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The elemental geochemical characteristics of Late Quaternary rock core from Yanwo Lake in the Great Wall Station area, King George Island, Southwest Antarctica

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Abstract This paper is manily to treat the change regularity of the contens, distributions, enrich coefficients and correlative coefficients of some trace and constant elements in the sediments of Late Quaternary rock core from Yanwo Lake in the Great Wall Station area, King George Island and to discuss the sedimentary sources in Yanwo Lake and the periodical changes of Late Quaternary climate and the environment in the area. It is concluded that the clastic sedimentary rocks, including volcanic sedimentary rocks, around Yanwo Lake are the major sources of Yanwo Lake sediments; the mantle material is also one of its sources and what is more, the continent-sourced materials are transported by the Antarctic glacier.

Key words elemental geochemistry, lacustrine deposits of Late Quaternary, Yanwo Lake, King George Island

1 Introduction

In recent years, the geochemical research of Antarctica attracted more and more attention of researchers at home and abroad (Barton, 1965; Birkenmajor *et al.*, 1985). Liu and Zheng (1988) studied the characteristics of elemental geochemical evolution of Tertiary subsilicate lava and volcanic clastic rocks of the island. Zhao *et al.* (1989) studied the background values of elements in the rocks, soils, surface water and atmospheric precipitation of the island. Zhang (1985) studied the Lake Quaternary geology and geomorphology of Vestford Hills, Antarctica. Li and Wang (1989) studied the Quaternary sedimentary geochemistry of Mills Valley. However, the research of Quaternary lacustrine geochemistry has been done little and this paper gives a primary analysis of the contents of the elements in the rock core from Yanwo Lake in the Great Wall Station area, King George Island, Antarctica.

2 A brief description of geological section

Bordering the sea on three sides and connecting with the ice sheet of King George Island on the north side, the Fildes Peninsula, King George Island is an area of non-ice hill and marsh which emerged during the Holocene. The landform of the whole area is rather gentle with an elevation of less than 200 m. The Quaternary deposits are better developed. The contemporary sand soil and clastic sediments deposited in valleys, on slopes, on seashore and lacustrine plain have a great thickness of 20～50 m, and most of them are distributed continuously. Geothermical degree ranges between −0.5～−1.0℃.

Professor Chen Xiaobo from Institute of Glaciology and Cryopedology, Chinese Academy of Sciences collects and provides the rock samples from Yanwo Lake in the Great Wall Station area, King George Island, Antarctica, which is situated at 62°13′14″ S, 58°57′38″W. The Yanwo Lake has an area of about 8800 m^2. Drilling well stands at 14.5 m above sea level, with a depth of 7.7 m. Sampling is taken at each interval of 10 cm, totaling 77 in number. The drilling reaches the basement rock of the lake. The drilling cores consist of a suite of coutinuous Quaternary sediments (Fig. 1), and may be considered as a representative section for the study of sedimentary geochemistry of Late Quaternary.

3 Sample treatment and analytical procedure

Sample treatment: The samples are heated at a temperature of 100℃ in drybox for about 8 hours for removing impurity. After cooling, they are ground into flour in agate bowl and sifted with 200 pore sieve sifter and reserved in dryware for use.

Standard: Standard adopted in the study is a mixed one from the Experimental Office of Neutron Activation Analysis, Institute of High Energy Physics, Academia Sinica. The standard reference sample made by NBS (NBS 1646) is used to supervise the mixed standard.

Analysis technics: The analysis method is Instrumental Neutron Activation Analysis (INAA) and the instrument SCORPIO-3000 program-controlled spectrometer. The γ spectrograph analysis and data progress are done through mini-computer PDP11/04.

4 Results and discussion

4.1 Content and distribution of elements in rock core of Yanwo Lake

According to regular classification of elemental geochemistry, the content ranges, average values and statistical data of 23 elements in rock core of Yanwo Lake are listed in Table 1. It shows how many in a percentage for the contents of Ca, Na, K and Fe, how many in a thousand for those of Ni, Zr, Sr and Ba, and that those of the rest elements are less than several hundred ppm.

