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ON CHEMICAL WEATHERING OF WEATHERING CRUST AT THE GREAT WALL STATION REGION, ANTARCTICA

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Abstract The chief aim of this study is to investigate the chemical weathering process of the weathering crust in Great Wall Station region of China (in Fildes Peninsula), Antarctica by the method of sedimentology.

CW, SW, GW, TW, WE weathering crusts developed on volcanic clastic rock, gray aptitic basalt with tuff or basaltic bedrock. On change of minerals, geochemical behaviors of elements, migration and enrichment regularities of elements, Correlation between element geochemical behaviors, change of weathering potential of rocks in chemical weathering process are studied by us.

We can see that the sequence fo weathering strengths of the abovementioned sections, from high to low, should reflected in TW, GW, CW and SWT and basical correspond with that calculated from the enrichment and differentiation indexes.

Key words Great Wall Station region, weathering crust, chemical weathering action, geochemical behaviors of elements, weathering potential.

Hyperegenic process, especially weathering, is characterized by an obvious regionality. A large amount of works have been carried out on the tropical and subtropical weathering, especially the chemical weathering, but there are very few research data about the chemical weathering in the frigid area such as Antarctica. Therefore, ones are always interested in the chemical weathering strength and its process in this frigid area of Antarctica. In weathering process of Antarctic rocks, migration, transformation, enrichment and other processes of materials are dependent on the climatic conditions and properties of elements and compounds. Compared with the tropical and subtropical weathering, it has not only the same laws but also its specific charcteristics.

The Fildes Peninsula on the southern King George Island, the largest island of South Shedland Islands, Antarctica, is an ideal area in which the chemical weathering in the frigid region of Antarctica can occur. Covering an area of about 35km2, the Fildes Peninsula is a hilly area at an elevation of less than 200m. The climate on the Peninsula belongs to a subantarctic oceanic type, with an annual average temperature of －2.1C

(1985—1990). The annual average precipitation is 634. 9 mm[*], mainly snowfall, with somewhat rainfall. Rainfall is distributed more equally and is slightly more in summer than in other seasons. In summer the ice and snow in this region almost entirely melts. Most of the region is covered with the paleogene volcanic rocks which include high—aluminium basalt, basaltic andesite, andesite, dacite and other volcanic lavas, as well as basaltic—andesitic volcanic agglomerate, volcanic breccia and other volcanic clastic rocks.

A Brief on Weathering Crust

1. CW fissure weathering crust

It is developed on volcanic clastic rock which constitutes a base of the second—step marine—deposition terrace south of the Great Wall Station. From the land surface down to 80cm depth, eight samples were taken at interval of 10cm. For the section there is no obvious change regularity from the upper to the lower in the contents of gravel, sand, silt and clay included. Silt—size content ranges from 7. 11% to 18. 89% and clay from 2. 30% to 11. 75%. The whole weathering crust is dominated by sand and gravel, up to 80% or more and hence this weathering crust belongs to a clastic type.

2. SWT weathering crust

It is developed in the base of the third—step marine terrace. Its parent rock is volcanic clastic rock which consists of light gray—green tuffaceous sand—stone and tuffaceous breccia, belonging to Fossil Formation of the Fossil Hill member. Its age is Eocene. For the section of weathering crust, from the surface down to 120 cm depth, six samples were taken according to lithological change. There is no distinct change in grain size. Silt content ranges from 6. 87% to 36. 59% and clay from 0. 99% to 8. 48%, belonging to clastic weathering crust [illegible].

3. GW weathering crust

It is developed on the base of the first—step terrace on the southern coast at elevation of 15 m. Gray aplitic basalt with tuff is its parent rock. The weathering crust is 80 cm thick and seven samples were taken. The characteristics of the weathering crust is that it is dominated by fine grained material without gravel. It consists of 70% of sand grain—size, varing silt content, from 0 to 30%, and varing clay grain—size, from 0 to 24%. Similarly, there is no sequential differentiation of grain size.

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[*] From the data(1985—1990)of Polar Meteorological Division, State Meteorological Bureau

4. TW weathering crust

It is developed on the bedrock at an astronomical observation site near the Great Wall Station. The bedrock constitutes the fourth—step sea terace and the parent rock of the weathering crust is the Fossil Hill Formation. The upper part of the weathering crust consists of fine sand and medium—coarse sand and the lower part is composed of medium—fine sand, silt coarse sand.

5. WE weathering crust

It is developed on basaltic bedrock at a seismological station site. Three samples were taken down to depth of 50cm.

Change of Minerals in Chemical Weathering Process

When chemical weathering takes place on rock, mineral components also change. On Antarctica, the continent considered to be a chemical quiet area, there is also destruction and reduction of the primary minerals and formation of hypergenic ones.

1. Change of rock—forming minerals

The main rock — forming minerals more sensitive to chemical weathering are hornblende, augite and feldspar. For all of the samples taken from the five weathering crust sections near the Great Wall Station the clastic mineral analysis is carefully carried out. Occurrence of each mineral in diffeerent sites in the weathering crusts is mapped in Fig. 1.

In Fig. 1, augite is found in every sample from the upper to the lower parts of both GW and TW weathering crust sections. The surface or part of the augite has suffered weathering and changed. It can be individually classified into one group called the weathered augites which mainly occurs in the upper part of the weathering crust. In all of the samples from TW section hornblende is found, but it is absent in two samples of the upper GW section, showing that in this region hornblende is much easier to suffer chemical weathering than augites. This is not coincident with the observed result of Goldich on Morton granite weathering crust (Geological Department of Nanjing University, 1961) and also is contrary to the stablity series of minerals in weathering zone usually considered. Curtis suggested that the relative stability of minerals was changeable under different weathering condidtions in different geochemical environments (Chalytski, 1962). It depends on agent, product and medium condition of mineral reaction. Therefore, The phenomenon that augite is more stable than hornblende in the

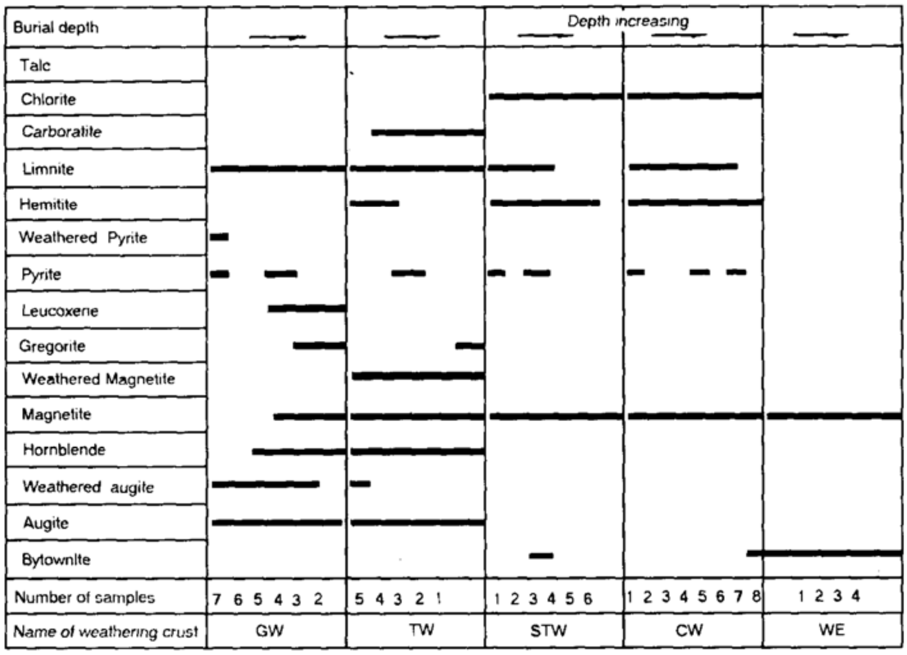


Fig. 1. Distribution of clastic minerals in weathering crust sections.

chemical weathering may be a special case in such frigid region of Antarctica. It may be related to the peculiar hypergenic geochemical environment and processes in this region.

