especially in K-feldspar[20], would be released continuously, making the ratios of U/Pb and Th/Pb increase steadily. Samples from the Pingba, Xinpu and Jishou profiles are distributed along the line of Th/U = 3.8 defined by UCC, and samples from the

Table 4 Partial trace element ratios, the percentage change of elements and REE parameters

Sample No.	Nb/Ta	Rb/Sr	Δ_{Nb}	Δ_{Zr}	ΣREE	$(La/Yb)_N$	δCe	δEu
Dolomitite weathering profiles								
1	13.779	1.465	807.6	885.8	284.769	17.489	0.66	0.77
2	14.076	1.487	821.9	960.8	309.138	18.508	1.02	0.70
3	12.741	1.697	800.4	1007.1	372.998	16.423	0.94	0.75
4	13.395	1.826	842.9	1002.7	1500.09	5.931	0.68	0.84
5	9.417	0.035	14.7	24.4	139.166	5.980	0.05	0.82
6	11.143	0.016	7.2	2.6	22.162	4.722	0.32	0.84
7	3.944	0.017	0	0	20.712	4.838	0.32	0.90
8	13.535	1.334	464.1	340.5	340.096	9.628	2.80	0.65
9	13.956	0.628	460.1	329.9	191.819	11.816	0.57	0.66
10	14.434	1.098	456.8	321.1	218.079	10.388	0.96	0.63
11	14.922	0.805	472.8	284.9	455.342	5.232	0.27	0.80
12	14.226	0.172	486.4	160.0	149.755	2.945	0.67	0.77
13	12.751	0.158	509.0	196.2	257.725	3.954	0.57	0.78
14	13.635	0.285	523.0	308.3	311.157	4.966	0.38	0.77
15	12.536	0.293	503.0	325.5	499.523	3.508	0.33	0.71
16	12.991	0.151	153.4	19.5	68.268	5.718	0.61	0.66
17	11.923	0.032	0	0	26.137	6.725	0.96	0.79
Limestone weathering profile								
18	13.969	4.481	92.5	79.4	146.905	6.522	2.32	0.79
19	14.728	3.947	91.1	88.6	407.674	11.667	0.57	0.73
20	13.808	3.361	75.7	81.2	331.586	14.040	0.58	0.74
21	14.960	0.062	0	0	41.323	9.635	1.01	0.73
22	12.606	3.561	585.6	729.8	328.207	8.651	0.50	0.81
23	14.437	3.220	660.8	748.0	865.972	11.088	0.50	0.82
24	14.906	2.829	704.5	766.6	432.917	5.993	1.23	0.75
25	14.689	3.752	744.1	836.0	522.582	7.517	0.82	0.76
26	14.864	2.692	683.4	752.3	685.051	4.539	0.54	0.76
27	13.263	0.011	0	0	13.684	8.090	0.73	0.80
28	14.411	9.365	49.683	52.855	116.018	8.368	1.60	0.85
29	14.436	10.224	39.951	48.703	198.147	11.804	0.78	0.77
30	14.792	9.963	36.997	41.987	178.974	9.376	0.57	0.76
31	14.007	0.559	0	0	80.266	12.664	0.89	0.75

Δ_{Nb}, Δ_{Zr} stand for percentage(%)change of Nb, Zr in soil relative to those in parent rock (TiO_2 as reference): $100 \times [(X_s/I_s)/(X_p/I_p) - 1]$ (see ref. [14]). X_s and I_s stand for the concentrations of element X and the reference element J in sample, X_p and I_p for the concentration of element X and the reference element I in parent rock; for the sample number see table 2; c) ΣREE for La—Lu and Y, $(La/Yb)_N = (La/La_N)/(Yb/Yb_N)$, $\delta Ce = (Ce/Ce_N)/[(La/La_N)^{0.5} \times (Pr/Pr_N)^{0.5}]$, $\delta Eu = (Eu/Eu_N)/[(Sm/Sm_N)^{0.5} \times (Gd/Gd_N)^{0.5}]$, and N for the standard value of chondrite(see reference [11]).