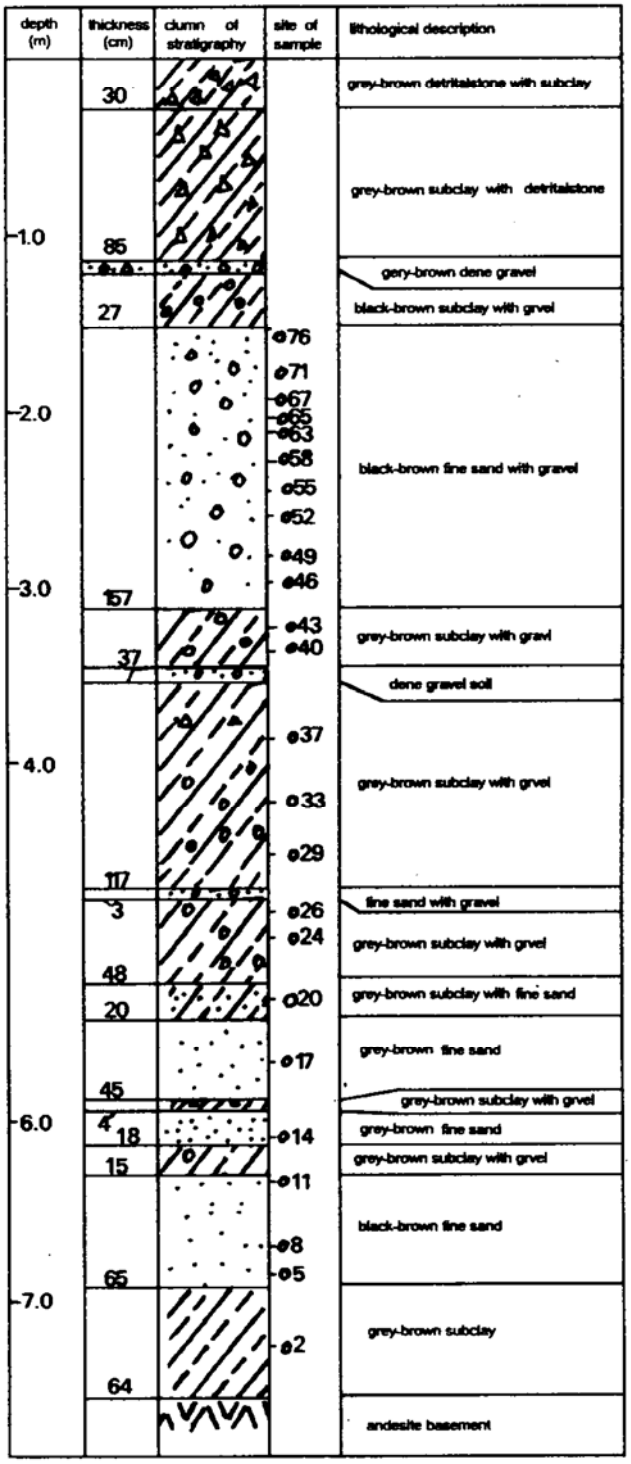

Fig. 1. Synthetic descriptions from sedimentary section of the Yanwo Lake Core(62°13′14″S, 58°57′38″ W).

It is also shown in Table 1. that the variation coefficients of 23 elements are all smaller than 1 and so are the standard deviations of most elements, showing that most of the elements are evenly distributed in the rock core and that the standard deviations of Ni, Zr, Zn, Sr and Ba are very greater, indicating that these elements are distributed unevenly. As compared with average contents of elements of the Tertiary volcanic rock in the same area (Zheng *et al.*, 1991); the average contents of Na, Cr, Fe, Co, Hf, V,

Th, Ba, etc. in rock core of Yanwo Lake are close to those of the Tertiary volcanic rock and the average contents of Ni, Zr, K, Cr, Rb, etc, are more than those of Tertiary volcanic rock. Among them the average content of Ni is 45 times greater than that of the Tertiary volcanic rock. The average contents of Zn, Sr, Ca, Ta are less than Tertiary volcanic rock. So it can be inferred that on the one hand, the clastic sedimentary rocks, including volcanic rock, around Yanwo Lake are major sources of the sediments of the lake, and on the other hand, mantle material is also one of its sources, and what is more, the continent-sourced material was transported from the Antarctic glacier.

The distribution of elements in different sediments of Yanwo Lake is listed in Table 2. Subclay is rich in Cs, As, Ba and poor in Cr and Hf. Fine sand is rich in Ni, Zn, Au, Sr and poor in Ta, Zr and W. Gravel is rich in Rb and poor in Fe, Cs, Th, As and Ba.