In WE weathering crust bytownite is better preserved, indicating that basic anothose can be better preserved in the frost region, where the water activity is weaker and Ca is not to be leached.

In general, in the weathering crust of this region reck —forming minerals are more preserved because of the weaker weathering on the one hand, the special geochemical environment results in change of relative stability sequence of minerals on the other hand.

2. *Change of heavy minerals*

Fig. 2 shows that magnetite is most extensively distributed in the weathering crusts, but it is absent in the upper part of GW weathering crust. In TW weathering crust the weathered magnetite with an oxidized edge can be found yet, showing that magnetite is unstable in the weathering process of this region. It transforms into ferric iron oxide and even disappears. In order to better understand the change of magnetite in weathering process, percent contents of the fresh and weathered magnetite, total magnetite amount, hematite and limonite in different samples of SWT and TW weathering crusts are listed in Table 1.

It can be seen in Table 1 that weathering of magnetite is by stages. In TW section, the total amount of magnetite is always higher, although a large amount of hematite bearing magnetite nucleus can be found in the lower part of the section, and until the total amount of magnetite suddenly decreases in the uppermost sample. Similar situation also occurs in SWT section. The content of magnetite is always higher, only in two samples close to the upper part the content of magnetite becomes very little. Fig. 2, 3 and 4 are constructed on the basis of the data in Table 1.

Table 1. Contents of different iron oxide minerals in weathering crusts.

Weathering crust section	Sample number	Fresh magnetite	Weatherd magnetite	Total amount of magnetite	Hematite	Limonite	Hematite + limonite	Burial depth
SWT	1			2	0.1	4	4.1	Depth increasing ↓
	2			5	0.1	0	0.1	
	3			55	0.1	0.1	0.2	
	4			40	0	0.1	0.1	
	5			60	0	0.1	0.1	
	6			78	0	0	0	
TW	5	7.09	2.95	10.04	50.59	1.97	52.56	Depth increasing ↓
	4	8.59	48.42	57.01	2.26	9.95	12.21	
	3	15.70	43.48	59.18	7.49	0	7.49	
	2	13.65	58.16	71.81	7.27	0	7.27	
	1	12.36	52.27	64.63	6.29	0	6.29	

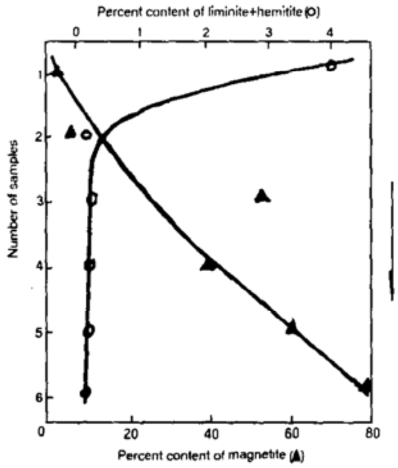


Fig. 2. Change of iron oxide in SWT weathering crust section.

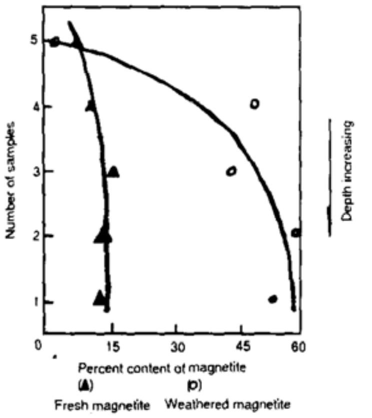


Fig. 3. Chang of magnetite in TW weathering crust section.

In the figures the content of magnetite decreases with shallowing of burial depth, but there is a distinct turning point exists, that is to say, the content of magnetite suddenly decreases after the weathring crust develops to a certain degree. The above-mentioned information shows that there are two weathering stages for magnetite. The lower part of the weathering crust can be called metastable zone of magnetite in which magnetite is gradually metasomated by hematite or limonite, forming a brown-red ferric oxide outer casting. In the upper part of the weathering crust the weathering has developed into the second stage, called unstable zone of magnetite, and then magnetite disappears largely and is transformed into other minerals.

Observation on polariscope indicates that ilmenite will be transformed into leucoxene in weathering process and it is not as stable as magnetite (Fig. 1). In GW and TW sections ilmenite disappears earlier than magnetite. And leucoxene together with magnetite disappears in GW section. In the whole weathering crust pyrite is in a metastable state and occurs intermittently in every part of each section, and only in the top of GW section the weathered pyrite can be found, showing that in polar area pyrite is more stable than magnetite in weathering process.

3. *Authigenic mineral formation*

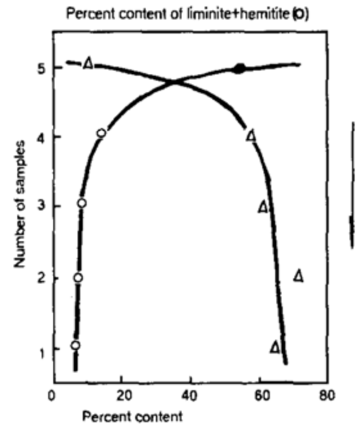
The authigenic minerals formed during weathering process in this area are hematite, limonite, chlorite, carbonate and talc. It can be seen in Figs 2,4. that the total amount of hematite and limonite increases with shallowing of burial depth (i. e. increasing weathering). And similar to magnetite, they are characterized by stages. The contents of hemitite and limonite suddenly increase near the upper weathering crust, with a distinct turing point, indicating that formation of ferric iron oxide minerals is characterized by zonation. Observation shows that magnetite is usually coated with hematite and limonite, indication that the latter is transformed from the former. However, what is the parent mineral of the coat and other shape of limonite? Correlation analysis has been made for the mineral contents of TW weathering crust and the result is listed in Table 2.

Table 2. Correlation matrix of different ferric oxides in TW weathering crust.

Fresh magntite	1					
Weathered magnetite	0. 648	1				
Total amount of magnetite	0. 729	0. 994	1			
limonite	−0. 611	−0. 960	−0. 925	1		
Hematite	−0. 607	−0. 005	−0. 093	−0. 156	1	
Limonite+hematite	−0. 749	−0. 971	−0. 983	0. 977	0. 059	1
	Fresh magnetite	Weathered magnetite	Total amount of magnetite	Limonite	Hematite	Limonite +hematite

In Table 2 the sum of limonite and hematite (i. e. total amount of ferric oxide minerals) is in a good negative correlation with total amount of magnetite (−0. 983), showing that ferric oxide minerals are mainly transformed from magnetite, in other words, ferric oxide increases with decrease of magnetite. Hematite is only correlated to fresh magnetite to some degree, that is to say, magnetite transformed into hematite firstly. Limonite is in a good negative correlation with the weathered magnetite, but in a little correlation with the fresh magntite, indicating that limonite is mainly transformed from the weathered magnetite. Therefore, it can be considered that magnetite is firstly oxidated to form hematite. And some can not be transformed theroughly, showing in a form of the weathered fresh magnetite which is further hydrated to form limonite. This coincides with the rsult of observation under polariscope.

Chlorite occurs in all sampls of SWT and CW sections (Fig. 5) and its content is plotted in Fig. 5.