Zhongzhuang and Dafang profiles along the simulated line of Th/U = 1.76. These could reflect the difference in the weathering intensity of the studied profile, and the reported average ratio of Th/U of the soil profile with the largest weathering intensity was $5.9 \pm 1.2(1\sigma)$[21]. So it is possible that the weathering intensity of the Pingba and Xinpu profiles was larger than that of the Zhongzhuang and Dafang profiles. This was consistent with the above postulation that because of the difference in weathering intensity, the degree of REE differentiation of the Pingba and Xinpu profiles was larger than that of the Zhongzhuang and Dafang profiles.

3 Discussion and conclusion

According to the field investigation, mineralogy and trace element geochemistry of the five soil profiles, the process of carbonate rock weathering and pedogenesis can be divided into two stages: the first stage, in which dissoluble residue of carbonate rock weathering accumulated to form soil and the second stage, the stage of chemical weathering of the residuum, which is similar to the weathering process of the other rocks.

It is possible to discuss the possibility of carbonate rock weathering to form the residium in the first stage in South China. For the five studied profiles with no other eolian addition, the thickness of carbonate rock dissolved to form 1 m soil and the needed time were calculated. The results are listed in table 5. 2 ~ 5 m thick carbonate rock was needed to form 1 m relict soil and 28000—84000 a dissolution time were required for the three studied profiles with 11%—39% muddy contents in the parent rock limestone. For the other studied dolomitite weathering profiles, because of the great difference in the muddy contents of parent rock dolomitites (4% for the Xinpu profile and 0.625% for the Pingba profile) H and T vary greatly: 13 m, 316 533 a for the former and 79 m, 25 637 a for the latter. If we neglect the erosion during the formation of soil profile, the time needed to form 5 ~ 6 m thick Pingba soil profile is 4—4.7 Ma. In addition, the dry and warm palaeoclimate of planetary wind system which was characterized by well developed late Cretaceous red carbonate breccia and early Tertiary red rock settings in carbonate rock distribution areas ended as early as 20 Ma ago in South China, followed by humid and warm period characterized by summer monsoon[23,24]. Meanwhile,

Table 5 The thickness of carbonate rock dissolved to form 1m soil and the needed time for the five studied profiles

Location of profiles		Type of rock	M(%)	G_2/t·m^{-3}	N(%)	H/m	T/a
Central Guizhou	Pingba	dolomitite	84.40	2.843	0.625	78.861	788 610
North Guizhou	Xinpu	dolomitite	87.73	2.802	4.000	12.992	216 583
	Zhongzhuang	limestone	91.63	2.597	11.607	5.046	84 100
West Guizhou	Dafang	limestone	91.16	2.555	15.610	3.795	63 250
West Hunan	Jishou	limestone	91.16	2.309	38.810	1.689	28 150

The formula to calculate the thickness (H) of carbonate rock dissolved to form 1m relict soil is expressed as $H = (h \times M \times S_1 \times G_1)/(N \times S_2 \times G_2)$[22]. h stands for soil thickness, supposed to be 1 m; M for the total amount(%) of dissolution residue in soil, deduced from average values of the total chemical analysis of soil samples; S_1 for distribution area of the relict soil, supposed to be 1 km^2; G_1 for the density of soil, 1.66 t/m^3[13]; N for the total amount of dissolution residue of carbonate rock deduced from the leaching experiment, that for the Jishou profile deduced from XRD half-quantitative analysis; S_2 for the distribution area of the dissolved carbonate rock, supposed to be 1 km^2; G_2 for the density of carbonate rock(t/m^3), calculated from the proposition of calcite (2.72 t/m^3), dolomite (2.85 t/m^3) and dissolution residue(1.66 t/m^3) in carbonate rock. The formula to calculate the dissolution time(T) of carbonate rock needed to form 1 m soil is expressed as $T = H \times S_2 \times G_2/v$. v stands for carbonate rock dissolution rate, because of rain precipitation being the largest in central Guizhou. For the Pingba and the other profiles v is selected to be 0.1 or 0.06 mm/a[23]; the other symbols are the same as above.

Guizhou altiplano only underwent slow crust uplifting and no other great tectonic activity had happened since the end of Triassic. So, even if strong erosion existed in Guizhou karst area, it is possible to form several tens meters thick carbonate rock weathering soil profile in the advantageous relief and geomorphologic unit.

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