Table 1. Element contents(ppm) and statistical values in sediments of rock cores of Yanwo Lake.

elememt		content range	arithmatical average value	standard deviation	coefficient of variation	average content in volcanic rock
petrogenetic element	Ca	$(1.62-5.33)\times10^4$	2.94×10^4	1.03	0.35	6.28×10^4
	Na	$(1.61-2.37)\times10^4$	1.94×10^4	0.23	0.12	1.17×10^4
	K	$(0.44-1.62)\times10^4$	0.99×10^4	0.39	0.39	0.60×10^4
ferri-family element	Cr	35.9—74.7	48.3	8.81	0.18	64.4
	Fe	$(6.91-6.56)\times10^4$	5.32×10^4	0.96	0.18	6.62×10^4
	Co	17.1—29.5	21.8	3.82	0.18	27.9
	Ni	657—1380	810	193	0.24	18
rare element	Rb	16.4—59.4	31.0	15.3	0.49	20.7
	Cs	0.46—2.01	1.00	0.39	0.39	0.79
	Ta	0.17—0.45	0.26	0.09	0.35	0.68
	Zr	184—642	289	115	0.40	75.2
	Hf	2.23—3.54	3.03	0.35	0.12	2.41
	Sc	19.1—34.1	25.6	4.79	0.19	31.5
radioactive element	U	0.50—1.61	0.81	0.32	0.40	0.81
	Th	0.75—2.68	1.70	0.47	0.28	1.78
tungsten —family element	W	2.07—5.72	3.32	0.88	0.27	
	Mo	4.83—8.22	6.15	0.86	0.14	
	Zn	6.75—49.6	31.3	17.2	0.55	147
chalcophile element	Au	0.00511—0.0288	0.00995	0.0047	0.47	
	As	1.12—14.0	6.99	3.78	0.54	
	Sb	0.23—0.82	0.38	0.16	0.42	
dispersion element	Sr	155—497	279	87.2	0.31	495
	Ba	95.7—349	218	75.2	0.35	213

4.2 Rich coefficients of elements in rock core of Yanwo Lake

Comparing average contents in sediments of Yanwo Lake with those of the earth crust, sedimentary rocks and loess, we can get the relative rich coefficients (Ki) of the elements in deposits. Calculated results are listed in Table 3. Relative rich coefficients of Ca, Na, K, Fe, Co, Hf, Sc, Sr in rock core of Yanwo Lake and crust are about 1.0, showing uniform distribution of elements. The crust is rich in W, Mo, Au and As and

the average content of Ni in rock core of Yanwo Lake, is 10 times greater than that in crust; Rb, Cs, Ta, V, Th and Ba are lower in rock core of Yanwo Lake than in crust.

As compared with relative rich coefficients of deposits in sedimentary rocks and loess, the elements can be classified into 3 types with elemental migration ability. The first type elements are K, Rb, Cs, Ta, Hf, V, Th, Zn, Sr and Ba, having strong migration ability with $Ki<0.1$. The second type elements are Na, Fe, Co, Zr, Sc and As, having moderate migration ability with $1.0<Ki<5.0$. The third type elements are Ni, Mo and Au, having weak migration ability with $Ki>5.0$. It is worth pointing out that the migration ability of elements in sediments is influenced by deposition condition and primitive mother rocks.

Table 2. The elements of different sediments in the rock cores of Yanwo Lake.

element	subclay	subclay with fine sand	subclay with gravel	fine sand	fine sand with gravel
Ca	2.66×10^4	4.47×10^4	2.61×10^4	3.01×10^4	2.92×10^4
Na	1.76×10^4	2.00×10^4	1.65×10^4	1.68×10^4	2.14×10^4
K	1.49×10^4	0.86×10^4	0.98×10^4	1.10×10^4	0.94×10^4
Cr	44.0	46.5	50.2	50.0	46.7
Fe	5.72×10^4	6.01×10^4	5.78×10^4	5.97×10^4	4.44×10^4
Co	22.4	26.1	23.1	23.9	18.7
Ni	711	738	785	1011	796
Rb	22.5	19.3	27.7	26.2	39.6
Cs	1.67	1.40	0.93	1.35	0.80
Ta	0.29	0.26	0.25	0.18	0.29
Zr	322	205	313	205	308
Hf	2.56	3.28	3.13	2.93	2.94
Sc	28.8	31.1	27.2	29.5	21.2
U	1.61	0.60	0.81	1.03	0.75
Th	1.95	1.66	2.06	2.03	1.20
W	2.67	4.24	3.38	2.76	3.30
Mo	6.23	6.51	6.36	6.52	5.72
Zn	26.8	19.4	40.4	41.5	21.9
Au	0.0126	0.0106	0.00948	0.0114	0.00949
As	14.0	6.59	8.67	10.1	3.57
Sb	0.28	0.41	0.46	0.45	0.29
Sr	286	281	271	307	277
Ba	277	223	239	252	177