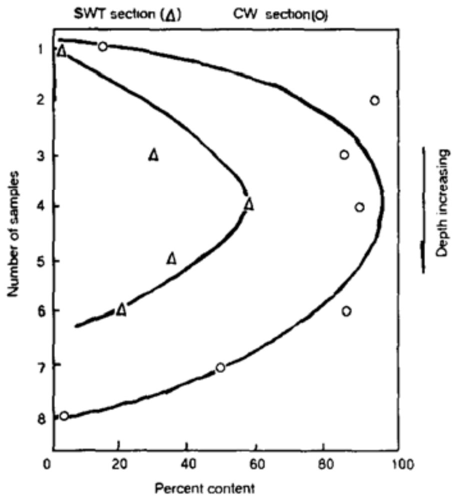


Fig. 4. Change of iron oxide in TW weathering crust section.
△magnetite ○ limonite+hematite

Fig. 5. Changee of chlorite content in SWT and CW sections.

In Fig. 5 we can see that chlorite content increases firstly and then decreases with strengthening of weathering from the upper section down to the lower. Chlorite is an authigenic mineral in weathering process. Observation under polariscope indicates that it is mainly transformed from volcanic glass, hornblende, etc. As chlorite contains ferric iron, when weathering develops to a certain degree, ferrous iron is transformed into ferric iron because of oxidization, which leads to destruction and transformation of chlorite to other clay minerals. Therefore, in the lower part of the weathering crust, in the early weathering process chlorite gradually forms and increases. And in the upper part, when weathering develops to a certain degree chlorite decreases because it is destroyed.

Carbonate occurs in the middle—lower part of TW section, and it mainly fills in micro—fissures, forming veins as observed under polariscope. This kind of carbonate is precipitated mainly because the upper materials are leached to the lower through weathering. Zonation also occurs in precipitation of carbonate and coincides with that of magnetite. Carbonate only occurs in the metastable zone of magnetite in the lower weathering crust rather than in the unstable zone of magnetite in the upper weathering crust, which is in correspondence with the general law of weathering crust zonation. The above—mentioned unstable zone of magnetite can be compared with layer A (the leached horizon) of the weathering crust and the zone is characterized by loss of materials. And the metastable zone of magnetite, corresponding layer B (the precipitated layer), is dominated by accumulation. Talc is also found in the top of GW weathering cryst and may be transformed from Fe—Mg minerals.

Geochemical Behaviors of Elements in Chemical Weathering Process

In chemical weathering process different elements should be migrated and redistributed, and some are more active and others are more stable. Geochemical behaviors of elements in weathering process depend also on different parent rocks and environments. There is no exception in Antarctic region.

1. Migration and enrichment regularities of elements in chemical weathering process

(1) Enrichment coefficient and its represented migration and enrichment trend of the elements in differnet samples.

In chemical weathering process the relative percent content of each element largely changes because of leaching of some materials. Assuming Ti content is constant under the condition with an equal volume to the parent rock in weathering process, the enrichment coefficient K can be given:

$$K_i = \left(\frac{C_i}{G_i}\right)_{relict} / \left(\frac{C_i}{G_i}\right)_{rock}$$

where C_i and G_i are the contents of elements i and T_i respectively, in the relict of weathering crust and the parent rock. The enrichment coefficient is larger than 1, showing that the element is enriched in weathering process; if it is less than 1, showing that the element is migrated in weathering process. The enrichment coefficients of elements in the different weatheing crust sections are listed in Table 3. In calculation, the bedrock samples from the lowest part of the weathering crust are regarded as the samples of the parent rocks.

In Table 3 we can see that Ca is an element with a heavy loss, indicating that it is strongly migrated in weathering process, with a very high activity. As a result, under the frigid polar climate Ca is an element with a maximum migration capability in chemical weathering process, which coincides with the research results of Zhao Junlin, etc (1989) on Antarctic soil. Similar to Ca, Sr is a very active element since Sr often occurs in isomorph with Ca. In addition, Na, U, Ta and Sb are also the elements liable to be migrated.

With a higher solubility, Na is an element very easy to be migrated under hypergenic condition, as it is in the tropical area. U is liable to form a complex anion with organic acid under hypergenic condition, its solubility increases greatly, with a strong migration capability. It is possible that the organic acid secreted by the lower plants such as lichen facilitates U migration.

In Table 3, the elements whose enrichment coefficients are around 1 are Al, Ba, Mg, Mn, Si, V, and Zn. Of them Al and Si are the elements difficult to be migrated in weathering process and they are more stable relative to the parent rocks. Ba solubility is very low under the low temperature and it is also an element difficult to be migrated.

Table 3. Enrichment coefficients of elements in different crust sections.

Name of weathering crust	samples number	Silt−size(<0.076mm)elements																							
		Al	As	Ba	Br	Ca	CO	Cr	Cs	Fe	Hf	K	Mg	Mn	Na	Rb	Sb	Sc	Si	Sr	Ta	Th	U	V	Zn
GW	2	0.70	3.05	1.19		0.36	1.39	0.56	1.20	0.56	0.86	1.27	0.56	0.44	0.38	1.24		1.19	0.77	0.00	0.91	0.80	1.09	0.46	1.52
	3	0.81	3.77	1.15		1.05	2.75	0.71	0.93	1.10	0.74	1.36	0.96	1.18	0.29	1.22		1.79	0.47	0.36	0.60	0.56	0.83	0.70	0.82
	4	0.99	10.33	1.24		0.67	2.55	1.11	5.13	0.92	0.66	1.61	0.00	0.74	0.28	1.58		1.83	1.03	0.58	0.19	0.50	0.63	0.75	1.35
	5	2.11	4.42	2.56		1.22	6.75	2.40	3.79	2.46	0.48	3.44	1.75	2.61	1.40	2.75		4.36	2.08	0.88	1.01	0.20	1.70	1.79	3.04
	6	2.55	4.40	3.02		2.00	6.66	2.32	3.50	2.35	2.97	3.85	1.54	2.94	1.47	3.45		4.93	1.06	1.22	1.29	0.25	1.21	1.91	1.38
	7	0.88	5.53	1.17		0.35	4.27	1.02	1.33	1.66	1.00	0.86	0.00	2.44	0.73	1.00		2.08	0.69	0.56	0.65	0.31	0.52	0.58	1.47
SWT	5	0.76	0.60	0.95	0.74	0.24	1.83	2.20	1.12	1.31	1.34	0.74	1.48	0.65	0.53	0.92	0.74	1.47		0.91		1.71		1.02	1.41
	4	1.11	0.96	1.76	0.00	0.38	2.02	2.07	4.59	1.55	1.35	1.05	2.17	1.58	0.79	2.81	0.40	0.21		0.75		1.52		1.19	0.00
	3	0.31	1.24	0.67	8.42	0.40	0.88	2.50	0.65	1.10	1.72	0.39	0.91	0.74	0.39	1.09	0.00	1.16		0.34		1.21		0.59	0.00
	2	0.26	1.16	0.50	4.09	0.47	0.83	2.44	0.57	1.05	2.12	0.00	0.77	0.76	0.40	0.56	0.57	0.93		0.28		1.47		0.60	0.74
	1	0.24	0.60	0.31	3.66	0.51	0.84	1.43	0.36	1.06	1.90	0.71	0.77	0.56	0.47	0.52	0.20	0.84		0.32		1.43		0.62	0.75
TW	2	1.11	1.00	0.68	0.48	0.93	1.00	1.00	0.45	0.97	0.92	0.59		0.87	0.94	0.61		0.95	0.53	1.43		1.07		1.02	0.93
	3	1.02	0.89	0.66	4.18	0.72	1.01	1.12	0.73	0.94	0.68	1.03		1.54	0.96	0.45		1.00	0.95	0.52		0.95		0.95	0.84
	4	1.47	1.17	1.31	3.32	0.58	1.62	1.38	0.71	1.34	1.16	1.17		6.29	1.16	0.54		1.44	1.39	0.00		1.40		1.21	1.46
	5	0.95	0.99	0.52	1.60	0.38	0.74	1.03	0.54	0.88	0.89	0.54		0.74	0.85	0.41		0.84	0.00	0.00		0.83		0.88	0.55
CW	7	0.94	0.62	0.28	2.77		0.65	1.24	1.09	0.68	0.86	0.63	0.77	0.50	0.94		0.89	0.84		0.63		0.79	0.55	0.86	
	6	1.28	0.82	0.58	1.24		1.08	0.88	2.04	0.79	0.98	0.91	0.66	0.61	1.05		2.02	0.96		1.14		0.95	0.00	0.92	
	5	1.51	0.80	0.63	0.41		1.11	1.07	3.25	0.69	0.77	0.89	0.79	0.60	1.02		0.00	1.02		0.63		0.87	0.58	0.99	
	4	0.99	1.04	1.10	1.05		1.26	1.23	1.45	0.99	0.92	1.15	1.08	1.07	0.81		0.80	1.24		0.61		0.99	0.49	1.11	
	3	0.71	1.198	0.73	1.50		1.12	0.82	0.68	1.03	0.98	0.00	0.56	1.84	0.74		2.00	1.31		0.53		0.68	0.60	1.08	
	2	0.62	0.55	0.59	1.23		0.58	0.65	0.45	0.80	0.91	0.00	0.54	0.58	0.58		0.79	0.98		0.00		0.71	0.00	0.97	
	1	0.62	0.62	0.52	0.82		0.48	0.96	0.65	0.77	0.88	0.66	0.58	0.62	0.88		0.00	1.25		0.68		0.49	0.47	0.78	
	Average	1.00	2.08	1.01	5.47	0.92	1.88	1.37	1.60	1.15	1.14	1.04	0.88	1.36	0.78	1.28	0.70	1.48	0.90	0.56	0.78	0.89	0.76	0.95	1.08
		Clay−size (<0.001mm) elements																							
GW	2	0.96	1.73	1.73		0.01	0.57	0.43	1.71	0.40	1.12	1.58	0.31	0.05	0.30	1.86		1.54	0.60		0.89	0.80	0.91	1.43	
	3	1.21	4.13	1.61		0.00	1.67	0.84	1.83	0.94	0.99	1.67	0.68	0.21	0.30	2.03		2.36	0.44		0.64	0.73	0.81	1.13	
	4	1.55	4.92	1.86		0.09	0.90	1.54	14.88	0.56	0.91	2.39	0.94	0.27	0.21	3.48		2.38	0.77		0.67	0.79	1.08	1.37	
	5	1.20	1.00	1.85		0.04	1.87	1.89	2.90	0.98	0.51	2.22	1.00	0.35	0.32	2.71		2.66	1.01		0.63	0.36	0.00	0.75	
	6	1.19	1.35	2.89		0.07	2.73	2.51	4.15	1.30	0.72	3.17	2.29	0.50	0.42	3.11		3.48	0.52		0.00	0.38	0.00	0.79	
	7	1.22	5.58	2.95		0.12	3.03	1.23	4.42	1.80	1.74	3.12	2.37	0.58	0.54	3.72		3.81	1.26		1.30	1.29	2.39	0.86	
SWT	6	1.02	1.12	0.69	2.17	0.04	1.27	2.51	1.16	2.49	3.96	0.74	2.80	0.28	0.41	1.72	0.60	2.03		0.50		8.02		1.37	
	5	0.72	0.91	1.12	0.00	0.06	2.90	7.56	1.63	1.69	2.48	0.45	2.48	0.39	0.37	1.27	'0.25	2.51		0.50		4.44		1.17	
	4	1.17	1.24	1.86	0.46	0.06	1.89	3.17	3.70	1.15	1.97	1.32	2.29	0.20	0.61	2.45	0.83	2.42		0.94		2.87		1.30	
	3	0.44	2.39	0.70	1.48	0.09	0.95	2.10	1.30	1.02	2.64	0.72	1.13	0.25	0.24	1.95	0.27	1.28		0.19		3.53		0.71	
	2	0.22	2.53	0.44	9.70	0.14	0.59	1.65	0.84	0.97	3.01	0.32	0.67	0.25	0.17	1.13	0.38	1.15		0.00		3.56		0.50	
	1	0.29	2.17	0.87	35.82	0.08	0.61	1.99	0.96	0.98	3.45	0.48	0.63	0.27	0.32	1.22	0.58	1.65		0.21		1.64		0.71	
TW	1	1.58	2.07	1.05	0.21	0.05	0.96	1.71	2.79	1.48	1.40	1.88		0.20	0.45	1.52		2.20	2.02			2.82		1.44	
	2	1.40	2.01	0.56	0.25	0.06	0.91	1.25	2.22	1.33	1.55	1.83		0.26	0.35	2.04		1.88	1.66			2.80		1.67	
	3	1.37	1.62	0.70	0.33	0.08	0.80	1.25	2.10	1.15	1.18	1.49		0.25	0.31	1.12		1.66	1.01			3.07		2.14	
	4	1.24	1.40	0.53	0.31	0.06	0.64	0.82	1.91	1.04	1.14	1.21		0.24	0.29	1.44		1.62	0.84			1.94		0.99	
	5	1.34	1.69	0.66	1.29	0.05	0.66	0.98	1.87	1.15	1.71	1.44		0.25	0.42	0.92		2.32	1.16			3.85		1.06	
CW	2	1.77	1.65	1.66	0.00		1.05	2.27	2.29	1.78	3.78	1.55	1.10	0.14	0.75			2.60				4.07		2.66	
	1	0.91	1.20	0.42	0.59		0.73	0.80	0.98	1.03	1.96	0.55	0.83	0.10	0.52			1.48				2.08		1.33	
WE	3	0.96	0.28	0.97	1.87	0.43	0.96	1.44	1.56	1.09	2.06	1.41		0.53	0.90	0.84		0.63		0.53		4.25		0.47	0.76
	2	1.82	0.87	2.04	1.74	0.40	4.42	5.06	3.57	4.13	2.66	2.53		1.21	0.94	2.21		1.34		0.00		6.03		0.75	2.18
	1	1.13	3.25	3.21	8.42	0.20	4.84	5.67	6.23	6.06	7.82	5.08		0.62	2.73	4.04		3.68		2.46		17.39		0.83	0.00
Average values		1.12	2.05	1.38	4.04	0.11	1.59	2.21	2.95	1.57	2.22	1.69	1.39	0.34	0.54	2.04	0.49	2.13	1.03	0.59	0.69	3.49	0.87	1.16	0.98
Total average values		1.06	2.07	1.19	4.75	0.52	1.74	1.79	2.28	1.35	1.68	1.36	1.11	0.85	0.66	1.71	[illegible]	1.50	0.96	0.57	0.73	2.19	0.73	[illegible]	[illegible]

Under oxidative condtion in hypergenic zone Mn is easy to form a high—valent oxide and also difficult to be migrated. In the tropical weathering process Mg belongs to an element easy to be migrated, but in the frigid zone it is preserved as it enters into the lattice of chlorite. The weak migration of V and Zn under the polar conditions is also supported by the research results of polar pedoliogy (Zhao *et. al.*, 1989), but its reason is not clear yet.

K, Rb, Fe, Co, Cr, Sc, Hf, Th and As are the more enriched elements in the weathering crust of polar area, with a certain migration. They are leached from the upper weathering crust and deposited in the middle weathering crust. K and Rb are mainly absorbed in clay minerals. Fe is enriched through forming iron oxides of hematite, limonite, etc. As isomorph, the transitional group of elements such as Co, Cr and Sc are enriched with Fe. In the weathering process of polar area Br, Cs, Tn and As are strongly enriched elements. For example, Br average enrichment coefficient is as high as 4.75. In the tropical weathering crust Br content increases with increasing organic material content. So, lift activity of a plant is the main reason for Br enrichment in weathering crust. Study on the sediments from the Xihu lake, Antarctica, also shows that Br hypergenic geochemical behavior is been affected by organic material (Xie *et al.*, 1991). Th and Cs are strongly enriched clay material and mainly absorbed in the interstitial lattices. Since there is a certain soil formaiton in polar weathering process, Th and Cs are also enriched and is consistent with the research result of the sediments from the Xihu Lake, Antarctica.