4.3 *A brief summary*

Sediments in rock core of Yanwo Lake are rich in Ni, Na, Au, Mo, Sc, Fe; K< Na, and poor in Rb, Ta, Th, V, Ba and Cs, indicating that material source of the lake is mainly primary rock in island-arc type from mantle material, such as basalt, basalt-andesite and transportation is not far from there, thus they remain a lot of characteristics of primary rock from island-arc type.

Correlation coefficient between elements in deposits of Yanwo Lake is listed in Table 4. It shows that relationship between elements has a certain difference. If obvious level is taken as: $0.01\leqslant p=0.05$, general correlation; $0.001\leqslant p=0.01$, obvious correlation; p

Table 3. Relative rich coefficients of the elements in sediments of rock core of Yanwo Lake

element	content(ppm)				relative rich coefficient(Ki)		
	Yanwo Lake	crust*	sedimentary rock*	loess in China**	curst	sedimentary rock	loess in China
Ca	2.94×10⁴	4.15×10⁴	2.53×10⁴	5.62×10⁴	0.71	1.16	0.52
Na	1.94×10⁴	2.36×10⁴	0.66×10⁴	1.26×10⁴	0.82	2.94	1.54
K	0.99×10⁴	2.09×10⁴	2.28×10⁴	1.63×10⁴	0.47	0.43	0.61
Cr	48.3	100	100	47.6	0.48	0.48	1.01
Fe	53.2×10⁴	5.73×10⁴	3.33×10⁴	3.88×10⁴	0.94	1.60	1.37
Co	21.8	25.0	20.0	21.0	0.87	1.09	1.04
Ni	810	75.0	95.0	39.0	10.8	8.53	20.8
Rb	31.0	90.9	200	98.4	0.34	0.16	0.32
Cs	1.00	3.00	12.0	7.60	0.33	0.08	0.13
Ta	0.26	2.00	3.50	1.00	0.13	0.07	0.26
Zr	289	165	200	230	1.75	1.45	1.26
Hf	3.03	3.00	6.00	6.05	1.01	0.51	0.50
Sc	25.6	22.0	10.0	12.5	1.16	2.56	2.05
U	0.81	2.70	3.20	3.15	0.30	0.25	0.26
Th	1.70	9.60	11.0	12.2	0.18	0.15	0.14
W	3.32	1.50	2.00		2.21	1.66	
Mo	6.15	1.50	2.00	0.59	4.10	3.08	10.4
Zn	31.3	70.0	80.0	79.0	0.44	0.38	0.39
Au	0.00995	0.004	0.001		2.49	9.95	
As	6.99	1.80	6.60		3.88	1.06	
Sb	0.38	0.20	2.00		1.90	0.19	
Sr	279	375	450	164	0.74	0.62	1.70
Ba	218	700	800	510	0.31	0.27	0.43

* Institute of Geochemistry, Academia Sinica(1977); * * Wen *et al.*, 1989.

$= 0.001$, extremely obvious correlation. When sample number $n = 24$ and freedom degree $f = 22$, critical values of the correlation coefficients are: $0.517 \leqslant p = 0.406$, $0.630 \leqslant p = 0.517$, $p = 0.630$ and the negative critical values of the correlation coefficients: $-0.517 \leqslant p = -0.406$, $-0.630 \leqslant p = -0.517$, $p = -0.630$. Table 4 shows that the elements of Cr, Fe, Co, Hf, Sc, Mo and As have obvious positive correlations and Cr, Fe and Co are of iron-race elements. Their radii, negativities and potentials of 3-valence cations are very similar and so they have similar geochemical behaviour. Therefore in the depositional progress, the behaviour of migration and enriching of them are similar. Sc and Mo usually replace other elements (such as Fe, Co) through endoptastical inphase because their 3-valence cations have similar radii, negativities and potentials which cause similar geochemical behaviours.

5 Conclusions

Most of elements are evenly distributed in rock core of Yanwo Lake in the Great Wall Station area, showing a stable tectonic condition during deposition. The values of standard deviation of Ni, Zn, Sr and Ba are relative large, showing possibility of deposits mixed with surrounding rocks, including volcanic rock.