Table 3 reflects not only the enrichment degree of each element in weathering process, but also the varying enrichment amounts in different parts of the weathering crust section. Change in enrichment coefficients of some typical elements in different weathering crust sections is shown in Fig. 6, indicating that element migration and enrichment features are not completely identical in different weathering crusts and reflecting effect of different landforms and lithological characters on chemical weathering.

In Fig. 6 we can see that there is a larger enrichment segment in the upper part of GW section for most elements in silt material of the section. Al, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, Rb, Sc, Sr and V, for instance, have this feature. However, the enrichment segment of Si, As and Cs is somewhat lower than that of the elements mentioned above, showing that there are only the precipitated layer (i. e. layer B) and the parent layer (layer C) in GW weathering crust. At the same time, as the enrichment coefficients of As and Cs are higher, both elements are enriched further down to the lower weathering crust. In clay—size material from GW section the enrichment segment of elements is not distinct enough, and only As and Cs are more enriched at the locality corresponding to the silty material mentioned above. Cr, K, Mg and other elements are

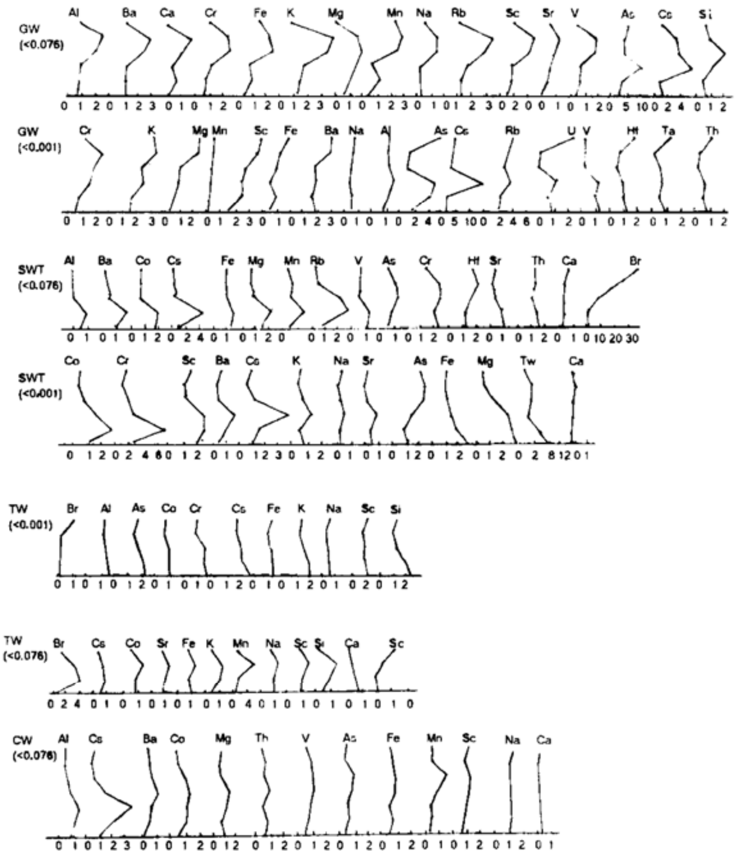


Fig. 6. Change in element enrichment coefficients in different sections of weathering crust.

enriched to a certain degree in the upper section. Mn, Na, Al, Hf, Ta and Th change slightly in the whole section, with stable contents, indicating that their contents in clay are not effected by weathering level. From the lower to the upper the contents of Sc, Fe, Ba and Rb increase slightly, showing that these elements trend to be enriched in clay in weathering process. Only U has larger lost in the upper section, showing its migration in this weathering process.

Slightly different from GW section, Al, Ba, Co, Cs, Fe, Mg, Mn, Rb and V in silt—size material of SWT section are more enriched in the lower section, reflecting the features of precipitating layer. And the enrichment part of As, Cr and Hf is slightly higher than that of the above—mentioned elements. In the upperpart of SWT section the enrichment coefficients for most elements are less than 1, in a leaching state. Therefore, all the layers of a standard weathering crust have been developed in this section, that is the leached layer in the uppermost (layer A), the precipitating layer in the middle part (layer B) and the parent material (layer C) in the lower part. In the whole section the enrichment coefficients of Ca and Sr are very low , tending to decrease upwards, reflecting that they are in a strongly leaching state. Just contrary to this, the more close to the land surface, the more strong enrichment of Br is, which resulted from life activities of some lower plants in polar area. In clay—size material of SWT section the enrichment laws of Co, Cr Sc, Ba, Cs and K are quite similar to that of these elements in silt—size material, all they are somewhat enriched in the lower section. Still, Na, Ca and Sc are strongly washed away and their enrichment coefficients are very low in the upper part of the whole section. As enrichment part is slightly higher, and for Fe, Mg and Th, the lower the section the higher the enrichment coefficients are.

Similar to GW section, in silt — size material from TW section the enrichment segment of CS, Co, Sr, Fe, K, Mn, Na, Sc and Si occurs in the upper section. The more close to the upper part of section, the smaller the Ca enrichment coefficient is, and the larger the leaching degree is. But Sr is contrary to this, still in a loss state. Br is somewhat enriched in the middle and lower parts of TW section. In clay—size material most of the elements remain in an unchangeable state. Ba is absorbed by clay in the top, with increase content. Si is somewhat leached in the upper part. the above—mentioned information shows that TW section is also in a stage of formation of precipitating layer, loam bed. In silt—size material of TW section, the enrichment coefficients of the most elements change slightly in the section, and only Al and Cs are more enriched in the lower section. Mn enrichment segment is slightly higher than that of Al and Cs.

(2) Redistribution of elements in clay — size and silt — size material during weathering process.

In Table 3 the average values of the element enrichment coefficients for different sections and in total silt—size and clay—size materials are listed. The total average values of the element enrichment coefficients in all the samples are also listed in Table 3. From the several quotas mentioned above, as the total average enrichment coefficients of some group of elements are larger than 1 (i.e. the element enrichment behavior in weathering process), the average enrichment coefficients of these elements in clay—size material are mostly larger than that in silt—size material. The examples are Ba, Cr, Cs, Fe, Hf, K, Mg, Rb, Sc, Th and V, and only Br is contrary. It shows that most of enriched elements further tend to be enriched in clay—size material. Just contrary to this, Br shows a trend to be enriched in silt—size material.

When the total average enrichment coefficients of some group of elements are less than 1 (i.e. element migration in weathering process), Their enrichment coefficients in clay—size material are mostly less than that in silt—size material, such as Ca, Mn, Na, Sb and other elements, but only V is exceptional. It indicates that soil formation occurs in Antarctic weathering process. During the process of clay mineral formation migrating elements are leached, which results in their lower enrichment coefficients in clay than that in silt—size material. In addition, the total average enrichment coefficients of Al, As, Co, Si, Sr, Ta and Zn are very close to their average enrichment coefficients in silt

—size and clay—size materails, showing that whether enrichment or migration occurs, they are not redistributed between silt—size and clay—size materials.

To examine enrichment or loss degree of the elements in silt—size and clay—size materials, a new concept, the enrichment—differentiation coefficient can be defined as:

$$R_i = \frac{M_i - N_i}{M_i + N_i} \times 10$$

where M_i represents the average enrichment coefficient of element in clay—size material and N_i is that in silt—size material. The enrichment differentiation coefficients calculated are listed in Table 4 (R absolute value is listed in the columns of GW, SWT TW and CW sections in the table).

The average enrichment—differentiation coefficients for each section in Table 4 show the differentiation degree of different elements between clay—size and silt—size materials in weathering process, and these figures are plotted in Fig. 7.

Table 4. Enrichment—differentiation coefficients for the weathering crust sections.

W.C. \ EL.	Al	As	Ba	Br	Ca	Co	Cr	Cs
TW	1.98	5.42	1.21	13.33	16.62	3.19	0.60	11.25
CW	3.41	5.54	4.91	12.54		0.11	4.44	1.79
GW	0.94	5.09	2.22		17.6	7.71	0.43	6.14
SWT	1.69	7.24	1.23	5.00	13.33	0.68	3.89	0.92
Ave. Val.	1.13	−0.15	3.10	−3.01	−15.73	−1.67	4.69	5.93

W.C. \ EL.	Fe	Hf	K	Mg	Mn	Na	Rb	Sb
TW	1.77	4.24	6.17		16.31	9.25	9.53	
CW	5.29	10.45	5.30	3.10	14.95	2.93		
GW	4.06	1.13	1.31	4.54	13.59	7.39	4.05	
SWT	1.31	5.30	1.44	3.11	10.44	3.91	3.14	2.53
Ave. Val.	3.17	6.43	4.76	4.49	−12.00	−3.64	4.58	−3.53

W.C. \ EL.	Sc	Si	Sr	Ta	Th	U	V	Zn
TW	5.96	10.28			9.29		3.64	
CW	6.07				11.92		7.03	
GW	0.04	2.67		1.22	4.96	1.39	0.29	
SWT	6.67		2.86		9.29		1.82	
Ave. Val.	3.60	1.35	0.52	−1.22	11.87	2.60	1.99	−0.97

In Fig. 7 we can see that the relative loss of elements in clay material, according to their loss degree and decreasing amount, are successively Ca, Mn, Na, Sb, Br, Co, Ta, Zn, As. Especially Ca and Mn, they have a very high loss. All of these elements are uneasy to be absorbed by clay material, but easy to be leached. In clay material the relatively enriched elements, according to their enrichment degree and decreasing amount, are successively Sr, Al, Si, V, U, Ba, Fe, Sc, Mg, Rb, Cr, K, Cs, Hf and Th, especially Th, its enrichment degree is quite high. These are the elements easy to be absorbed by clay minerals or easy to be preserved as particles in minerals.

The stronger the weathering degree is, the more intensive the soil formation is, It leads to the enlarged differentiation of different elements in clay—size and silt—size materials. Thus, under this premise it can be considered that the enrichment—differentiation coefficients can represent a weathering degree. Statistics of R absolute values in different weathering crusts listed in Table 4 was made in a range from 0.04 to

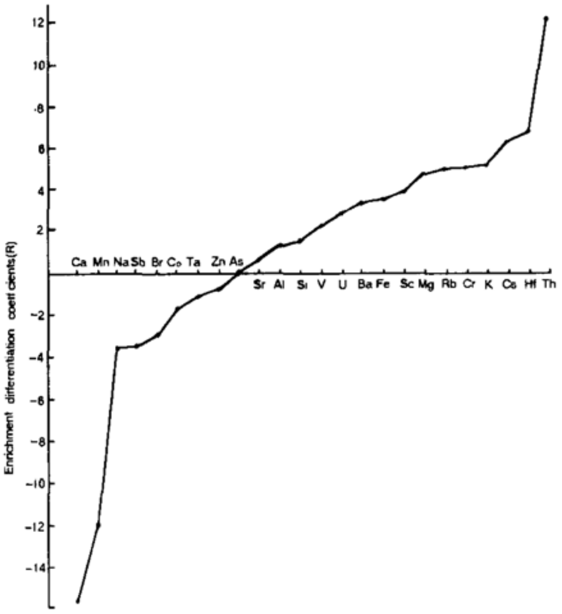


Fig. 7. Differentiation of each element between silt-size and clay-size materials in weathering process.

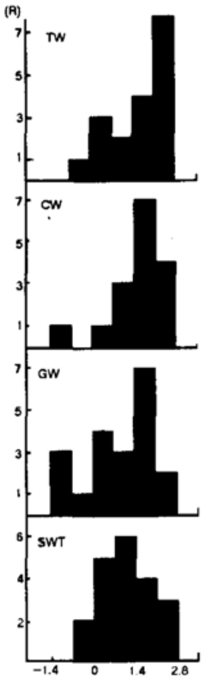


Fig. 8. Histograms of R absolute values in different weathering crust sections.

17. 6 by taking logrithm 0. 7 as an interval. And histograms of R absolute values for different sections can be constructed (Fig. 8.). In Fig. 8 we can see that R absolute values for different sections are basically coincident with their lognormal distribution. It also reflects the different weathering degrees of every weathering crust section. The peak value of R value distribution for TW weathering crust ranges from 2. 1 to 2. 8 with peak shape to right. Thus it belongs to a section with a relatively maximum weathering degree. The peak values of R value distribution for both CW and GW sections range from 1. 4 to 2. 1 less than that for TW. The peak shape for CW tends to right, but that for GW tends to left. Therefore, it is considered that the weathering degree is stronger than that of GW. The major peak value of R value distribution for SWT ranges from 0. 7 to 1. 4, less than the corresponding values several weathering crust sections mentioned above. It can be considered to be a section with a relatively weakest weathering degree. The weathering degrees of four weathering crust sections studied on Antarctica, in reducing order are successively TW, CW, GW and SWT.

2. *Correlation between element geochemical behaviors in chemical weathering process*

To examine correlation between elements in the weathering crust can lead to distinguish migration and association laws of elements in weathering process under polar condition.

The correlation matrix can be obtained by using the varying element contents in the different grain-size materials of the weathering crust. The results are listed in Table 5. In the Table the critical value of correlation coefficients is 0. 429 under a condition of 0. 01 confidence. Because of the samples uncompletely determined the correlation coefficients of several elements such as Zn, U, Ta, Si, Ce, etc. are singly listed in Table 6. In the Table the critical values of correlation coefficients of each element with 0. 01 confidence are listed. On the basis of the correlation coefficients by significance examination the elements can be roughly divided into four assemglages. The first one is dominated by Fe, Co and Mg, with a distinct corrlelation coefficient between them, that is to say, in the weathering crust sections their geochemical behaviors are similar. The related to this assemblage are As and Mn. It can be considered that they mainly occur as Fe minerals or Fe-Mg minerals. The second assemblage is characterized by K, Rb, Ba, Hf, Th and Zn. Except bad correlation between K, Th, Zn and Hf, There is a distince correlaiotn between other elements The elements more related to this assemblage are still Ta and V. For the elements of this assemblage they mainly occur as interlayer absorbate in clay minerals. It is intersting that there exists an obvious negative correlation between the elements of this assemblage and that (Fe, Co, etc.) of the first assemblage. On the one hand, it inherits from the parent rock since Fe, Co, Mg, etc. are the sideropohile elements which are mainly stored in Fe-Mg minerals. and Ba, Hf, K, Rb, Th, Zn and other elements with a big ion radius are the lithiophile ones which are mainly stored in the light-colored minerals. So the elements in these two assemblages are in the different occurrence states. On the other hand, in the hypergenic weathering process the geochemincal behaviores of these two element assemblages are different. The elements of the first assemblage tend to be accumulated in iron oxide and that of the second assemblage in clay minerals. When Fe — Mg minerals are more in the parent rock, weathering develops towards iron oxide formation, and when the light — colored minerals are more in the parent rock, weathering develops towards formation of clay minerals. Therefore, it causes the negative correlation of the above — mentioned two element assemblages in weathering process. The third assemblage consists of Sc, Ti and V, and Al is closely related to this assemblage. As mentioned in the previous paragraph, the elements of this assemblage changeless in weathering process, belonging to a group of stable elements. The fourth assemblage is composed of Na, Sr and Br which are the more active elements, with a larger migrating capability in the weathering crust.