The distribution of elements in the sediments of the lake is: subclays contain rich Cs, As and Ba and poor Cr and Hf, fine sands contain rich Ni, Zn, Au, Sr and poor

Table 4. Interrelated matrix of elements in sediments of rock core of Yanwo Lake.

	Ca	Na	K	Cr	Fe	Co	Ni	Rb	Cs	Ta	Zr	Hf	Sc	U	Th	W	Mo	Zn	Au	As	Sb	Sr	Ba
Ca				−−																−			
Na	.107				−−	−−		+					−−				−	+++		−−−	−−		
K	-.31	-.317				+							+				++			+			
Cr	-.613	-.241	.357		++	++		−				+	++				+++	−		+			
Fe	-.282	-.617	.392	.609		+++		−−−	+			++	+++				+++			+++	+		
Co	-.167	-.517	.408	.622	.954			−−−	+			++	+++				+++			+++	+		
Ni	.003	.094	.059	-.057	.141	.061			+													+	
Rb	.103	.481	-.284	-.415	-.691	-.638	.079						−−−		+		−−−	++		−−	−		
Cs	.003	-.384	.334	.142	.493	.462	.412	-.204					+++							+	+		
Ta	-.085	.339	.278	.356	-.028	.109	-.205	-.009	-.104														
Zr	-.142	.189	-.212	.109	-.058	-.097	.000	.072	-.029	.122													
Hf	-.365	.072	-.02	.476	.536	.569	.198	-.094	.172	.035	.054		+										
Sc	-.143	-.621	.456	.532	.95	.939	.181	-.634	.659	-.038	-.119	.44					+++	−		+++	++		
U	-.212	-.268	.099	.166	.185	.086	-.167	-.252	.117	.008	-.007	-.214	.189					−					
Th	.006	.058	-.144	-.075	-.371	-.325	-.227	.502	-.159	.216	-.097	-.03	-.356	-.151								−−	
W	-.082	-.099	-.033	.177	.207	.184	-.319	-.27	-.206	.097	-.077	.192	.131	.066	-.17								
Mo	-.247	-.512	.579	.642	.831	.811	.131	-.665	.28	.07	-.209	.374	.759	.061	.395	.259		−−		+++	++		
Zn	.078	.717	-.306	-.258	-.494	-.385	.019	.606	-.137	.148	.174	.219	-.449	-.428	.383	-.314	-.531			−−	−	−−	
Au	.066	-.044	-.01	-.024	.137	.167	.028	-.001	-.007	-.182	.108	.063	.175	.188	-.319	.124	.144	.041					
As	-.458	-.685	.477	.448	.786	.658	.174	-.545	.473	-.206	-.072	.282	.743	.395	-.313	.15	.675	-.559	.187		+		
Sb	.058	-.602	.356	.305	.511	.51	.051	-.414	.453	-.102	-.313	.236	.523	.14	-.239	.174	.595	-.444	.068	.453			+
Sr	.046	-.336	.157	-.008	.227	.134	.437	-.342	.315	-.257	-.072	-.074	.175	-.095	-.53	.301	.377	-.599	.107	.315	.209		
Ba	.258	-.394	.171	-.019	.252	.231	-.159	-.284	.183	-.02	-.089	-.31	.314	.225	-.208	-.093	.197	-.386	-.103	-.018	.406	.002	

* +: general correlation; ++: obvious correlation; +++: extremely obvious correlation; −: general negative correlation; −−: obvious negative correlation; −−−: extremely obvious negative correlation

Ta, Zr, W; the gravels contain only rich Rb and elements of Fe, Cs, Th, As and Ba are poor.

In comparison of relative rich coefficient of elements in the rock core of Yanwo Lake with those of crust, sedimentary rocks and loess, the results show that the elements of K, Rb, Cs, Ta, Hf, V, Th, Zn, Sr and Ba have a strong migrating ability, whereas, elements Ni, Mo and Au have a weaken one.

The correlative coefficients of the elements in the rock core of Yanwo Lake show that: of 231 elements, 63 have a correlation in ratio, amounting to 27.3% in total. Most of elements have a similar geochemical behaviour.

Synthetical analysis results show that the clastic sedimentary rocks, including volcanic rocks round Yanwo Lake are major source of the sediments of the lake. The mantle material is also one of its sources. These sediments come from the basal andesite and are transported not far away, so they maintain the characteristics of island-arc type. Additionally, it is also possible that the continent-sourced material is carried by the Antarctic glacier to the lake.

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