The correlation coefficient matrices of different elements in silt — size and clay — size materials of each weathering crust section are separately calculated, as shown in Tables 5

Table 5. A correlation matrix of the elements in weathering crust sections.

	Al	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	Mg	Mn	Na	Rb	Sc	Sr	Th	V	Ti
Al	1.000																			
As	−0.056	1.000																		
Ba	0.226	−0.401	1.000																	
Br	−0.134	0.091	−0.181	1.000																
Ca	−0.156	0.015	−0.211	0.115	1.000															
Co	−0.117	0.472	−0.539	0.031	0.133	1.000														
Cr	−0.146	−0.092	0.276	0.014	−0.229	0.106	1.000													
Cs	0.416	0.142	0.119	−0.113	−0.196	−0.038	0.086	1.000												
Fe	−0.316	0.634	−0.560	0.270	−0.092	0.653	0.144	−0.282	1.000											
Hf	0.046	0.045	0.611	0.096	−0.227	−0.429	0.030	−0.026	−0.126	1.000										
K	0.244	−0.442	0.911	−0.173	−0.235	−0.672	0.240	0.170	−0.627	0.522	1.000									
Mg	0.213	0.356	−0.407	0.042	−0.030	0.509	0.058	0.164	0.484	−0.254	−0.418	1.000								
Mn	−0.070	0.427	−0.214	0.051	0.291	0.662	−0.090	−0.102	0.396	−0.239	−0.385	0.119	1.000							
Na	0.131	−0.146	−0.224	0.525	0.367	0.168	−0.212	−0.286	0.070	−0.181	−0.291	−0.066	0.304	1.000						
Rb	0.207	−0.413	0.886	−0.182	−0.299	−0.701	0.271	0.252	−0.604	0.534	0.938	−0.414	−0.428	−0.388	1.000					
Sc	0.244	0.563	0.170	0.150	−0.321	0.075	0.326	0.082	0.393	0.367	0.141	0.278	0.099	−0.202	0.134	1.000				
Sr	0.247	−0.198	−0.196	0.177	0.186	0.178	−0.207	−0.023	−0.140	−0.342	−0.202	0.153	0.132	0.608	−0.285	−0.185	1.000			
Th	0.025	0.061	0.494	−0.197	−0.316	−0.399	−0.026	0.105	−0.173	0.760	0.446	−0.108	−0.319	−0.472	0.471	0.218	−0.443	1.000		
V	0.546	0.313	0.366	0.007	−0.151	−0.093	−0.030	0.227	−0.013	0.486	0.278	0.111	0.091	−0.060	0.251	0.545	0.012	0.426	1.000	
Ti	0.311	0.392	0.178	0.456	0.099	0.031	0.027	0.053	0.191	0.416	0.079	0.167	0.228	0.336	0.076	0.502	0.113	0.247	0.557	1.000

P(0.01)=0.429

0.429

Table 6. The correlation coefficients of several special elements to other elements.

Zn	0.163	−0.082	0.699	−0.215	−0.252	−0.440	0.356	0.499	−0.371	0.417	0.675	−0.379	−0.137	−0.376	0.777
U	0.033	−0.165	0.561	−0.125	−0.070	−0.234	−0.3908	−0.051	−0.251	0.451	0.434	0.085	−0.013	−0.168	00.432
Ta	0.178	−0.434	0.528	0.062	−0.433	−0.456	−0.422	−0.175	−0.301	−0.678	0.413	−0.084	−0.329	0.007	0.377
Si	0.131	0.083	0148	−0.049	−0.179	−0.167	0.068	0.128	−0.152	0.032	0.219	−0.224	−0.054	−0.043	0.172
Cl	−0.537	−0.592	0.359	0.153	0.258	0.121	0.481	−0.409	−0.252	−0.323	−0.096	−0.228	0.060	−0.099	−0.114
	Al	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	Mg	Mn	Na	Rb

Zn	0.290	−0.425	0.517	0.423	0.156	1.000					P(0.01)=0.555
U	0.178	−0.214	0.684	0.272	0.453	0.192	0.567				P(0.01)=0.647
Ta	0.114	−0.296	0.700	0.398	0.496	−0.016	1.000	0.554			
Si	0.036	−0.440	0.284	0.043	0.228	0.232	0.246	0.356			P(0.01)=0.620
Cl	−0.445	0.057	−0.374	−0.480	−0.562	0.026			0.172	−0.077	P(0.01)=0.856
	Sc	Sr	Th	V	Ti	Zn	Ta	U	Sb	Zr	

and 6. In silt—size material element association regularities basically in correspondence with those in the whole weathering crust. they are also divided into four element assemblages, i.e. As, Co, Fe and Mn; Ba, K, Rb and Zn; Br and Na, and Sc, V, Ti and Cr assemblages. The elements, Hf and Th, also have a certain correlation to Ba, K, Rb and Zn assemblage. Still, Co of the first assemblage is in a negative correlation to K and Rb of the second assemblage. In clay—size material the geochemical behaviors of some elements have changed, although the element assemblages are similar to those mentioned above. For example, Hf and Th are separated from the Ba, K and Rb assemblage and join the Ti and V assemblage. The elements related to the Hf, Th, V and Ti assemblage are still Al and Sc, which form an assemblage with more stable content. The Ba, K and Rb assemblage is still in a negative correlation to the Co, Fe, Mg and As assemblage. In addition, in clay—sze material Mn is better correlated to Ca, indicating that Mn, as Ca, has become an active element.

3. *Change of weathering potential of rocks in chemical weathering process*

In fact, change of rocks in weathering process can be regarded as a process in which the rocks are transformed from the unstable state of high energy to the stable state of low energy under hypergenic conditions. The higher the energy state of parent rock, the easier the rocks to be weathered, and the more complete the rocks to be weathered, the lower the energy stage of the rocks is. To measure the weathering energy state of the rocks, a concept of weathering potential can be defined:

$$h=\frac{100\times(K_2O+Na_2O+CaO+MgO)}{TiO_2+Al_2O_3+Fe_2O_3+CaO+MgO+Na_2O+K_2O}$$

Where h is the weathering potential, when it is high, the rock is unstable under the land surface condition, conversely, the rock is stable. The weathering potential of the parent rocks and the average weathering potential of the weathered rocks were calculated for the four sections mentioned above and are listed in Table 9.

The data in Table 9 is plotted in Fig. 9. In Fig. 9 we can see that the weathering potentials of the parent rock for each weathering crust, from high to low appear successively in TW, GW, CW and SWT. The same sequence is also found for silt—size material of the weathered rock, and both numerical values are very close. The weathering potentials of clay material are not in this sequence.

From the numerical values, the weathering potentials of the parent rocks are larger than that of silt—size material of the weathered rock, and the latter is larger than that of

Table 7. A correlation matrix of the elements in silt—size material of weathering crust sections.

Al	1.000																				
As	−0.309	1.000																			
Ba	0.058	−0.295	1.000																		
Br	−0.217	−0.069	−0.277	1.000																	
Ca	−0.447	0.011	−0.216	0.039	1.000			P(0.01)=0.574													
Co	−0.058	0.775	−0.452	0.040	−0.139	1.000															
Cr	−0.390	0.265	0.219	0.213	−0.149	0.080	1.000														
Cs	0.550	0.257	−0.136	−0.155	−0.129	0.299	−0.137	1.000			0.574										
Fe	−0.372	0.642	−0.339	−0.391	−0.186	0.686	0.447	−0.174	1.000												
Hf	−0.225	−0.149	0.702	0.063	−0.110	−0.384	0.293	−0.274	−0.106	1.000											
K	0.145	−0.489	0.857	−0.134	−0.154	−0.603	0.134	−0.090	−0.530	0.570	1.000										
Mg	0.140	0.407	−0.469	0.154	0.116	0.532	−0.113	0.367	0.395	−0.320	−0.516	1.000									
Mn	−0.230	0.742	−0.246	−0.033	−0.125	0.787	0.084	0.017	0.641	−0.176	−0.474	0.281	1.000								
Na	0.129	−0.362	−0.350	0.644	−0.238	−0.162	0.005	−0.260	0.212	−0.152	−0.214	0.073	−0.151	1.000							
Rb	0.096	−0.480	0.914	−0.183	−0.137	−0.649	0.185	−0.109	−0.513	0.644	0.918	−0.583	−0.512	−0.239	1.000						
Sc	−0.259	0.573	0.123	0.142	−0.214	0.439	0.620	−0.151	0.721	0.279	−0.021	0.252	0.480	−0.055	−0.086	1.000					
Sr	0.447	0.124	−0.372	0.181	−0.190	0.047	−0.195	0.228	−0.036	−0.308	−0.179	0.379	−0.165	0.457	−0.219	−0.060	1.000				
Th	−0.203	−0.033	0.566	−0.131	−0.051	−0.353	0.008	−0.071	−0.304	0.624	0.448	−0.166	−0.158	−0.400	0.488	0.003	−0.347	1.000			
V	−0.031	0.447	0.129	0.105	−0.324	0.336	0.339	0.046	0.533	0.218	0.017	0.419	0.392	−0.105	−0.059	0.721	−0.061	0.129	1.000		
Zn	−0.211	−0.311	0.740	−0.162	−0.081	−0.447	0.252	−0.276	−0.385	0.457	0.699	−0.667	−0.310	−0.289	0.723	−0.078	−0.458	0.528	−0.237	1.000	
Ti	−0.196	0.390	0.009	0.504	−0.167	0.157	0.352	−0.013	0.547	0.340	−0.111	0.371	0.150	0.158	−0.090	0.596	0.017	0.411	0.533	−0.124	1.000
	Al	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	Mg	Mn	Na	Rb	Sc	Sr	Th	V	Zn	Ti

Table 8. A correlation matrix of the elements in clay—size material of weathering crust sections.

P(0.01)=0.608

	Al	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	K	Mg	Mn	Na	Rb	Sc	Sr	Th	V	Ti
Al	1.000																			
As	0.069	1.000																		
Ba	0.301	−0.471	1.000																	
Br	−0.100	0.271	−0.100	1.000																
Ca	−0.221	0.081	−0.197	0.355	1.000															
Co	−0.207	0.228	−0.616	−0.061	0.060	1.000														
Cr	−0.039	−0.300	0.256	−0.103	0.005	0.306	1.000													
Cs	0.386	0.064	0.214	−0.031	−0.020	−0.260	0.141	1.000				0.608								
Fe	−0.299	0.631	−0.730	0.130	0.124	0.697	−0.048	−0.391	1.000											
Hf	0.228	0.212	0.557	0.212	0.010	−0.380	−0.259	0.084	−0.160	1.000										
K	0.323	−0.428	0.949	−0.184	−0.171	−0.715	0.229	0.292	−0.742	0.434	1.000									
Mg	0.299	0.324	−0.461	−0.082	0.142	0.669	0.123	−0.089	0.596	−0.296	−0.439	1.000								
Mn	0.039	0.471	−0.340	0.425	0.669	0.485	0.191	−0.069	0.574	0.034	−0.343	0.665	1.000							
Na	0.177	−0.020	0.001	0.611	0.267	0.127	−0.120	−0.160	−0.049	0.224	−0.189	0.028	0.291	1.000						
Rb	0.294	−0.423	0.892	−0.151	−0.119	−0.730	0.207	0.376	−0.758	0.409	0.966	−0.487	−0.355	−0.227	1.000					
Sc	0.554	0.608	0.132	0.256	−0.195	−0.072	0.065	0.157	0.144	0.342	0.149	0.243	0.301	0.115	0.092	1.000				
Sr	0.354	−0.349	0.034	0.090	−0.114	0.063	−0.043	−0.108	−0.307	−0.211	−0.058	0.047	−0.160	0.499	−0.119	−0.060	1.000			
Th	0.207	0.160	0.442	−0.224	−0.157	−0.268	−0.269	0.113	−0.084	0.866	0.360	−0.223	−0.136	−0.092	0.323	0.196	−0.283	1.000		
V	0.693	0.291	0.428	−0.034	−0.314	−0.294	−0.147	0.304	−0.227	0.657	0.378	−0.019	−0.080	−0.011	0.337	0.548	0.099	0.645	1.000	
Ti	0.579	0.413	0.348	0.399	0.249	−0.252	−0.061	0.197	−0.100	0.655	0.321	0.055	0.416	0.395	0.330	0.640	0.007	0.376	0.651	1.000

Table 9. The weathering poentials of the parent and weathered rocks for the weathering crust.

	Parent rock	Weathered rock	Weathered rock	Parent — weathered rock	Parent — weathered rock	Parent — weathered rock
TW	39.66	32.11	19.69	7.55	19.93	12.42
GW	37.69	31.74	22.38	5.95	15.31	9.36
CW	30.74	30.99		—0.25		
SWT	28.39	29.56	20.87	—1.17	7.52	8.69

clay material, showing that clay material is much closer to the final product of weathering than silt — size material. The difference between weathering potentials around rock weathering reflect different rock weathering degree. The differences between weathering potentials of the parent rocks and silt—size material of the weathered rocks between the former and clay material, and between the silt—size and clay materials listed in Table 9 and plotted in Fig. 9. The higher the difference between weathering potentials around weathering is, the larger the weathering degree is. In Fig. 9, we can see that for each section the differences between weathering potentials of the parent rocks and silt—size material of the weathered rocks, between the former and clay material of the weathered rocks and between silt—size and clay—size materials of the weatherd rocks, from large to small, appear successively in TW, GW, CW and SWT, which is completely coincident with the sequence of the weathering potentials of the parent rocks for each section. It indicates that in this area the weathering potentials of the parent rocks, from high to low determine the weathering degree of these rocks in weathering process. The higher the weathering potential of the parent rocks is, the higher its weathering strength is. Therefore, the sequence of weathering strengths of the above — mentioned four sections, from high to low, should reflected in TW, GW; CW and SWT and basically correspond with that calculated from the enrichment and differentiation indexes.

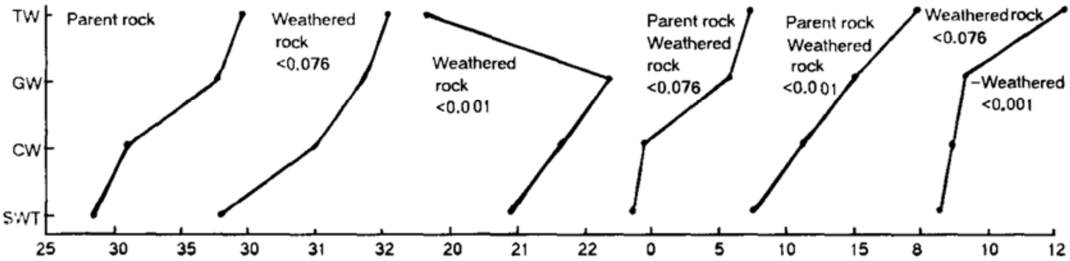


Fig. 9. Change of weathering potentials of different weathering crusts in weathering process.

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